# A Volunteer's Handbook For Monitoring Maine Salt Marshes

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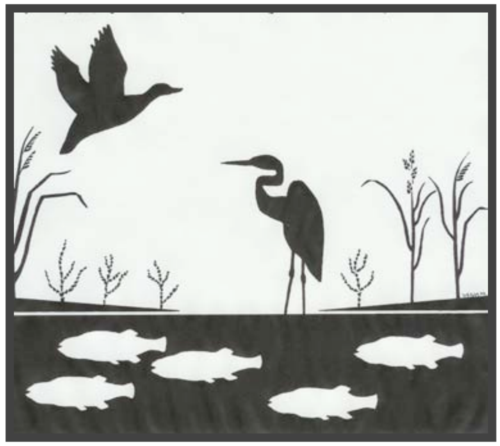

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This manual is an integration of protocols found in the "Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine" (*Global Programme of Action Coalition for the Gulf of Maine Workshop, 1999*), "A Volunteer's Handbook for Monitoring New England Salt Marshes" (*MA Office of Coastal Zone Management and the Executive Office of Environmental Affairs, 2002*), and "Field Methods Manual: U.S. Fish & Wildlife Service (Region 5) salt marsh study" (*U.S. Fish & Wildlife Service, 2002*). Much of the manual text was used with consent from the authors of the "A Volunteer's Handbook for Monitoring New England Salt Marshes" and "A Volunteer's Handbook for Monitoring New Hampshire Salt Marshes" (*DU and NHCP, 2003*).

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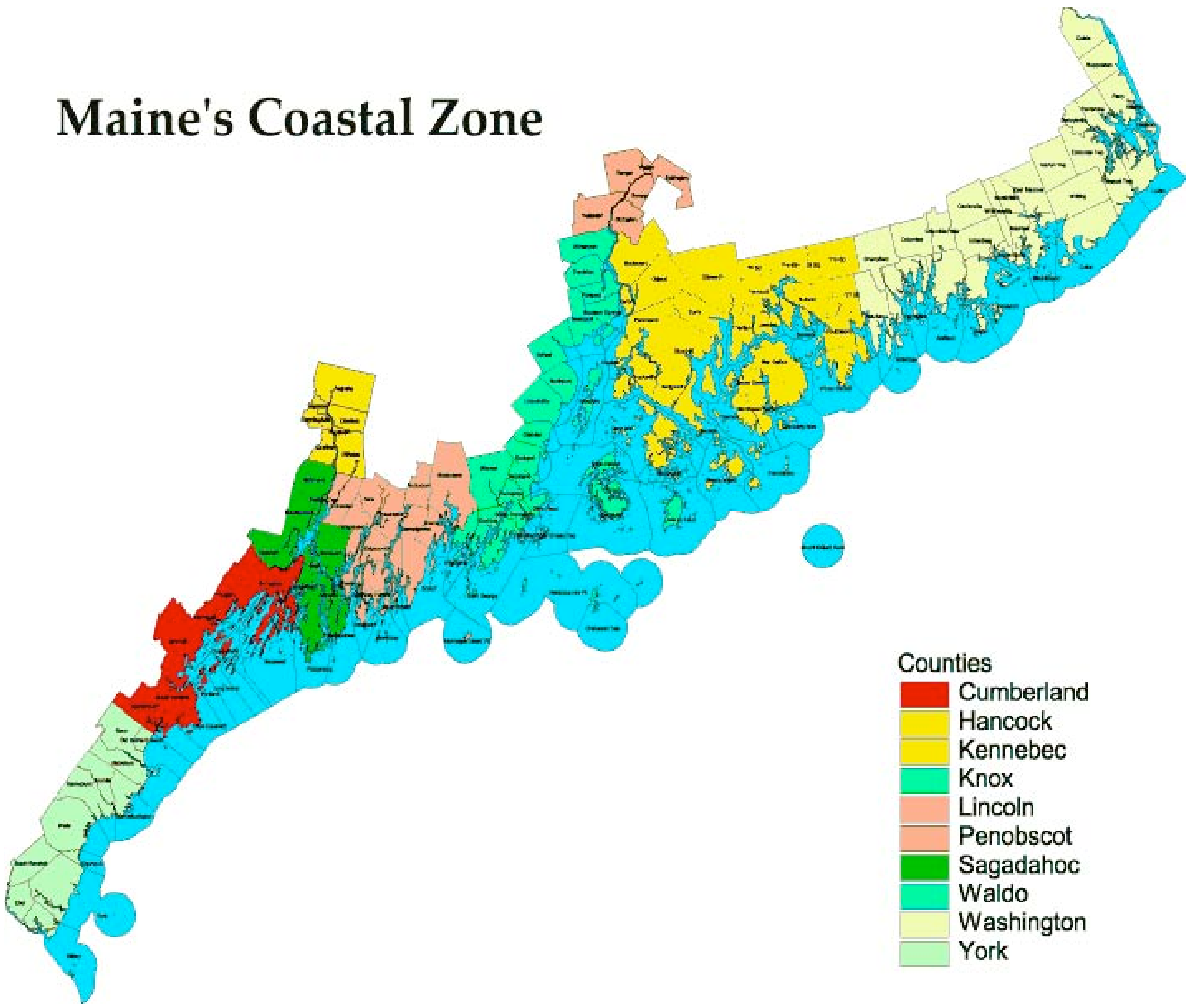



Maine's coastal zone encompasses all political jurisdictions in Maine that have land along the coast or a tidal waterway, such as a river or bay. It includes 5,300 miles of coastline, encompassing 136 towns, two Plantations, 10 unorganized townships, and one Indian Reservation. Thousands of islands, 4,613 to be exact, are also in the coastal zone.

The zone encompasses Maine's territorial waters, which extend three miles out to sea.

*Courtesy of Maine Coastal Program*

# Table of Contents



**Please Note:**

This manual was created to provide volunteers and project collaborators with a brief overview of the ecology and importance of local salt marshes and the human activities that have impacted them. Specific protocols will be used to monitor a few indicators of salt marsh functions to facilitate management decisions. For further information and resources on these topics please see Appendix A.

Terms printed in bold type at their first appearance are defined in the Glossary (Appendix B).

If you believe a particular salt marsh or other coastal wetland ecosystem is in need of restoration, please contact Maine's Habitat Restoration Coordinator at the Maine Coastal Program 207-287-3261.

# Chapter 1: An Introduction to Salt Marsh Monitoring

**Salt marshes** are beautiful coastal landscapes that provide rich **habitat** to a great **diversity** of plants, **invertebrates**, fish, birds, and mammals. For many people, the opportunity to see snowy egrets stalking fish is reason enough to be concerned about protecting salt marsh health. Salt marshes are extremely important for a variety of reasons besides their beauty or the biological diversity they support. Salt marshes are among the most productive ecosystems on the planet, and serve as nursery grounds for several economically important fish and shellfish species. Salt marshes also help fuel **food webs** by recycling and exporting tremendous amounts of nutrients. Salt marshes protect shorelines from storm damage by dispersing wave and tide energy, and help purify water by assimilating potential pollutants.

*Webhannet marsh, Wells, ME*

Over the last three centuries, vast areas of salt marshes have been ditched, drained, and filled by humans who perceived them as barren unproductive areas of little economic value. Direct **wetland** filling, point source pollution, nonpoint source pollution, invasive species, ditching, diking and restriction of tide flow by road and railroad crossings have all taken a heavy toll on New England coastal salt marshes. In 1969, during the beginning of an environmentally active period in the US, John and Mildred Teal published their book *Life and Death of a Salt Marsh*, which highlighted the beauty, importance, and plight of these ecosystems. This book helped foster public appreciation for salt marshes and launched the next three decades of salt marsh conservation.

Scientists use a variety of methods to assess salt marsh health, also referred to as **biological integrity**. By comparing modern aerial photographs and maps with historical documents using Geographic Information Systems (GIS), researchers are able to estimate changes to wetland extent or boundaries over time. Generally, these studies have found a decline in salt marsh area resulting from human manipulation and development. Researchers also collect field measurements of various biological, physical, and chemical **parameters**, which are used as **indicators** of overall salt marsh health.

*Montsweag River, Wiscasset, ME*

Although regulations help reduce further human impacts to salt marshes, regulations alone are not sufficient to adequately protect these critical and sensitive habitats. Scientists are currently developing and employing tools to detect **biological impairment** in salt marsh ecosystems. Eventually, the information generated from these assessments will help to improve regulatory and other protection efforts.

A growing number of organizations are becoming involved in conservation projects aimed at restoring or protecting salt marshes. Through the Maine Marsh Monitoring Program (MMMP), local citizens, under the guidance of salt marsh experts, are collecting field data to document salt marsh health and are looking for evidence of habitat degradation and biological impairment. Scientists refer to this effort as **monitoring**, or "the unbiased collection and precise recording of data over time." The MMMP applies an integrated approach to monitoring that combines biological, physical, and chemical measurements. Use of this approach provides a comprehensive assessment of salt marsh ecosystem health. By assisting with monitoring efforts, volunteers provide a valuable service to scientists trying to develop a better understanding of salt marshes, to managers aiming to track impacts and recovery rates of salt marshes as well as protect and restore salt marshes.

**The goals of this manual are to:**

- provide volunteer monitors with the necessary background and training to successfully collect scientifically reliable field data;
- foster salt marsh education and stewardship in communities throughout the coast of Maine;
- promote and assist with the stewardship, protection, and restoration of salt marshes; and,
- expand the number of qualified individuals who can help scientists study the condition of the region's marshes.

## Salt Marsh Monitoring in New England

The protocols contained in this manual are the culmination of over ten years of collaborative effort among wetland scientists throughout the Northeast, including representatives from state and federal agencies and non-profit groups, to develop salt marsh assessment techniques for measuring wetland health by examining resident plants, animals and their habitat. Despite decades of research into salt marsh ecological processes, widespread assessment of New England salt marshes didn't occur until 1995 following a series of pilot projects to develop monitoring protocols. In 1997, the U.S. Environmental Protection Agency declared wetland monitoring a national priority and convened the national Biological Assessment of Wetlands Workgroup in which wetland scientists from federal and state agencies and universities collaborated to improve methods for evaluating the biological integrity of wetlands. In 1999, the Global Programme of Action Coalition (GPAC) held a workshop for resource managers and scientists to recommend regional standards for salt marsh monitoring protocols. Historically, several restoration partnerships in Maine have used environmental consultants and contractors instead of volunteers to collect pre and post restoration information. Use of trained volunteers will allow biologists to collect more good quality data inexpensively and effectively, and will provide participants with an opportunity to experience salt marshes. The methods used by the Marsh Monitors volunteer program described in this manual are volunteer-friendly and are consistent with recommendations from the GPAC report, entitled *Regional Standards to Identify and Evaluate Tidal Restoration in the Gulf of Maine* and the *Field Methods Manual: U.S. Fish & Wildlife Service (Region 5) Salt Marsh Study*, used in several wildlife refuges and coastal National Parks along the U.S. North Atlantic coast.

## The Role of Volunteer Monitors

Some people may view participation in a volunteer monitoring program as a daunting task and wonder "How can I help?" and "What will my contribution mean?" As participants in the monitoring program, volunteers will receive training to collect data in salt marshes throughout the coast. When training is complete, volunteers will join scientists, resource managers, and other experts in collecting field data. You do not need a college degree in biology to be a volunteer monitor – all you need is enthusiasm and a willingness to learn. Participants will be able to adopt regular monitoring schedules at particular sites, or may sign up for pre-determined monitoring sessions spread intermittently throughout the field season. Program coordinators will assist volunteers with scheduling, data collection, and data recording, and will track volunteer participation as match for federal funds.

## The Importance of Volunteer Monitoring

Volunteer participation in salt marsh monitoring efforts provides an invaluable service to resource managers, scientists, and communities throughout New England. Volunteer participation enables scientists to develop larger data sets, provides resource managers with services that can be used as match to access increased federal funding for protection and restoration efforts, and provides program coordinators with valuable feedback about data collection and recording methods. Coastal resource managers rely on current data to assess current conditions and future changes in salt marshes in order to develop effective protection and restoration strategies. Scientists who assess the effectiveness of various restoration and protection strategies incorporate data into a regional database. Thus, by participating in the Maine Marsh Monitoring Program, volunteers provide direct support not only to protection and restoration efforts in the State but also to similar efforts throughout the Gulf of Maine.

Volunteer monitors also become informed ambassadors for salt marshes by being active in local planning and decision-making and fostering salt marsh stewardship and awareness in coastal communities. Volunteers, communities, resource managers, and scientists all benefit from this type of partnership.

## The Application of Volunteer Data

For many decades volunteers have been counting birds, taking water quality samples in lakes, listening for breeding amphibians, and collecting stream invertebrates to provide valuable data to state and federal agencies.

Many scientists and resource managers have invested considerable time and resources to train volunteers to conduct salt marsh monitoring. This investment enables volunteers to collect data that are as accurate and defensible as data collected by staff scientists. The guidelines and procedures outlined in this manual and taught at workshops are not mere suggestions – volunteers need to follow these guidelines explicitly to ensure data quality. Using this manual, volunteers can gather data that will directly influence the conservation and management of coastal resources.

## Level of Technical Expertise

Volunteer monitoring requires only an interest in salt marshes, careful attention to detail, an ability to navigate across sometimes-unpredictable marsh terrain, and a willingness to devote time and energy toward marsh conservation. This manual employs technical language and scientific species' names in order to communicate in well defined and commonly agreed upon scientific terminology. Volunteers are not expected to know and use all of these terms, however, volunteers are encouraged to learn scientific terminology and ask questions of program coordinators at any time throughout the field season.

## Safety Issues

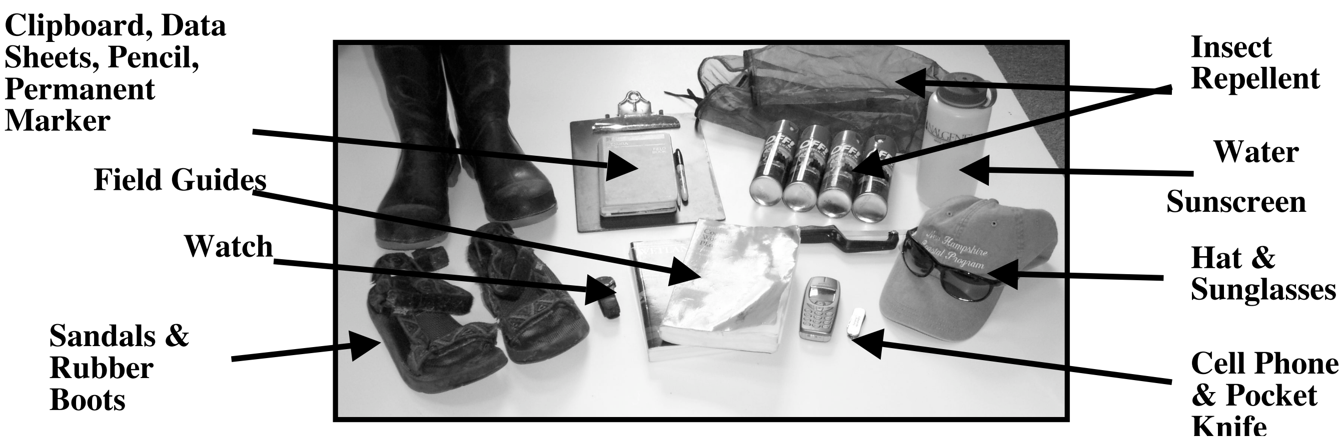
Volunteers will be walking and wading in salt marshes. This can be an enjoyable experience, but volunteers should take steps to protect themselves and the salt marsh from harm. Salt marshes can be dangerous places, or at the very least difficult to walk through. Volunteers must be prepared for all types of conditions. Scorching sun, biting flies, ticks, poison ivy, deep mud, slippery surfaces, and unstable footing can combine to make an uncomfortable experience for unprepared volunteers. Step carefully, but volunteers can rest assured that they will quickly find their "marsh legs"! Humidity in salt marshes can reach uncomfortable levels because of evaporation from saturated soils and transpiration from vegetation. The marsh can get very hot because there is no shade. In addition, light intensity is high and the marsh and surface water reflect sunlight. The lack of shade, high humidity, and continuous activity can cause monitors to get very hot. All program participants should be sure to wear sunglasses and a wide brimmed hat, bring plenty of water and sunscreen, and carry an emergency calling device such as a whistle or cell phone.

Estuarine streams and tidal flats contain deceptively deep mud, and when you are stuck knee deep as the tide rolls in there is nothing more welcomed than a helping hand from a fellow team member. Marshes also have a large appetite for loose-fitting shoes! It is easier to sink your foot into deep mud than it is to pull your foot out, and oftentimes shoes are lost if they are not laced tightly. The best type of footwear is knee-high rubber boots or rubber hip waders if crossing streams.

Poison ivy is very common in the high marsh-upland transitional zone, and it is important that sensitive individuals wear long clothing to protect themselves. In addition, ticks, mosquitoes, and other biting insects can be both a nuisance and serious health threat, carrying West Nile Virus, Lyme Disease, and other maladies. Long clothing and insect repellent are effective deterrents, and volunteers should thoroughly check themselves for ticks after leaving a wetland.

## Essential Field Equipment

Volunteers should always bring the following items when entering a marsh to be comfortable and safe:




## Care of the Salt Marsh

Salt marshes are fragile and sensitive ecosystems. Volunteers should be mindful of how their activities affect the marsh and take appropriate steps to minimize impacts, since most types of monitoring require that volunteers walk across the marsh surface. Vegetation is easily trampled, and substrate compaction and erosion can be problematic. When entering estuarine streams and crossing ditches, select areas of bank that aren't too high or too steep; clambering up and down steep stream banks will quickly result in bank erosion.

Wildlife disturbance can be a concern at some locations. Birds may breed or nest in the salt marsh, marsh border, or adjacent dune areas. If possible, identify important breeding territories and avoid these areas during the nesting season. **Invasive species** such as the **non-indigenous** form of *Phragmites australis* have become a major problem in coastal wetlands. Most invasive plants have evolved rapid dispersal abilities and rely on people and other animals to transport them to new sites. We can help curtail the spread of invasive species and pathogens by thoroughly rinsing waders, footwear, and sampling equipment immediately after leaving one marsh and before moving to another.

# Chapter 2: New England Salt Marshes: Ecology, Value, and Conservation

Salt marshes are among the most productive natural ecosystems on Earth. They support a rich diversity of plants and animals that are uniquely adapted to inhabit wetlands that constantly change with the twice-daily ebb and flow of the tide. Today, salt marshes are treasured for the biodiversity they support, their contribution to marine productivity and commercial fisheries, their ability to anchor sediments and protect shorelines from erosion and flood damage, and their capacity to improve water quality.

Before European settlement, Native Americans depended on salt marshes for the plentiful hunting and fishing found there. Early settlers also valued salt marshes for the hay and pasturage they provided for livestock, and even today a market exists for salt marsh hay as high quality mulch. Despite their importance, humans have impacted New England salt marshes since the Colonial period. Marshes were ditched to promote the growth of salt hay, *Spartina patens*. In the early-mid $20^{th}$ Century salt marshes were perceived as barren, unproductive, mosquito-filled wastelands that could only be improved by filling, draining, or dredging. As a result, humans have converted countless acres of salt marshes to roads, farms, parking lots, neighborhoods, and even cities. For instance, large areas of Boston were once productive salt marshes and mudflats:

There are at present about 3,240 acres of city real estate in an area that contains old Boston, Roxbury and Back Bay…When the Puritans arrived to settle this area, there existed only 1185 acres of dry land on which to build. Four hundred eighty-five acres of the present 3240 acres were salt marsh and 1570 acres were shallow water, which was part marsh, part mud and sand flat, and part open water even at low tide. There was a gain of 2055 acres of dry land made by filling the marshes and lowlands." John and Mildred Teal 1969, *Life and Death of the Salt Marsh.*

Our understanding of the importance of salt marshes has increased in the last few decades, and today there are strict laws and regulations designed to protect salt marshes from destruction and pollution. Yet, coastal development continues throughout New England and natural resources face increasing pressure as communities try to find a balance between development and healthy natural ecosystems.

*Tidal restriction at Drakes Island marsh, Wells, ME*

This chapter introduces some important concepts of salt marsh biology and ecology, including their formation and succession, characteristic plant communities, **food webs**, and importance as nursery area and wildlife **habitat**. Also covered is the importance of salt marshes to humans, and the many ways that humans have destroyed, degraded, and polluted them. An understanding of salt marsh biology and ecology is imperative for anyone who is conducting basic **monitoring** in these habitats. The current condition of salt marshes is the product of ever changing natural processes and human disturbances, and any successful monitoring program must be mindful of both.

## Biology & Ecology of New England Salt Marshes

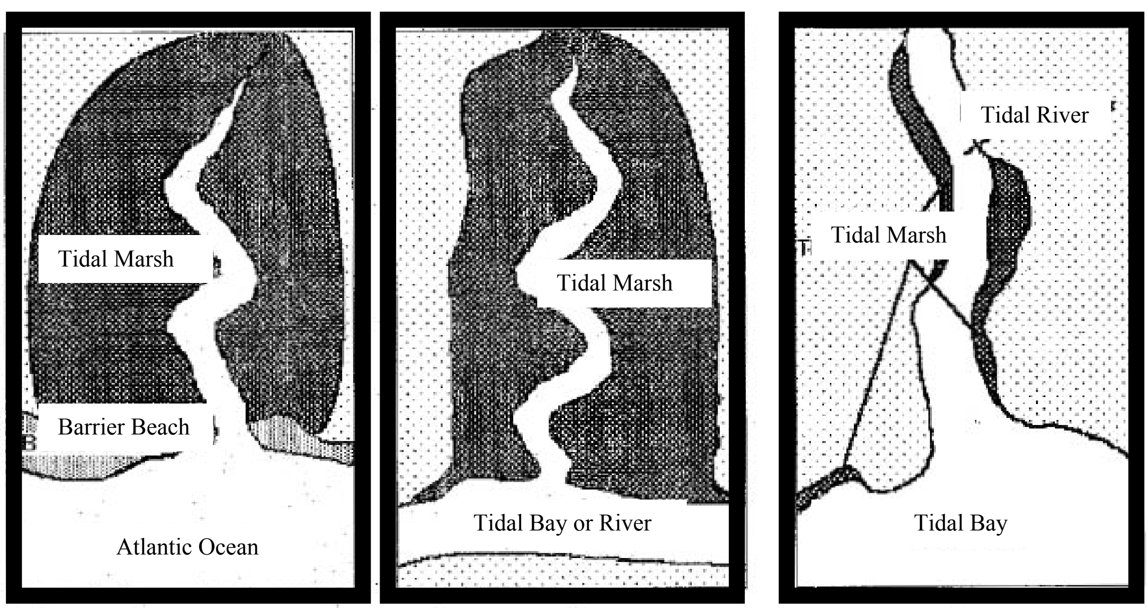
Life in coastal wetlands is characterized by extreme fluctuations in salinity, saturation, and weather on a daily and seasonal basis. In general, New England coastal wetlands experience regular patterns of flooding and exposure with the ebb and flow of the tide. Wetlands associated with estuaries also contend with daily and seasonal fluctuations in salinity. In a single day, a crab in a coastal wetland might be submerged in seawater, caught in a rainstorm, exposed to the open atmosphere, and as a result, experience salinities between 10 to 35 parts per thousand (ppt). Normal seawater in the Gulf of Maine ranges from salinities of 30 to 35 ppt. Plants and animals inhabiting these habitats must be highly specialized to deal with such extremes.

## Salt Marsh Development

Coastal wetlands exist in areas that are regularly flooded by tidal waters. They develop along embayments, barrier beaches, islands, and **estuaries** that form the link between the ocean and non-tidal freshwater habitats. While this manual focuses on salt marshes, tidal mud flats and rocky beaches are examples of the other coastal wetlands whose conditions are less hospitable to the establishment of plant communities.

Salt marshes develop in sheltered, **intertidal** coastal areas where the absence of severe winds and waves allows fine sediments to settle and accumulate and for plants to eventually take root. Salt marshes form along barrier landforms and islands, coastal ponds, and tidal creeks or rivers. Salt marshes of various types and sizes are common along the Atlantic seaboard of the US as far north as the Canadian Bay of Fundy.

Variation in topography, geology, tides, sediment supply, wave exposure, and rate of sea level rise along the Maine coast lead to the development of different marsh types. Three basic types of tidal marshes in Maine are **coastal/back barrier marshes, finger marshes**, and **fringe marshes**, as described below.




Back Barrier Marshes　　Finger Marshes　　Fringe Marshes

**MAINE MARSH TYPES**

*after Bryan and Dionne, 1997*

**Coastal/Back Barrier Marshes**

- associated with back barrier beaches
- most common west of Sheepscot Bay
- located adjacent to and have direct access to the Atlantic Ocean
- dominated by high marsh
- notable examples are located in Wells and Scarborough

**Finger Marshes**

- area of high marsh is large compared to size of channel
- elongated shape follows long axis of channel
- a notable example, Back River, is located on the north side of Route 1 in Woolwich

**Fringe Marshes**

- found along protected shoreline in estuarine reaches and rivers (coves, indentations, small tributaries, meanders, or at the toe of eroding bluffs)
- limited development of high marsh
- strongly influenced by ice erosion; also affected by erosion from river flow and waves
- often bordered by mud flats
- notable examples along the shorelines of the York River can be seen from the Maine Turnpike

Two other types of marshes are influenced by tides yet support different plant communities. Brackish marshes exist further inland along estuarine systems and have salinities ranging from 0.5 to 18 ppt. Brackish marshes can support typical salt marsh plants along the seaward edge of the marsh, but also support a high diversity of freshwater and slightly salt-tolerant wetland plants. Tidal freshwater marshes occur at the inland limit of estuaries where tides continue to cause fluctuating water levels but seawater fails to penetrate. Tidal freshwater marshes support a high diversity of wetland plants that are intolerant of salinity. Identification of plant and animal **species** from brackish and freshwater marshes is an important skill for studying salt marshes because tide restrictions frequently cut off salt marshes from their tidal influence, causing salt **tolerant** organisms to be out-competed and replaced by brackish and freshwater organisms.

## Salt Marsh Plants & Zones

Salt marshes can be ecologically challenging places to live because of wide daily fluctuations in salinity, water depth, temperature, and oxygen. Few plants have evolved adaptations to cope with the extreme conditions of salt marshes. Plant **zonation** in a salt marsh results from species-specific adaptations to physical, chemical, and biological conditions. Looking out on a healthy salt marsh in full summer growth, one can observe distinct zones of plant growth. Bands of tall grasses inhabit the saturated banks of creeks and bays, and this zone is bordered by a flat "meadow" of grasses, rushes, and sedges that may extend landward for a great distance before transitioning into upland habitats where there is a greater diversity of shrubs, flowering plants, and grasses.

*Salt marsh plant zonation, Little River marsh, Wells, ME*

**Marsh Border**: The marsh border is at the marsh's upland edge and other isolated marsh areas where elevations are slightly above the high marsh. This area is usually only flooded at extreme astronomical tides and under irregular conditions such as storm surges or wind-driven tidal inundations, and is not generally waterlogged or severely salt stressed. A high diversity of rushes, herbs, shrubs, and even trees exists here. Examples include *Juncus gerardii* (black grass), *Juncus balticus* (Baltic rush), *Iva frutescens* (high tide bush), *Baccharis halimifolia* (sea myrtle), *Agropyren pungens* (stiff-leaved quackgrass), *Solidago sempirvirens* (seaside goldenrod), and *Panicum virgatum* (switchgrass).

**High Marsh**: The high marsh lies between the low marsh and the marsh's upland border. The high marsh can be very expansive in some areas, sometimes extending hundreds of yards inland from the low marsh area. Soils in the high marsh are mostly saturated, and the high marsh is generally flooded during higher than average high tides. Up to 25 species can be found in this zone, with the dominant species being the grasses and rushes such as *Spartina patens* (salt hay grass), *Distichlis spicata* (spike grass), *Juncus gerardii* (black grass) Juncus balticus (Baltic rush), and the short form of *S. alterniflora* (smooth cordgrass). Other plant species commonly found in the high marsh are *Aster tenuifolius* (perennial salt marsh aster), *Limonium nashii* (sea lavender), *Triglochin maritima* (seaside arrow grass), *Plantago maritima* (seaside plantain), and *Salicornia europaea* (common glasswort).

**Pools:** Pannes are located within depressions in the high marsh. They have irregular, shallower slopes edges and deeper sections. Pools are generally more permanent water-holding features in the high marsh that can be vegetated with submerged aquatic species such as *Ruppia maritima* (widgeon grass).

**Pannes**: Pannes are interspersed with pools in the high marsh. They are shallower than pools and hold standing water but dry out during extended dry periods. Salinity can reach extremely high concentrations in pannes and only the most salt-tolerant species can exist at panne edges, including *Salicornia spp*. (glassworts), *Plantago maritima* (seaside plantain), and the short form of *Spartina alterniflora* (smooth cordgrass) as well as some blue-green **algae**.

**Low Marsh**: The low marsh is located along the seaward edge of the salt marsh. The low marsh is usually flooded at every tide and exposed during low tide. Plants in this zone do not survive continuous submergence and this determines the lower limit for these plants. The low marsh tends to occur as a narrow band along creeks and ditches, whereas the high marsh is more expansive and is flooded less frequently. The predominant plant species found in the low marsh is the tall form of *Spartina alterniflora* (smooth cordgrass). This species can reach a height of six feet and is very tolerant of daily flooding and exposure.

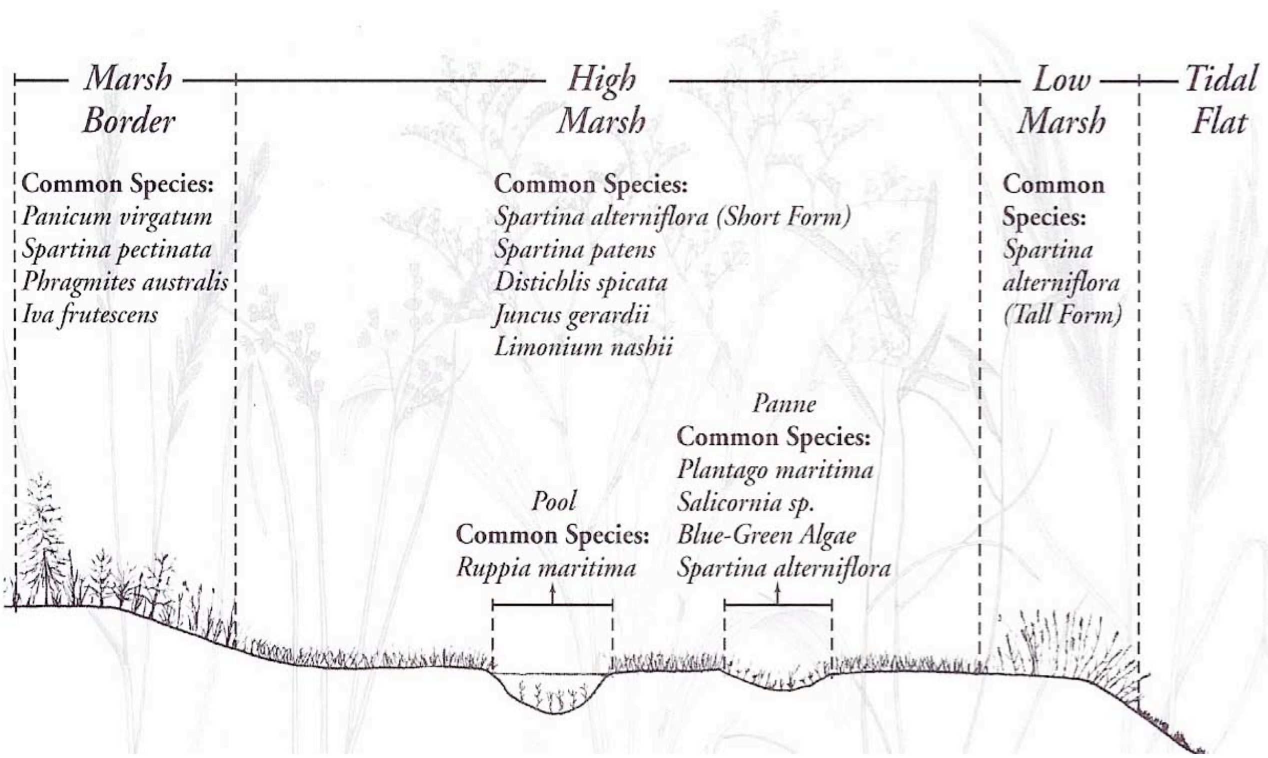



*Figure 2.1. Plant zonation in northeastern salt marshes. Courtesy of MA CZM*

## Salt Marsh Succession

*Fringe marsh, Vinalhaven, ME*

As mentioned, salt marshes develop in sheltered coastal areas that are protected from severe wind and wave action where the combination of low energy and deposition of fine sediments (sand and silt) favors the establishment of plant communities. One of the first plants to take hold in these areas is *Spartina alterniflora,* whose seeds are dispersed by wind and water. *Spartina alterniflora* is a perennial plant that develops an extensive system of underground stems, called **rhizomes**, which stabilize sediments and reduce erosion. As this plant establishes itself, it forms dense stands that buffer wave energy and trap sediments, promoting further development of the infant salt marsh.

Bacteria and fungi slowly decay organic matter produced by a growing stand of *Spartina alterniflora*. Over time, the accumulation of **detritus** and estuarine sediment results in the formation of peat. Peat accumulation occurs for many years and raises the elevation of the marsh enough to reduce flooding frequency. Once this occurs, high marsh plants such as *Spartina patens* and *Distichlis spicata* can become established, which in turn accelerates peat accumulation and eventually allows a greater diversity of salt marsh plants to exist there. A mature salt marsh has a well-defined low marsh and high marsh that continue to expand seaward and landward over time. The landward migration of the salt marsh occurs as the marsh keeps pace with sea level rise. As the height of the sea increases very gradually, so too does the surface of the marsh. Unfortunately, coastal development at the marsh's edge prohibits this landward migration, and over a long time, sea level rise and hardened shorelines may become a major cause of salt marsh loss.

Higher than normal tides deposit large amounts of dead plant material or other debris called wrack on the marsh, creating bare or open areas by shading and killing the plants below and often slightly lowering the marsh elevation underneath. These depressions may become pannes or pools. Opportunistic plants like *Salicornia spp.* and *Distichlis spicata* quickly colonize these open areas. Over time, typical high marsh plants may out compete and replace opportunistic species. Naturally disturbed patches on the marsh surface undergo a predictable succession from early colonizing marsh plants to dominant grasses. The important thing to remember about salt marsh succession is that the appearance, productivity, and biological diversity of a salt marsh constantly change due to natural processes. Human disturbance and pollution certainly affect salt marshes, but the distinction between natural processes and human impacts is sometimes fuzzy, and can lead to uncertainty in environmental impact studies.

Salt marshes are detritus-based ecosystems. Scientists define **detritus** as decomposing plant and animal material. Bacteria, fungi, microscopic plants and animals, and some larger animals all contribute to the decomposition of dead plants, resulting in detritus. Many invertebrates eat detritus and associated decomposers. These invertebrates are called detritivores. Certain detritivores eat detritus directly (some snails, crabs, and amphipods) whereas others eat sediment that contains detritus (fiddler crabs, snails, shrimp, and worms).

A third group of consumers are filter feeders, which include clams, mussels, and some worms. Filter feeders actively filter food (phytoplankton, zooplankton, detritus) from the water column. A fourth group of consumers are predators, which includes a wide variety of invertebrate and vertebrate animals. Terrestrial insects and spiders are important predators in the high marsh vegetation. Killifish, glass shrimp, and blue crabs are three common predators in the low marsh. There are also many birds that prey upon salt marsh animals, such as terns, plovers, egrets, and herons.

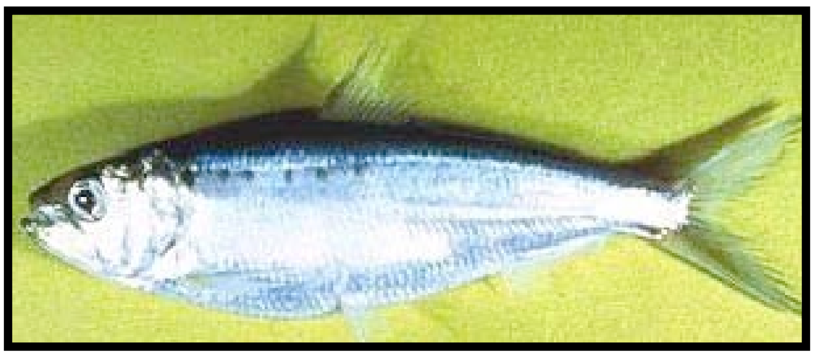
## Importance of New England Salt Marshes

Salt marshes are dynamic and productive ecosystems that provide important benefits to humans and wildlife alike. Most notably, salt marshes are important nursery grounds and wildlife habitat, provide flood and erosion control, improve water quality, and offer recreational retreats.

### Nursery Grounds and Wildlife Habitat

A rich diversity of invertebrate and vertebrate animals depends on salt marshes during some stage of their life cycle. Many invertebrates are well adapted to daily cycles of exposure and flooding associated with the change of tides, providing these organisms with competitive advantages in a productive ecosystem.

Many animals are not adapted to live in salt marshes all the time, yet have found ways to capitalize on the food and safety that salt marshes provide during essential times of their life cycle. Many marine fish use salt marshes as breeding grounds or nursery habitats for juveniles, where they find an abundant supply of prey (such as worms, mollusks, and crustaceans). Flounder, tomcod, smelt, shad, Atlantic salmon, sturgeon, eels, and striped bass are just a few examples of game fish that use salt marshes at some point during their lives. Non-game fish such as mummichogs, silversides, and sand lance also rely on salt marshes and are key forage species for game fish such as striped bass and bluefish. Blue crabs forage for prey in the low marsh during high tide but move offshore during low tide; unlike green crabs and fiddler crabs, blue crabs cannot tolerate long periods of exposure.



*Herring*

Animals do not need to enter salt marshes to benefit from their productivity. Every ebb tide carries a flush of nutrients and detritus into offshore areas, where it is eaten by a variety of consumers and helps fuel marine food webs. In addition, fish and crustaceans that feed in salt marshes and then move into subtidal areas are essentially transferring salt marsh-derived nutrients into marine food webs.

Many wading birds, shorebirds, and waterfowl use salt marshes to nest, breed, feed, or rest during migration. Some of these birds are rare, threatened or endangered, such as the bald eagle, northern harrier, least tern, osprey, and salt marsh sparrow. Salt marshes are also habitat for Maine listed species such as the eastern box turtle. Deer, muskrats, otters, foxes, and coyotes may also forage in or near salt marshes.

### Erosion Control and Flood Protection

Salt marshes are very effective at stabilizing shorelines. Without the extensive root networks of salt marsh vegetation, sediment would quickly be transported away by wind and waves, leading to severe erosion. Salt marsh vegetation also absorbs wave energy and storm surges, temporarily stores floodwaters, and slows water velocity. Waterfront home and business owners that have marshes between their property and the ocean benefit from the strong line of defense salt marshes provide against storm damage. Some states are even investing in salt marsh restoration projects because it is a cost-effective way of protecting coastal communities from storm surges, tropical storms, and Nor'easters.

## Water Quality Protection

Streams, rivers, surface runoff, and subsurface groundwater flow all transport pollutants from uplands to marine environments. Salt marshes and the vegetated buffers that border them provide a natural filtration process that can help improve the quality of water that passes through salt marshes before reaching the ocean. Salt marshes take up nutrients such as nitrogen and phosphorus and break down or bind a variety of organic and inorganic pollutants. Although salt marshes are capable of absorbing small levels of excess nutrients, high amounts of certain pollutants such as nitrogen may eventually impair marsh productivity and disrupt food webs. It is important to minimize nutrient inputs to salt marshes in order to maintain valued ecological functions and food webs.

## Recreation and Education

Salt marshes offer a wide variety of recreational and educational opportunities for people of all ages. They are popular areas for birding and wildlife viewing. Photographers and artists have long sought the natural beauty of salt marshes for inspiration and solace. Salt marshes are excellent sites for waterfowl hunting and recreational fishing, and kayakers enjoy exploring bays, rivers, and creeks at high tide. As vibrant ecosystems, salt marshes are unique "outdoor classrooms" allow easy access to a rich diversity of plants and animals for natural history and marine biology study and are well suited for coastal ecology lessons.

*Scarborough Marsh, Scarborough, ME*

## Threats to New England Salt Marshes

350 years of wetland destruction and pollution have left a lasting legacy on New England salt marshes. Among the challenges facing wetland managers and scientists today are the identification of imperiled salt marshes, the prioritization of sites for restoration, and the development of methods to measure the effectiveness of restoration efforts. The most common threats to salt marshes are changes to natural **hydrology**, nonpoint and point source pollution, and coastal development.

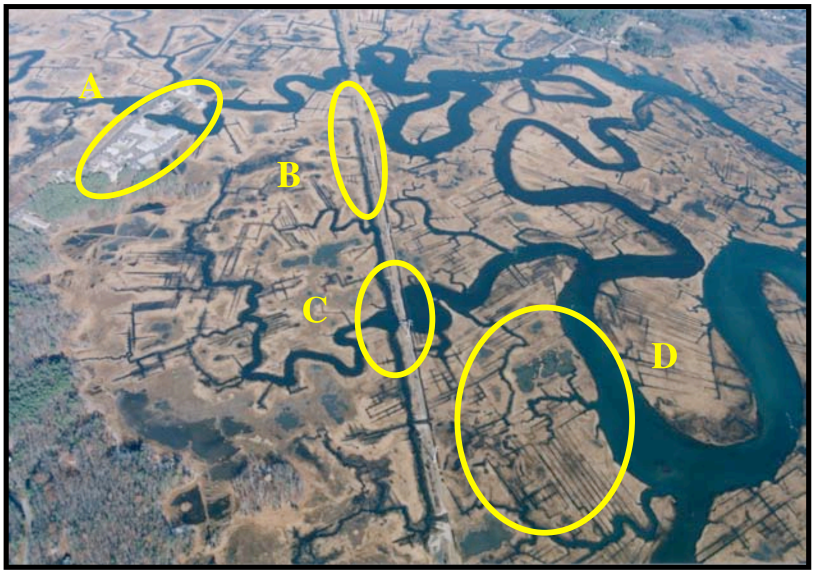



*Figure 2.2. Human impacts such as: A.) filling of marsh for development, B.) installation of railroad on the marsh surface, C.) tidal restriction, and D.) grid ditches affect the Hampton-Seabrook estuary.*

**Changes to Natural Hydrology: Tidal Restrictions, Ditching, Wetland Filling and Stormwater Runoff**

Throughout coastal New England, there are vast areas of wetlands that were productive salt marshes until roads or railroads severed their connection to the sea. Humans built transportation routes on salt marshes because they were open and flat. Horses and carts were the first to use these routes, followed by steam locomotives in the latter half of the 19th century.

In the 20th century, humans continued to create and pave roadways on some of our most valuable wetlands to accommodate automobiles. These roadbeds divided salt marshes into two sections – one with direct unlimited tidal connection to the ocean, and one with restricted or in some cases no access to the ocean (Fig. 2.1). Causeways created for road and railroad crossings are tidal restrictions that have had enormous impacts on landward salt marshes by reducing or eliminating tidal exchange – the force that controls salt marsh ecosystems. Tidal restrictions led to the disruption of natural flooding regimes, alterations to soil and water chemistry, and changes to natural plant and animal communities. These changes led to the establishment and proliferation of invasive species such as the non-native form of *Phragmites australis* (common reed) or *Lythrum salicaria* (purple loosestrife).

Many local, state, and federal groups are working to restore salt marshes. The most common method of restoring natural hydrology is to install larger culverts under roads, railways, and similar barriers to increase tidal exchange. Mosquito control ditches dug in the 1960's also altered salt marshes. Dredged spoil dumped on salt marshes from activities such as harbor maintenance are also removed from targeted areas to allow natural vegetation to return.

*Phragmites can dominate degraded marshes.*

Increased freshwater runoff is another way that humans continue to alter the natural hydrology of salt marshes. In undisturbed coastal landscapes, rainfall and snowmelt are temporarily stored in wetlands and forests, or taken up by plants. In urban communities, much of the landscape has become rooftops and pavement, and rainfall and snowmelt flow rapidly over these surfaces into nearby streams and wetlands. Salt marshes in urban watersheds may receive enormous volumes of stormwater runoff, which can lead to increased erosion, sedimentation, altered salinity levels, and changes in soil saturation levels.

### Environmental Pollution

Human activities release enormous amounts of polluting substances to the air, water, and soil. The list of pollutants is virtually endless, and their effect on natural ecosystems is not well understood. The runoff of nutrients, such as nitrogen and phosphorus from fertilizers, septic systems, and farm and pet waste are common nonpoint sources of pollution that in high enough concentrations can change the structure and function of natural ecosystems. Excess nutrients are a particular problem in salt marshes because they eventually lead to **eutrophication**. Industries and combustion engines release numerous heavy metals, such as mercury, lead, and aluminum, which pose lethal and chronic health risks to wildlife and humans. Pesticides that are applied to lawns, gardens, forests, and ponds to kill so-called “nuisance” species often affect non-target species.

It is beyond the scope of this manual to detail all the types of pollutants and their effects on the environment, but consider this fact: every time it rains, stormwater picks up sediments, nutrients, chemicals, and heavy metals from the landscape and carries these pollutants into waterways or storm drains that may lead to streams, rivers, and salt marshes. Salt marshes are depositional areas and therefore are likely to store these pollutants for long periods.

### Human Development

Coastal New England has witnessed unprecedented population growth and urban development over the past three decades. Real estate values have skyrocketed, increasing the pressure on landowners to sell or develop their land. Waterfront property is particularly valuable because of the great views, serenity, and access to the ocean that it can provide. Urban sprawl leads to ever-increasing amounts of impervious surface area, altering surface and groundwater hydrology and increasing nonpoint sources of pollution. The net effect of coastal development and land use change on salt marshes is the loss of upland buffers and new exposure to a wide variety of human-derived pollutants and disturbances. Salt marshes in urban watersheds may receive enormous volumes of stormwater runoff, which can lead to increased erosion, sedimentation, lowered salinity levels, and changes in soil saturation levels. By 2025, it is expected that an additional 25% of New England watersheds will be developed.

The upland buffer and marsh border provide important habitat for a wide variety of wildlife that also utilize the adjacent salt marsh, including many songbird and mammal species. Elimination or alteration of upland buffers indirectly alters bird and wildlife use of salt marshes. Noise pollution and light pollution can affect bird and wildlife behavior. Human disturbance of the landscape may enable potentially damaging species such as *Phragmites australis,*

*Webhannet marsh, Wells, ME*

*Lythrum salicaria*, house sparrows, raccoons, and opossums to establish themselves in salt marsh ecosystems and alter natural food webs. Domestic and feral cats may also decimate wild bird populations near residential areas.

Because of their ecological importance as well as the widespread threats they face, salt marshes are worthy of continued monitoring and research to assess their ecological health, and action to improve or maintain their condition.

## Salt Marsh Restoration in Maine

Resource people in Maine who can facilitate local restoration work can be found at all levels, from municipal officials, university extension and non-profit organization staff, to state and federal agency personnel. In particular, the Natural Resource Conservation Service, National Oceanic and Atmospheric Administration, US Fish and Wildlife Service Gulf of Maine Office and many non-governmental organizations are actively restoring salt marshes in Maine. Projects have included replacing undersized culverts, restoring hydrology by selectively filling ditches or removing dikes, removing invasive species such as *Phragmites*, and removing fill. Oversight of salt marsh restoration activities in Maine is managed by Maine's Habitat Restoration Coordinator at the Maine Coastal Program.

*Tricolored Heron and Snowy Egrets*

# Chapter 3: Elements of Study Design

In recent years, public awareness of the importance and plight of salt marshes has grown. Local citizens have become increasingly involved in monitoring programs that support salt marsh preservation and restoration efforts. It can be highly rewarding to take part in salt marsh monitoring – participants can learn about the natural communities of estuarine wetlands and share in public efforts to preserve and protect natural resources. However, it is imperative that volunteers collect data in an organized way so that the information they generate is useful to scientists and resource managers. This goal is easier than you think! The key to a successful monitoring program is a sound study design. A study design identifies project goals, and provides specific objectives and methods to achieve those goals. Adherence to procedural protocols ensures data quality. A study design requires that investigators think through and describe how to conduct monitoring to achieve project goals in the form of a document that is read and understood by everybody involved in the monitoring program.

*Little River marsh, Wells, ME*

Successful volunteer monitoring programs usually have at least one thing in common: someone to coordinate the monitoring activities, training workshops, logistics, equipment, data sheets, and report preparation. The program coordinator is the hub for the collective effort of the group, and pulls together all the various elements of the project to achieve results and maintain continuity. The program coordinator usually develops the study design and helps to ensure data quality and consistency, no matter where, when, or who collects the data. Established monitoring programs may be fortunate enough to have funds to compensate the program coordinator, though in many cases the program coordinator is participating as a volunteer. The high quality data provided by volunteers is then **analyzed** and **interpreted** by regional salt marsh ecologists.

## What To Measure, How, and When

This manual provides guidelines and methods for monitoring three biological parameters (birds, nekton, and vegetation) and four physical/chemical parameters (groundwater, surface water, root-zone salinity, and tidal regime). There are many factors that program coordinators take into consideration when determining which of these parameters to measure. They weigh the pros and cons of each, their relative cost and resources available, and the level of effort and expertise required.

The program coordinator will be responsible for selecting parameters, arranging training sessions, and scheduling fieldwork. Volunteer monitors can gain a greater understanding of salt marshes by measuring several parameters, though they may achieve project goals by measuring only one parameter. It is better to sample fewer parameters carefully and thoroughly than to sample several parameters at the expense of data quality.

A small amount of good data is far better than a large amount of poor data! Action taken based on flawed data has the potential to actually cause damage. Volunteer data are more valuable to resource managers and scientists when groups carefully follow a study design and use the guidelines and methods provided in this manual.

## Site Selection and Sampling Locations

How do resource managers conduct their research? How many sites should be monitored? Should an entire marsh be monitored, or just a portion? How do we decide what areas to monitor? Deciding which marshes to monitor and where to sample within these marshes is an important task that should be resolved during the development of a study design.

## The Comparative Approach

The methods described in this manual are based on use of a comparative approach. There are two primary ways to establish this comparison; the Before-After Comparison and Reference Site-Study Site Comparison (see Box 3.1). When it is feasible, program coordinators will try to incorporate both a Before-After Comparison and Reference Monitoring programs. Combining the two comparative approaches will provide much greater insight into the overall effects of the **stressor**. The Before-After Comparison allows groups to document the actual response of a marsh to the addition or removal of a stressor, and the Reference Site-Study Comparison allows groups to understand restoration targets and provide information and guidance for designing the restoration project.

Reference sites are salt marshes that lack some or all of the disturbances of the study sites or mimic neighboring sites. Reference sites are important because many of the impacts to salt marshes have occurred over extended periods of time. Many times it is not known what impacted sites were like prior to disturbance. Therefore, reference sites are used as reasonable approximations of conditions in the absence of a particular stressor and are an extremely important part of the study design.

**Box 3.1.** Example of the comparative approach.

***Example***: A group wants to study the effects of a tide restriction on a marsh that will be removed in two or three years. Two different study approaches may be considered:

**BEFORE-AFTER COMPARISON**

**Definition:** Study a salt marsh before and after a stressor is added or removed.

**Application:** Study the restricted marsh for 1 - 2 years before the removal of the tide restriction and for 1 - 2 years afterward. Compare how salt marsh parameters change after the removal. Natural processes respond slowly to change, and restored salt marshes will continue to evolve and respond for a long time; perhaps up to 20 years.

**REFERENCE SITE-STUDY SITE COMPARISON**

**Definition:** Compare a salt marsh affected by a particular stressor to a similar salt marsh without that stressor.

**Application:** Use the restricted marsh as the study site and choose a suitable reference site. Usually the unrestricted portion of the salt marsh is a suitable reference site. Compare parameters from the restricted side to the unrestricted side of the salt marsh. This study will provide useful information that will help to plan for the actual restoration and to estimate restoration response. After the removal of the tide restriction, the reference site can serve as a target to help evaluate how the study site is responding.

## Four Common Study Areas

Salt marshes may differ for reasons unrelated to pollution or disturbance. Tidal range, geology, landscape setting, and salinity are just some of the variables that influence salt marsh ecology. Ideally, study sites and reference sites are selected because they are similar in nearly every way except the stressor of interest. Resource managers take into account natural differences between study sites and reference sites and address these differences when analyzing and presenting data. Volunteers will be monitoring at four categories of salt marshes: regional reference sites, marshes with tidal flow restrictions, marshes affected by surface alterations, and marshes affected by pollution, invasive species, and land use.

### 1. Regional Reference Sites

These salt marshes are generally as pristine as can be found today and include environmental conditions and biological diversity that are representative of a given region. Regional reference sites tend to be large expanses of salt marsh that are owned by conservation entities and are far from human development. Ideally, they lack linear or grid ditches that resulted from the Works Project Administration (WPA) of the 1930s and other attempted mosquito control or drainage projects. Sometimes, recreational activities such as bird watching, walking, or kayaking are permitted at reference sites, but in general, these marshes experience little human disturbance. Regional reference sites typically represent the best achievable condition for salt marshes in a given region.

### 2. Salt Marshes With Tidal Flow Restrictions

A tidal flow restriction is a reduction in normal tide range resulting from a completely or partially blocked channel. Roads, railroads, and other man-made creek crossings often bisect the marsh into a tidally restricted side and an unrestricted side. The restrictive features of these crossings include undersized or blocked culverts, tide gates, or bridges that restrict full passage of tidal flow. For tidal flow restriction studies, the unrestricted side can be used as the reference site and the restricted side as the study site, because in the absence of the restriction, it is generally assumed that the two sides would resemble each other.

*Tide gates at Addison marsh, Addison, ME*

### 3. Salt Marshes Affected by Surface Alterations

Changes have been made in Maine salt marshes since Europeans settled here. Changes include: diking to convert to upland; ditching to enhance harvest of salt marsh hay; and later ditching intended to drain standing water from the marsh or to drain storm water from developed uplands. Roads were built across marshes. Marshes were used to deposit dredge materials and filled for development projects.

The relative impacts of each alteration within a marsh system may vary with its location and degree of natural recovery.

**4. Salt Marshes Affected by Pollution, Invasive Species, and Land Use**

Surrounding land uses influence the types and amount of pollutants that enter coastal wetlands, and many researchers are interested in studying the effects of land use and pollution on salt marshes. A common approach is to utilize one or more regional reference sites, with the understanding that there may be some environmental differences between the reference and study sites, such as location in the estuary, soils, topography, or tide exposure. Other reference areas could be parts of the same salt marsh that are farthest from the impacts, or nearby salt marshes whose upland habitat is relatively undisturbed. Program coordinators consult with agency scientists or other professionals when selecting reference areas for this category of study sites.

*Edge development at Moody marsh, Moody, ME*

## The Evaluation Area

Once study and references sites are chosen, the next step is to decide where to sample. This task may sound easy for a small salt marsh, but it can be daunting in a 400-acre salt marsh. The study design needs to account for variation in the sizes and environmental condition of reference sites and study sites. To address size variability, scientists have designed an approach to examine comparable portions of reference sites and study sites, called **evaluation areas**. The evaluation area is delineated as follows:

*Example: A group is interested in examining the effects of a tidal flow restriction (roadway and culvert) that has divided a salt marsh into two parts – a six-acre restricted area and a 280-acre unrestricted area. They need to know where to survey the plant community. Here are two common concerns:*

1. The unrestricted (reference) area is too big – nearly fifty times larger than the restricted marsh. Sampling the entire 280-acre salt marsh is not feasible or realistic. One plant transect might be a half-mile long!

2. Because of the size difference, you are apprehensive about comparing the restricted marsh to the unrestricted marsh – size alone would likely allow a greater diversity of plants to exist at the reference site.

To address these and other concerns, managers have developed protocols to select representative areas of salt marshes called evaluation areas. Evaluation areas are delineated in a consistent way using specific protocols, and therefore reduce bias associated with size difference between salt marshes. The location of the evaluation area is also important to isolate and assess the effects of land uses and related impacts like stormwater and fill.

1. From a designated start point on the bank of the salt marsh creek, bay, or salt pond, extend a line along the bank edge for 300 ft (Figure 3.1-1a).
2. At both the start point and the end point, create transects that run perpendicular from the salt marsh banks to the upland edges.
3. The salt marsh and creek habitat that falls between the two comprises the evaluation area (Figure 3.1-1.b).

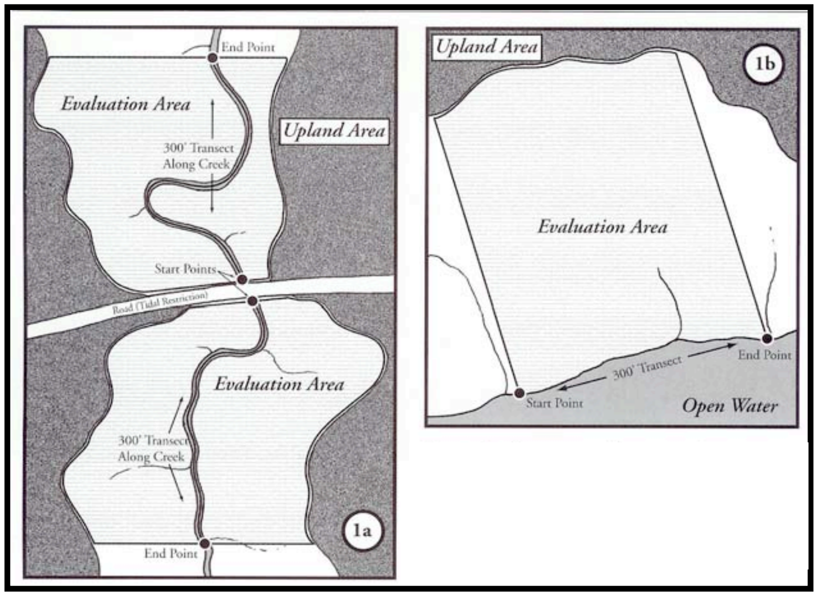



***Figure 3.****1. Delineating evaluation areas. 1a shows the evaluation area on both sides of a tidal flow restriction, and 1b shows the evaluation area along an open water feature. Courtesy of MA CZM.*

## Cause and Effect

A sound study design should attempt to demonstrate cause and effect. For example, a study design might attempt to answer the question: Is a tidal flow restriction affecting a neighboring salt marsh community? To determine cause and effect, resource managers must take great care to select suitable reference sites.

Every study has goals, objectives, and limitations. The approach detailed in this manual will indicate if two sites are different, but may not fully explain why they are different. For example, a tidal flow restriction is likely to be a major cause of the reduced diversity and increased **abundance** of invasive species, but other factors may be at work as well. For instance, there may be a major **groundwater** seep in the study area causing substantial flows of fresh groundwater, which naturally reduces the salinity throughout the system. A population of *Phragmites australis* may have existed at a site for decades, so expectations for removing this invasive species by eliminating the tidal flow restriction may be overly optimistic.

*Phragmites stand at a tidally restricted salt marsh*

Though we can never be entirely certain of cause and effect in comparative studies, we can overcome some uncertainty by using statistics and weight of evidence. Weight of evidence is the same in ecology as it is in law enforcement - the more we know about a situation, the more possibilities we can rule out. Volunteer monitoring projects that measure more parameters will be able to build a stronger case for their conclusions.

Proposals to carry out restoration activities usually depend on making a strong but not necessarily conclusive case for cause and effect. Although the data may suggest a restoration activity would improve the health/condition or value of a particular marsh, it is impossible to predict the outcome of any specific restoration projects with 100% certainty. For this reason, data collection before and after such projects ("pre" and "post" restoration monitoring) is extremely valuable in improving our understanding of effective restoration strategies. Volunteer monitors can make important contributions to salt marsh protection and restoration without providing academic-level research. In many cases the data provided by volunteer groups help to identify salt marshes that deserve closer examination, such as a groundwater study, detailed soil and elevation mapping, or further chemical analysis. Another significant function of volunteer monitoring is to track specific parameters like vegetation, fish, and salinity in restoration projects. Observing and documenting the shift from one **community** type to another, or the reduction of invasive species over time, is sometimes as important as understanding exactly why these changes are occurring. Restoration, remediation, protection, and conservation efforts nearly always result from information provided by collaborative efforts between concerned citizens, groups, communities, and professional scientists.

*Monitoring at Little River marsh, Wells, ME*

# Chapter 4. Data Management, Quality Assurance, and Quality Control

Volunteer monitoring coordinators must ensure that data collected is accurate. Poorly collected samples or data that are carelessly analyzed or presented may mislead people about the quality of the ecosystem. While good data legitimate management decisions, bad data weaken confidence in management actions.

Program coordinators must be able to demonstrate that the data collected by their volunteers are consistent over time, collected and analyzed using standardized and acceptable techniques, and comparable with data collected in other assessments using the same methods. Such assurances include having program coordinators check each incoming data form for decimal errors, missing information, and general problems.

*Recording data accurately is an integral part of monitoring.*

At the start, the program coordinators will institute a strict quality control and quality assurance plan designed to minimize data collection errors, remove out data that do not meet rigorous standards, and develop a strategy to present the results. Such a plan will enable program coordinators to stand behind their results and justify their conclusions. All volunteers should scrupulously follow the outlined methods such as:

Field data should be recorded on datasheets provided (Appendix A). A separate field data sheet should be used for each site and survey date. Datasheets include information described previously in the protocols (study site, date, station identification, habitat description, species name, total number of individuals, lengths, comments, environmental parameters, etc).

One person should perform all of the data entry so that entries are consistent. If two people are working together, one can observe while the other records information.

When collecting data, there are some things you should keep in mind:

1. Data should be entered neatly, legibly, and thoroughly so that there is not any missing, incomplete, or incorrect information.
2. Make sure that all sections of the datasheet are filled out before moving to the next sampling station.
3. If a variable cannot or was not measured (instrument failure, fish escaped), explain on the datasheet for that section the reason for the missing data. Record the reason/explanation in the field. Do not wait until you return to the office to record the reason or explanation.
4. When the observations have been completed for a site, it helps to review the data sheet to ensure that all the necessary data are accurately recorded and that everything is legible
5. All field data should be transferred to digital format as soon after sampling. Field data are easily incorporated into common spreadsheet or database programs that are designed for comprehensive data management.
6. If an error is made in recording data, do not erase. Draw a single pencil line through the incorrect values and enter the correct values.
7. After the data are entered, it is important to carefully proof the data for errors to insure the data are correct and to maintain quality assurance and quality control of the data.

# Chapter 5: Ecology of Salt Marsh Vegetation

Plants are the primary food source for salt marsh ecosystems. Most plant material is consumed after it dies as detritus by microbial decomposers and invertebrate consumers. A salt marsh is physically dependent on its plants – plant roots and stems anchor the **substratum** and enable the gradual build up of peat. Plant communities, along with variation in tidal exchange, geology, and chemical parameters such as salinity, shape salt marsh habitat and help determine which species of invertebrates, fish, birds and other animals will be found there.

Seaside Goldenrod
*(Solidago sempervirens)*

Salt marshes are an extremely dynamic habitat for plant species because of wide daily and seasonal fluctuations in surface water and root-zone salinity, temperature, and dissolved oxygen. For this reason, the few plants species which are found in salt marshes fill extremely specialized ecological niches. Plant zonation results from species-specific adaptations to physical and chemical conditions (see Figure 2.1., page 8)

## Why Should Vegetation Be Monitored?

Plant communities respond to human disturbances and subsequent changes to salinity, natural hydrology, invasive species, or pollutant levels. Often, scientists compare a disturbed marsh with an undisturbed marsh to see how vegetation has responded to the disturbance. For example, a study may compare the plant communities in two salt marshes on either side of a railroad bed to try to understand how the restriction altered a previously contiguous ecosystem. Alternatively, a study may record plant communities in one salt marsh over time and watch how vegetation changes in response to the introduction and proliferation of invasive species such as *Phragmites australis* or freshwater wetland species such as *Typha latifolia* (broad-leaf cattail). Many types of disturbance allow plants that could not otherwise live in salt marshes to gain a foothold, reproduce, compete, and perhaps replace native species.

Marsh Orach
*(Atriplex patula)*

## When Should Vegetation Be Monitored?

Plants are an important and easy parameter to measure, and sampling should be performed once a season at the time of maximum standing biomass in mid summer (mid July through August). Sites should be monitored both pre- and post-restoration in years 1, 2, and every 3-5 years thereafter.

## Where Should Vegetation Be Monitored?

Resource managers and program coordinators will establish evaluation areas to be surveyed. If a creek or river channel bisects the salt marsh (this is the case for most tide restricted sites), your group may survey for plants on both sides. If this case there will be one set of **transects** on each side of the channel.

Transects run from the creek edge to the upland edge, according to a consistent compass bearing (Figure 5.1). For example, all six transects will be laid on a bearing of 275 degrees from the bank to the upland edge.

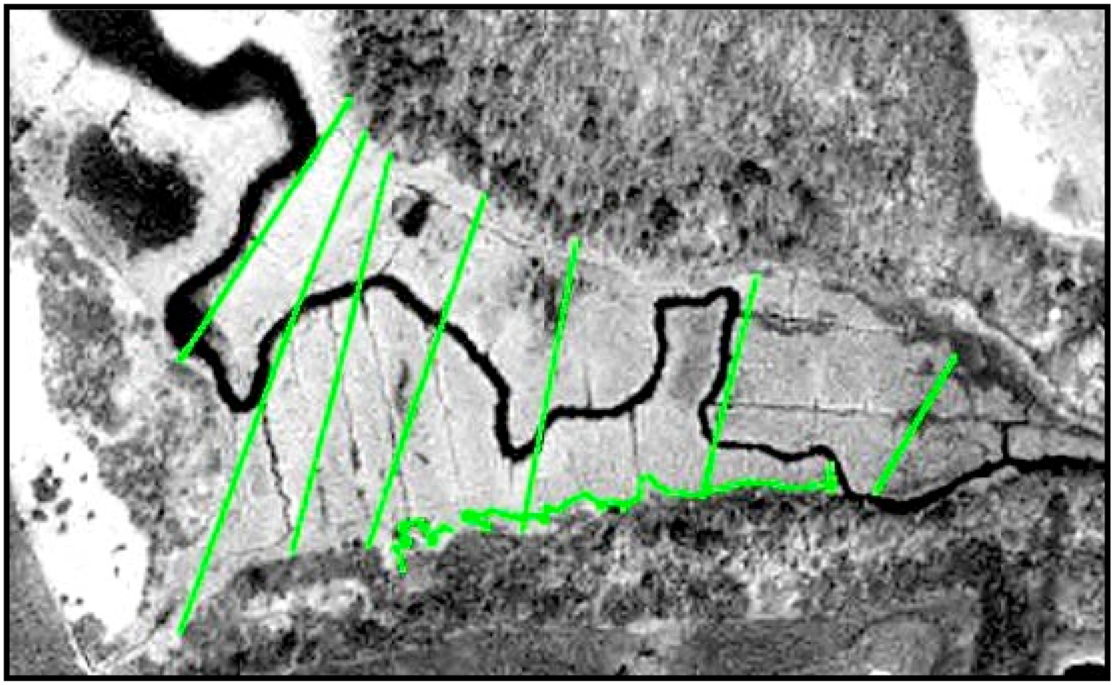


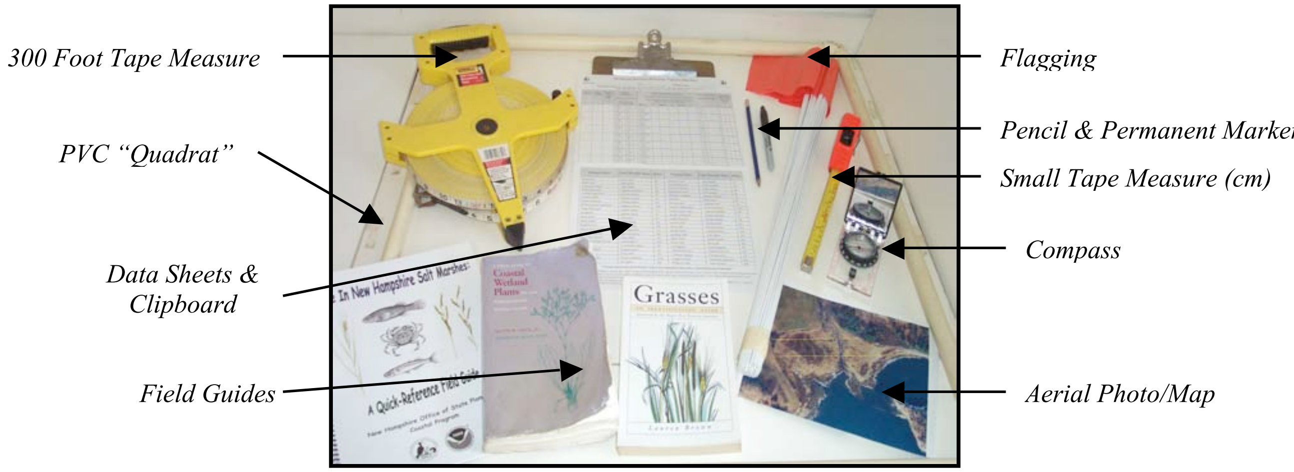
***Figure 5.1***: *Vegetation transects at Pickering Brook salt marsh, Greenland, NH*

## How Should Vegetation Be Monitored?

### Sampling methods

**1)** Permanent Photo Stations
Photographs taken from permanent stations can provide additional **qualitative** information on changes in a plant community over time. Permanent photo stations should be indicated on maps and marked with permanent field markers. The stations should include views of any restoration activities or structures. Landscape photos are taken at north, south, east, and west compass bearings to cover a panorama of the entire marsh. For stations located at the site of a tidal restriction, bearings that illustrate the downstream marsh are desirable as well. Landscape photographs should include a person or an object for height scale. Photos should be taken at the time of vegetation sampling.

**2)** Transect/Plot Method
The general marsh community and species of concern are sampled using _$m^2$ quadrats. In this method, quadrats are placed along a transect at pre-determined intervals.




## Equipment

Equipment costs for monitoring vegetation using the transect method are relatively low compared with other parameters. Salt marsh vegetation surveys require a _ m$^2$ plot sample quadrat constructed from _ inch PVC piping, a comprehensive field guide to wetland plants, a compass, a 50-100 foot tape measure, and flagging.  Program coordinators are responsible for building quadrats and supplying all necessary equipment.  However, volunteers are welcome to bring their own field guides as well.

## Vegetation Survey Protocol

<u>Transect/plot method</u>**:**

1. Starting at the creek edge (the equivalent of 0 feet along the transect), place the quadrat at the following intervals leading away from the creek edge and toward the end of the transect: 0 feet (plot 1), 10 feet (plot 2), 50 feet (plot 3), 100 feet (plot 4), and every 50 feet thereafter until you reach the upland edge. *The first plot is always placed at the beginning of the transect and the last plot is placed at the salt marsh upland border regardless of whether or not the 50 foot interval falls there.*

2. Facing the upland edge with the creek or bay at your back, *always walk on the left side of the tape measure and place the quadrat/plots on the right side.* This ensures that you will not trample plants to be surveyed and that plot position is consistent. Position the quadrats so that the bottom of the left-hand corner of the frame is always located at the designated distance on the measuring tape, such as 0, 10 or 50 ft.  Record the plot, transect number, cover type (Box 5.1), and distance from the creek edge in the space provided on the data sheet.

3. Starting with the first plot on the first transect, identify every plant whose root and stem fall within the _m$^2$ quadrat. Use a field guide to identify plants. Record the habitat description within each plot as creek edge, low marsh, high marsh, pool, panne, or upland edge in the space provided on the data sheet.

*Recording vegetation cover within a quadrat*

4. Record the abbreviation for the scientific name of each species you have identified in your plot on the data sheet (Table 5.1).  Abbreviations consist of two to three letters based on the Latin name of the plant, and can be found on the back of the data sheet or on the clipboard.

5. For each species, estimate percent cover by visual examination. Estimate percent bare ground, dead, and areas of open water as well. *The percent cover estimates will always total 100%* (Figure 5.2).

6. If there are species of concern within the plot (Common Reed, Purple Loosestrife, Narrow or Broad-Leaf Cattail), count their stems then measure the height (cm) of the three tallest individuals within each plot.

**Box 5.1. Cover Type/Species Categories**

When collecting vegetation data, please be sure to note the following cover type/species categories:

- **Bare:** Includes mud and sand. These are areas that are not flooded with water and are devoid of standing live, standing dead, or macroalgae. There can be a thin film of surface water within the bare category.

- **Dead Vascular Plants:** Identified by species. This category only includes standing dead (attached) plants.

- **Live Vascular Plants:** (Herbaceous and shrubs) identified by species.

- **Macroalgae:** Identified as "algae."

- **Open Water:** Permanent standing water is identified in plots that are partly within a creek, ditch, pool, or flooded panne.

- **Wrack:** Wrack is material that has floated into the plot. This is general dead (not attached) plant material.

## Plant Identification

Proper identification of wetland plants is an important skill for salt marsh vegetation surveys. Fortunately, New England salt marshes support a low diversity of plants, and the number of species that volunteers will regularly see is limited. Volunteers should try to become familiar with plant **morphology** and plant ecology to become competent with species identification. Several books integrate key information on identification, ecology, and distribution. These books can be invaluable to those without a strong **taxonomy** background.

- One of the best publications available for northeastern North America is *A Field Guide to Coastal Wetland Plants of the Northeastern United States*. This field guide provides excellent drawings, clear descriptions, and user-friendly keys for 59 species found in salt and brackish marshes, as well as many other plants found in freshwater wetlands.
- *Life in New Hampshire Salt Marshes: A Quick-Reference Field Guide*

Always consult the program coordinator if you have trouble identifying a specimen using a field guide. If you are still unable to identify a particular species, you should call the specimen "Unknown Species 1" or "Unknown Species 2" in your field data sheet and place the plant and part of its roots into a re-sealable plastic bag (along with a label) for later identification. Once you have identified the plant, the spreadsheet or database can be adjusted. Also, keep voucher specimens of plants you think you identified properly, but need confirmation from someone with more expertise. Vegetation surveys are typically conducted prior to restoration activities, 1 and 2 years following restoration activities, and every 3-5 years thereafter. Several data analysis techniques can be used detect and analyze changes to a vegetation community over time.

***Table 5.1.*** *Common names, scientific names, and abbreviations of salt marsh vegetation*

| Common Name | Latin/Scientific Name | Abbrev | Common Name | Latin/Scientific Name | Abbrev |
|---|---|---|---|---|---|
| Baltic Rush | *Juncus balticus* | JB | Saltmarsh Bulrush | *Scirpus maritimus* | SM |
| Black Grass | *Juncus gerardii* | JG | Saltmarsh Bulrush | *Scirpus robustus* | SR |
| Broad-Leaf Cattail | *Typha latifolia* | TL | Saltmeadow Grass | *Spartina patens* | SP |
| Bushy Knotweed | *Polygonum ramoissium* | PR | Saltwater Cordgrass | *Spartina alterniflora* | SA |
| Common Glasswort | *Salicornia europaea* | SE | Sea Blite | *Sueda linearis* | SL |
| Common Reed | *Phragmites australis* | PA | Sea Lavender | *Limonium nashii* | LN |
| Glossy Buckthorn | *Rhamnus europaea* | RE | Seashore Alkali Grass | *Puccinellia maritima* | PUM |
| Halberd-Leaved Tearthumb | *Polygonum arifolium* | PAR | Seaside Arrow Grass | *Triglochin maritimum* | TM |
| Hedge Bindweed | *Convolvus sepium* | CS | Seaside Goldenrod | *Solidago sempervirens* | SS |
| Jewelweed | *Impatiens capensis* | IC | Seaside Plantain | *Plantago maritima* | PM |
| Marsh Elder | *Iva frutescens* | IF | Sensitive Fern | *Onoclea sensibilis* | OS |
| Marsh Orach | *Atriplex patula* | AP | Silverweed | *Potentilla anserina* | PAS |
| Meadowsweet | *Spiraea latifolia* | SPL | Slough Grass | *Spartina pectinata* | SPE |
| Narrow-Leaf Cattail | *Typha angustifolia* | TA | Speckled Alder | *Alnus rugosa* | AR |
| Northern Bayberry | *Myrica pensylvanica* | MP | Spike Grass | *Distichlis spicata* | DS |
| Olney Three Square | *Scirpus olneyii* | SO | Sweet Gale | *Myrica gale* | MG |
| Overlooked Hedge Hyssop | *Gratiola neglecta* | GN | Sweetgrass | *Hierochloe odorata* | HIOD |
| Poison Ivy | *Toxicodendron radicans* | TR | Switchgrass | *Panicum virgatum* | PV |
| Purple Loosestrife | *Lythrum salicaria* | LS | Tall Meadow Rue | *Thalictrum pubescens* | TP |
| Red Fescue | *Festuca rubra* | FR | Unknown Species | *Unknown species* | UK |
| Reed Canary Grass | *Phalaris arundinacea* | PHA | Virginia Creeper | *Parthenocisis quinquefolia* | PQ |
| Rugosa Rose | *Rosa rugosa* | RR | Widgeon Grass | *Rupia maritima* | RM |
| Saltmarsh Aster | *Aster tenufolius* | AT | | | |

• If macroalgae/microalgae is found, write "algae" in species placeholder of the "Species Present & Percent Cover" column of the datasheet and record percent cover.

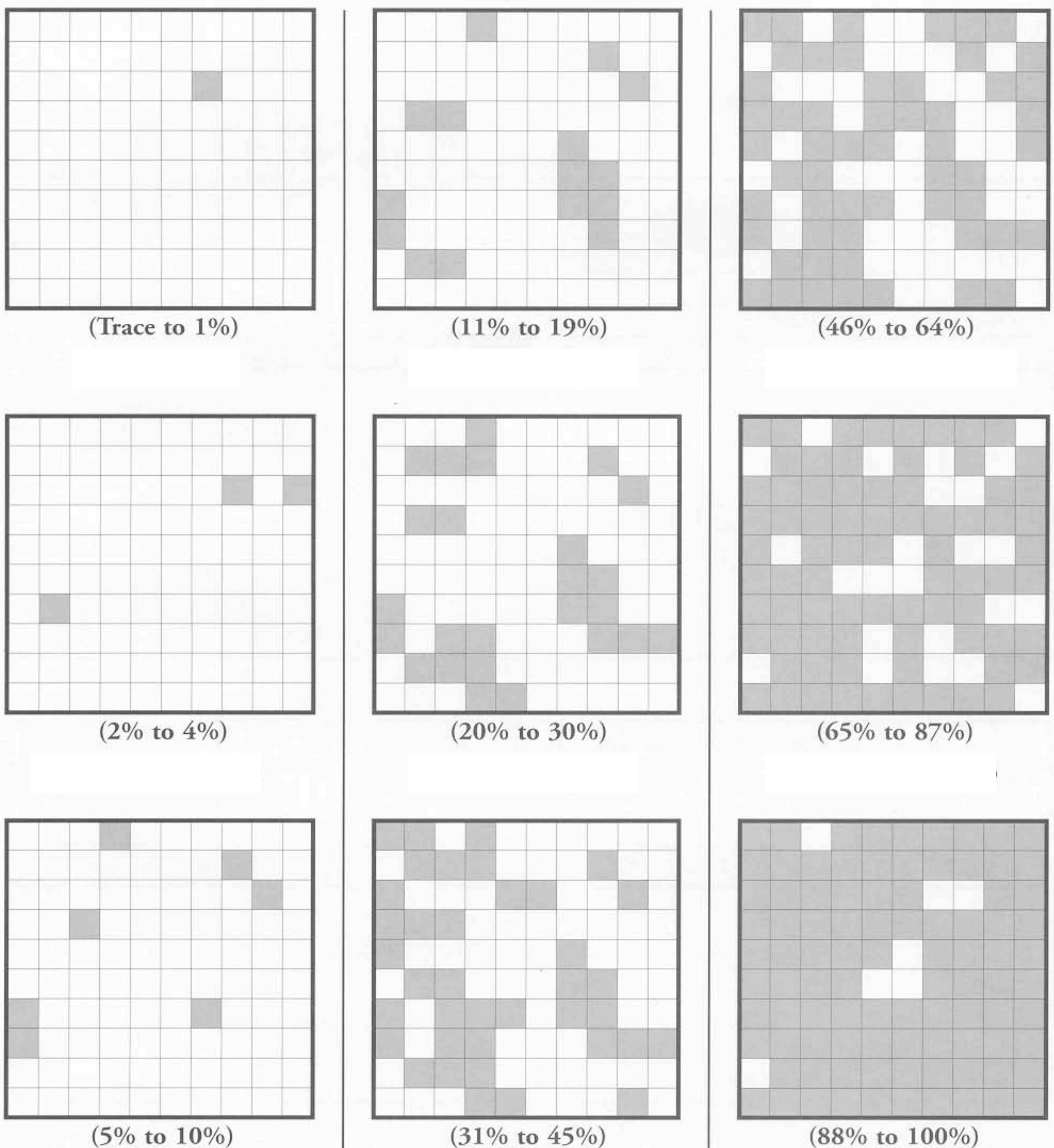
• If the genus of a plant is known but the species is unknown, write the Genus with a "spp" in the species placeholder of the "Species Present & Percent Cover" column datasheet and record percent cover. *For Example: Scirpus spp.*

• Please note the section of a transect by placing an N for north, S for south, E for east and W for west after the transect number. *For Example: T1-N = Transect 1, North*. Transects should run north south or east west .

***Figure 5.2.*** *Estimating percent cover in quadrat plots (%).*

## Salt Marsh Vegetation Survey
### Standard Cover Classes and Midpoints for Estimating Abundance

One method for obtaining abundance values is to estimate the percent of a plot occupied by the target plant. To assess percent cover, one estimates the area of the plot frame ($1 m^2$) that is covered by all of the leaves, branches, and stems of the target species. Since visual estimates may vary from one person to another, standard cover classes and midpoint abundance values are used to reduce variability. The following figures illustrate nine standard cover classes. For each plot, first identify and list the species present, then for each species determine which figure best describes its cover. Record the midpoint value on the data sheet.



# Chapter 6: Nekton

Salt marshes support diverse and abundant **populations** of creatures that swim. Collectively, these organisms, including fishes and many types of invertebrates, are referred to as **nekton**. This chapter focuses on fish, shrimp and crabs that occupy estuarine wetlands. Salt marshes support most life stages of fish and crabs, which are essential components of the food web and represent a large proportion of the total animal biomass and biological diversity in a marsh. Some species spend only a small portion of their lives in salt marshes, whereas others rarely ever leave. Marsh residents such as mummichogs and four-spine sticklebacks reside in marshes throughout their lives. Transient species use salt marshes during critical development periods such as **spawning** or juvenile rearing and are important seasonal components of salt marsh condition. Transients include forage species such as Atlantic silverside, and commercial and sport species such as winter flounder and striped bass.

*Volunteers tally and identify nekton collected using a lift net.*

It is challenging to sample nektonic organisms because their distribution and abundance varies greatly throughout the marsh and over time. The use of salt marshes by fish and crabs can vary from tide to tide, marsh to marsh, species to species, and year to year. Even meteorological events such as a full moon or new moon will influence what you are likely to find in a salt marsh. Unlike plants or benthic invertebrates, nektonic animals are highly mobile and difficult to capture. Despite these challenges, fishes and crabs are fun to study and learn about, can be important indicators of salt marsh condition, and in many cases are the impetus for marsh restoration.

The goals and objectives of a study will dictate the sampling methods used. Monitoring efforts will usually attempt to gather baseline information on species presence and relative abundance to evaluate potential differences between reference and study sites and allow evaluation of monitoring techniques. Volunteers can easily obtain qualitative information about common marsh species. **Quantitative** estimates are possible as volunteers gain experience with salt marsh sampling.

## Why Should Nekton Be Monitored?

Scientists do not fully understand the influence of marsh degradation on fish and crabs, though they continue to investigate this important topic. Tide restrictions may alter fish and crab communities by reducing habitat availability, accessibility, and quality on the restricted side. Many species are **sensitive** to changes in dissolved oxygen, salinity, and nutrient levels that result from pollution and surface runoff. Changes to salt marsh vegetation resulting from upland human disturbance, alterations to natural hydrology, or invasive species may affect fishes or crabs that require native or natural plant communities.

## When Should Nekton Be Monitored?

Most study sites will have 1-2 daytime sampling efforts per year; one in early summer and another in late summer-early fall unless there are species or processes unique to other seasons that are of interest. Fish and crabs are typically sampled from June through September, although surveys can be conducted year round. Nekton sampling in ditches should occur at the same relative tidal stage or tidal cycle and should occur only after the marsh surface is empty of tidal water. Sites should be monitored both pre- and post-restoration in years 1, 2, and every 3-5 years thereafter.

## Where Should Nekton Be Monitored?

The number of individual samples required depends on the habitat under examination, but we will probably conduct at least 10 samples of each sampled aquatic habitat (pool/panne and tidal creek/ditch) during each sample period. All sampling stations will be randomly selected prior to monitoring. Once sampling stations have been chosen, their locations will be marked with stakes or flagging. Their positions can also be recorded using high-accuracy GPS.

## How Should Nekton Be Monitored?

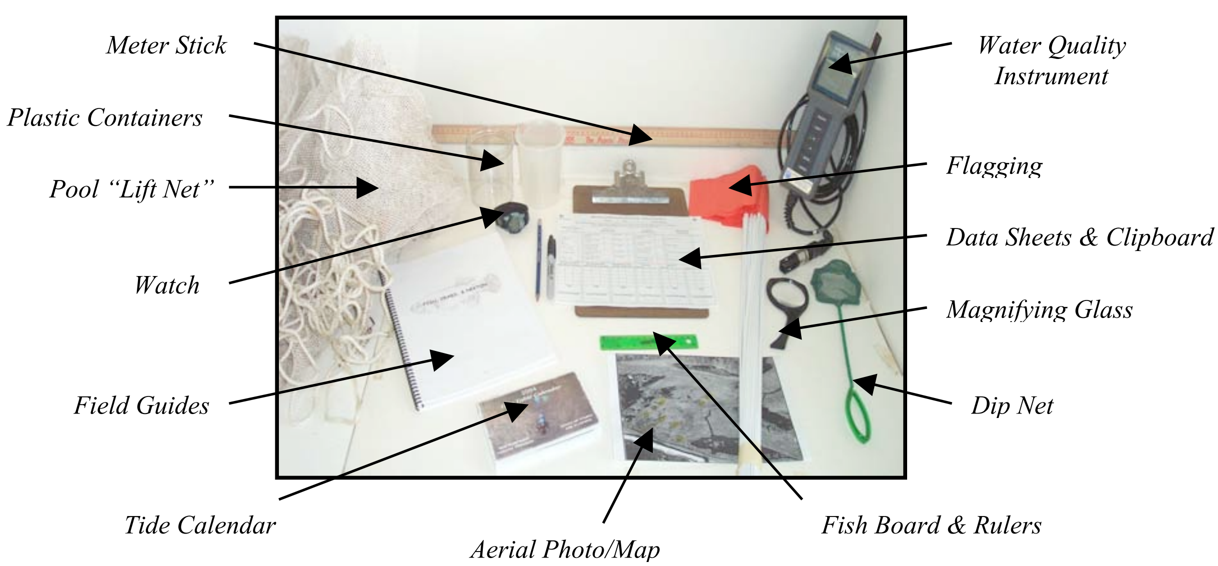
### Sampling Methods

I) Ditch Nets
Ditch nets will be used to sample small creeks and man-made ditches.

II) Lift Nets
Lift nets are used to sample nekton in pools, pannes and plugged ditches.

### Equipment

There are a variety of equipment and methods used to collect salt marsh nekton, each suitable for different conditions, habitats, and target organisms. You will need aerial photos of study sites showing boundaries of study areas and approximate locations of ditches, or program coordinators will have already selected these areas, and they map be located on an aerial map. You will also need "ditch nets", "lift nets", small rulers, containers to hold the fish, meter sticks to measure water in the nets, and small "dip" nets.



**Nekton Survey Protocol**

I) Ditch Nets

The center body of the net should line the sides and bottom of 1 linear meter (approximately) of a ditch. There are two "doors" on the open ends of the net, which when pulled, rise up to close off the ends of the net, enclosing an area of water that is 1m long and as wide as the ditch.

1. Place nets at the station locations in the ditches at least 30 minutes before sampling. This is done to minimize any disturbance to nekton caused by placing the net in the ditch. This usually means that the nets are placed at flood or slack tide.

2. Setting up a ditch net usually requires 2 people, each standing on opposite sides of the ditch or pool. One person will take stakes labeled "A" and "B" and place the stakes into the bottom of the ditch close to the side of the ditch. The other person will take stakes labeled "C" and "D" and place them on the opposite side of the ditch. The net should be stretched tight between stakes "A" and "B" and stakes "C" and "D" so that approximately 1 meter length of ditch is sampled (Figure 6.1).

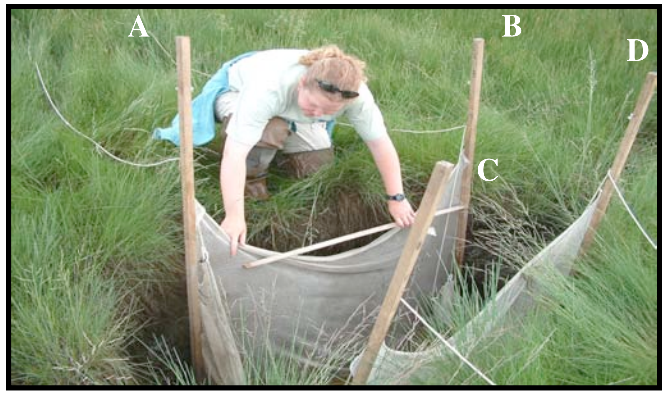



***Figure 6.1.*** *Measuring dimensions of a ditch net*

3. Pull the ripcords to make sure that the lines are not tangled and that the doors will pull up smoothly and quickly.

4. Push the doors and the center of the net down into the bottom of the ditch with the meter stick. Make sure that the net lay down on the bottom of the ditch, so that fish passage through the net is not impeded.

5. Measure the distance between all the stakes (*e.g.* "A" to "B", "B" to "C", "C" to "D", and "D" to "A") and the diagonal distance between stakes "A" and "C" and record these on the datasheet (Appendix C). These distances are measured when the net is placed in the ditch and are necessary to calculate the area of water that is sampled.

6. Lay the ripcords strait away from the nets along the marsh surface as far from the net as possible without pulling on the doors.

7. Record the time that the net was installed in the space provided on the data sheet.

*Approaching a ditch net after drawing the ends closed*

8. After 30 minutes, pull the ditch nets. Two people are required to pull the ditch nets. Quietly and slowly approach the nets from opposite sides of the ditch, with one person on either side. Upon reaching the ripcords, kneel and wait quietly for approximately 2 minutes. Do not handle the ripcords during this time, as the vibrations on the cords can be transmitted to the stakes and possibly disturb nekton that are in the net. At a pre-determined signal, both people quickly pull on the ripcords. The doors of the net will pull up,

enclosing nekton within the net. Once the edges have been fully raised, both people should approach the net.

9. Quickly lift the net out of the ditch and onto the marsh surface. The best way to do this is to have both people pull the stakes out simultaneously (while still maintaining pressure on the rip cords). One person should hand all four stakes to the other and lift the net out of the ditch and onto the marsh surface. It is important to quickly pull the stakes and net out of the ditch. This creates a bag of netting in the center of the net where nekton are trapped (because otherwise, the nekton could still leave through the sides of the doors).

10. Record the time that the net was collected in the space provided on the data sheet.

11. Lay the net out on the marsh surface and identify, count, and measure the nekton.

12. For each sample, measure and sex up to 15 individuals of every species (to the nearest mm). Measure fish from the tip of the snout to the tip of the caudal fin; shrimp from the tip of the rostrum to the tip of the telson; and crabs from the distance between the two furthest points across the carapace. Generally, dominant fish species such as mummichogs (*Fundulus heteroclitus*) are counted and measured in two age classes: juveniles (<45 mm) and adult male and female (>45 mm). Enter juveniles and adults separately in the spaces provided on the data sheet.

13. Return the nekton to the water as soon as possible to limit mortality.


*Juvenile mummichog; 37 mm in length*

14. During nekton collection, collect water quality information (i.e. using a YSI instrument) such as water temperature (degrees Celsius), salinity (parts per thousand), dissolved oxygen (milligrams per liter and percent saturation), and depth of water in ditch. If you have the equipment and resources, you may decide to collect additional water quality parameters such as pH and turbidity.

15. Record water quality and depth information in the spaces provided on the data sheet.

II) Lift Nets

1. Select a section of a pool for sampling so that the net may be placed on the bottom and pulled easily with minimal disruption to water and sediment.

2. Place nets into position at least 30 minutes prior to sampling.

3. Set-up requires 2 people, one on each end of the net. Unwrap net so that weighted cords are on the bottom, facing the ground. Make sure there are no holes, tears, or bunches in the net.

4. With one person on each short end, drape the net on the surface of the water. Weights should slowly lower the net to the bottom.

5. Starting at the center, gently press the entire width of the net into the mud using a long stick with rounded ends securing the net to the mud bottom. Secure the rest of the net by pressing it into the mud at 1-2 foot intervals down the length. (Tip: At 1-2 feet from center, place rounded stick gently on the net. Move net slowly toward the center and depress into mud. This will ensure that the center does not shift out of the mud).

*Installed lift net with well-placed drawstrings*

6. Make sure that all edges and corners are lying flat or depressed into the mud. Pockets will leave areas for fish to hide.

7. Lay the ripcords out on the marsh surface as far from the net as possible without pulling on the net.

8. Measure the length and width of the net and record in centimeters.

9. Measure the depth of the pool at the most common depth and record in centimeters.

10. Record the time of installation and on the data sheet.

11. Pulling the net is two to four person procedure. Each person should approach ripcords quietly and slowly to reduce disturbance to the pool and net. Once at the ripcords, kneel and wait approximately 2 minutes. At a pre-determined signal, pick up the rope and quickly pull up and out while stepping backwards to lift the net out of water. After 2-3 seconds, most of the water will have drained from the net and the narrow width may be folded to form an "envelope" to prevent fish from escaping. *Do not touch cords until signal is given. Vibrations will cause fish to retreat from net.*

12. Keeping net folded; bring the net to a stable high marsh surface for recording.

13. Place fish in containers with water, as they are collected from the net.

14. Separate crabs and other potential predators using several containers.

15. Follow nekton measurement procedure as explained for the ditch net method.

16. Record temperature, salinity, dissolved oxygen (% saturation and mg/ml) immediately following collection.

# Chapter 7: Birds

Birds are the most conspicuous animals inhabiting New England salt marshes because they fly around, sing, and attract attention. For centuries, scientists and naturalists have studied avian life history, behavior, environmental requirements, and responses to environmental disturbance and pollution. The concept of using birds as sensitive environmental indicators has long been established: miners brought caged birds into mines to serve as indicators of air quality, giving rise to the expression "canary in a coal mine." More recently, scientists have studied how nesting, hatching, and fledging success can reflect environmental conditions. This chapter provides the guidelines and methods needed to conduct a monitoring for salt marsh birds, and discusses how birds may be used as environmental indicators.

*Parker River National Wildlife Refuge, Newburyport, MA*

## Why Should Birds Be Monitored?

Wetland birds require certain types of habitats for different aspects of their lives such as nesting, feeding, or migration. Salt marshes offer a variety of habitats such as mudflats, open water, and various types of vegetation. Birds have evolved a variety of adaptations to exploit the resources in these habitats. For instance, herons and egrets have long legs well suited for wading in shallow water and beaks suited for catching fish and invertebrate prey. Habitat diversity in salt marshes results from a variety of physical, chemical, and biological variables. Alterations to physical variables such as hydrology, chemical variables such as salinity, or biological variables such as vegetation will affect the type and distribution of habitats in a salt marsh, and therefore the biological communities that can live there.

Humans may alter the habitat that a bird requires. For instance, Salt Marsh Sharp-tailed Sparrows (*Ammodramus c. caudacutus*) require suitable densities of *Spartina patens* and *Spartina alterniflora* for nesting and feeding. As discussed in previous chapters, alterations to natural hydrology or salinity regimes may reduce the availability of these vegetation types. Humans may also alter the abundance of important prey items. For instance, herons and egrets require high densities of fish, and excessive pollution or alterations to natural hydrology might reduce fish populations to the point where herons and egrets cannot get adequate nutrition. Birds that require specific habitats or conditions - called **specialists** (egrets and sandpipers) - may avoid salt marshes that have been altered by disturbance or pollution, while birds that can tolerate a wide range of conditions - called **generalists** (gulls and crows) may thrive in these areas.

Birds are long-lived and highly mobile, and over the course of their lives can learn to recognize favorable locations for breeding, nesting, feeding, and migration. Scientific research has shown that birds will choose wetlands that have the best conditions to meet their needs. Birds are usually able to recognize if the vegetation is suitable for nesting, or if prey abundance is sufficient for themselves and their young, and if predation risk is low. Birds prefer to avoid stressful situations, and will usually only affect a bird's decision to inhabit a particular salt marsh - some birds avoid wetlands near highways and urban areas because of noise pollution, and large numbers of cats from suburban developments might be a deterrent for birds. Birds that seek out favorable habitats will be more healthy, more likely to have healthy offspring, and may be at lesser risk of mortality.

Birds are just one of several types of organisms that inhabit salt marshes. Although there are shortcomings to using birds to assess the condition of salt marshes, they can yield insight that may be overlooked by studying only plants, invertebrates or fish.

## Bird Identification

Bird identification requires careful visual observations and keen auditory skills. Although some birds are very distinctive, many others look similar and often confuse even the most skilled observers. Some difficulties may arise from the fact that many birds molt twice a year and the appearance of their plumage changes. Juvenile birds that have not developed adult characteristics will often be difficult to identify. Recognizing birdcalls can be an important means of identifying species, (particularly cryptic species), but commonly available recordings often do not include all species you will encounter. Most birds that regularly use the salt marsh, with the exception of the sparrows, are generally silent until disturbed. Many bird identification books are available, and rely on a suite of illustrations, photographs, and descriptions. For best results, gather the bird identification materials you are most comfortable with and use a variety of clues (shape, posture, size, coloration, behavior, habitat, and birdcalls) to identify species or groups of closely related species.

*Egrets and Greater Yellowlegs in salt marsh pool*

As stated previously, actual bird surveys require constant attention by the observers so that they do not overlook any species or miscount individuals. Volunteers should spend several days practicing in the field before actually conducting field surveys to familiarize themselves with the birds and survey conditions. During these "practice runs," volunteers should follow a series of steps to narrow the range of possibilities for any given species and arrive at the proper identification; these steps are outlined below. Volunteers will not conduct actual field surveys until they are proficient with identifying birds by sight.

The first step for visual observation is to determine what general type of bird you are looking at. You should know key characteristics for a few basic groups of birds, based largely on shape and posture. Familiarize yourself with the main group of birds, many of which you probably already know to some extent, so that you can ask yourself simple questions such as:

- Is it gull-like? (gulls, terns)
- Is it duck-like? (ducks, geese, swans)
- Is it hawk-like? (Ospreys, eagles, hawks)
- Is it a wading bird with long legs? (herons, egrets)
- Does it run along the ground like a sandpiper? ("shorebirds" - sandpipers, plovers)
- Is it a perching bird? (Large group of birds, which includes mostly songbirds)

Once you identify the general group a bird belongs to, consult a bird book to find the species that the bird most resembles. You should be familiar with the organization of your book so you can quickly reach the appropriate section and spend more time comparing closely related species. It is sometimes helpful to take notes or photographs to assist in identification. Using common species for comparison, you should focus on details such as size (bigger or smaller than a robin?), shape (long and thin or plump and round?), coloration (brown? what shade?), and any distinguishing marks or features (any streaking or other noticeable marks?).

*Black Ducks and Mallards at the marsh shoreline*

Pay attention to the bird's behavior, including feeding, roosting, flying, and the types of habitat it occupies. Be mindful of the time of year, because in the summer and fall you are likely to see immature birds or post-breeding adults whose plumage is different than what is illustrated in most books. Some groups of birds are difficult to identify, including sparrows, flycatchers, young gulls, fall warblers, and starlings (due to the many variations in their plumage).

Birdcalls are frequently more difficult to learn than visual cues, but knowing the calls will dramatically increase your ability to identify birds in the field. This is particularly true for birds that are cryptic or otherwise difficult to see because of weather, darkness, or heavy cover. Listening to birds as they are calling is perhaps the best way to learn their calls, because this "hands on" approach will enable you to create strong and long-lasting associations between a species' appearance and call. But remember that most birds that regularly use the marsh are silent unless disturbed.

## Bird Activity and Habitat

You can determine the importance of a wetland to a particular species by recording its activity and habitat usage. Here are some examples:

- Some birds (such as gulls, ducks, and hawks) will fly over a wetland on their way to somewhere else. You should not count birds that are cruising high above a wetland unless it looks like they are hunting (such as an osprey looking for prey).
- Some birds (such as swallows, swifts, and flycatchers) cruise at low altitude over the marsh and feed on aerial insects. You should count these low-flying birds.
- Some birds feed almost entirely within the salt marsh yet nest and perch in adjacent wetland buffers because the vegetation may be more dense and protected. You should count birds in the marsh and the upland buffer and record where you observed them.
- Do your best not to count the same individual twice. Since birds may be flying around, this may be difficult. If a bird flies off in one direction and out of sight and then another individual of the same species appears to fly back from the same area, it is possibly the same bird. Use your best judgment.
- If you cannot identify a bird, do not spend too much time looking it up in your book, since you will miss other birds that fly by. Jot a few notes and try to figure it out later – such as color, general size and bird group – gull, waterfowl, shorebird, etc.

## When Should Birds Be Monitored?

Recent studies in Maine found a strong correlation between the tide cycle and sharp-tailed sparrow singing activity. Sharp-tailed sparrows sing much more just after the new moon tide. Therefore, observers should focus survey activity around these periods to ensure that each point is sampled during this time period.

## How Should Birds Be Monitored?

### Sampling Methods

Scientists use two types of field protocols to monitor birds: walking transects and point counts. Walking transects and point counts have been used in all New England states, New Brunswick, and Nova Scotia in order to ensure consistence and comparability in data collection. This data will provide the baseline estimates for salt marsh breeding bird distribution and abundance and aid in establishing a long-term monitoring program for these under sampled taxa. Therefore, it is important to accurate record where each point is located in a marsh so comparisons with future surveys will be valid.

I) Point Counts
Surveys are conducted from a single vantage point overlooking the marsh, and require observers to record all species and individuals seen or heard within a fixed amount of time.

1. Salt marsh bird surveys are created to adequately cover the marsh's study area. In large marshes a line of sampling points may be on the outside edge of the marsh and then move further into the marsh as the route continues, forming a loop so that the observer ends up at the starting point without having to backtrack.

2. The points will be at least 25m from the upland edge, which is unsuitable or non-marsh habitat, and will include a 50m radius of observation. Point centers should be 150m apart, leaving the outside edge of each point 50m apart (see Figure 7.1).

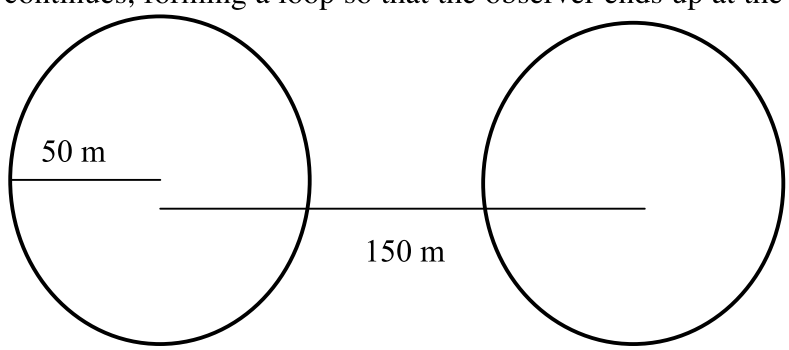



***Figure 7.1.*** *Diagram of bird observation points.*

3. This creates a sampling design where each point is independent from another, thus avoiding counting the same individuals twice. In small marshes or fringing marshes, there may be sampling in unsuitable habitat or close to an edge.

4. Some of the sampling points will have a paired flag to signify the 50m edge to assist with estimating distance to birds.

II) Walking Transect
These are sometimes used alone or in conjunction with point counts. Birds are counted along a standardized path between point counts.

## Equipment

Of the parameters covered in this manual, birds are among the least costly to monitor. Observers only need 5 pieces of equipment to monitor birds: binoculars, field guides, pencils, a clipboard and patience! Binoculars range in price, but most backyard birdwatchers and outdoor enthusiasts already have a pair. Recommended bird identification field guides include:

- *Field Guide to the Birds of North America*
- *National Audubon Society Sibley Guide to Birds*
- *Field Guide to Birds East of the Rockies.*


## Bird Survey Protocols

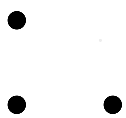
Point Counts/Walking Transect Combination

1. Point counts should be conducted from sunrise to 11 am during the breeding season, and should occur at various parts of the day during the non-breeding season surrounding the high tide. If a survey is conducted late at one session, be sure to conduct the next survey earlier in the day. Point observations should be conducted for 10 minutes each. Points should not be run in high winds or strong rain, but a light drizzle is acceptable.

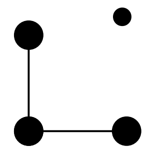
2. Field surveys require constant attention, and there is little time for looking at books during fieldwork. Identify, count, and record on the data sheet all birds observed during the 10-minute point. (Table 7.1)

3. Record when the bird was observed during the ten minutes; between 0-3 minutes, 3-5 minutes and 5-10 minutes. (This allows researchers to compare these data to Breeding Bird Survey data and helps researchers develop a long term monitoring program). It is important to note that when the count is divided into time intervals, only count the new birds detected in each time interval (i.e., once an individual bird is recorded, do not count it again). So if you observed a Willet in the first 30 seconds and then detected the SAME bird 5 minutes later, that is still 1 Willet. *Do not count that bird again in the 5-10 minute time period.*

4. Use the forestry dot method to count individuals, then at the end of the day, go through the data sheets and add up the dots for each cell. For example:



= 3 individuals observed

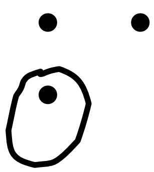


= 6 individuals observed

5. Record whether the individual was within one of three distance categories (0-50m; 50-100m, or beyond 100m). Most of the analyses will be conducted on species within 50m, but researchers also want to be able to include **vagile** species and species with large territories.

Each point and line counts as an individual bird of the same species. When counting, fill the corners in first, then connect them with lines until there are 10 symbols. This avoids many mistakes made using the slash and cross method of tallying.

**NOTE:** Salt marsh sparrows are a species that rely heavily on salt marshes in New England. Until recently, little information was available on their habitat requirements. For this reason, if a salt marsh sparrow is heard singing please indicate this on the data sheet, and circle the dots that represent birds that were seen only (did not vocalize). This gives researchers the ability to pull males only from the data. All non-circled dots indicate that the individual was heard or both seen and heard. This will not be used in the overall monitoring design but may be a useful guide for future research.



= 2 salt marsh sparrows observed (did not vocalize), 1 SSTS heard

### Data Entry in the Field

One person should perform all of the data entry so that entries are consistent. If two people are working together, one can observe while the other person records information.

*Volunteer monitors observing birds*

*Table 7.1*. *Birds observed using salt marshes in Maine*

| Species | AOU Code | Species | AOU Code |
|---|---|---|---|
| American Black Duck (*Anas rubripes*) | ABDU | Killdeer (*Charadrius vociferous*) | KILL |
| American Crow (*Corvus brachyrhynchos*) | AMCR | Herring Gull *(Larus argentatus)* | HEGU |
| American Goldfinch (*Carduelis tristis*) | AMGO | King Rail (*Rallus elegans*) | KIRA |
| American Robin (*Turdus migratorius*) | AMRO | Least Bittern (*Ixobrychus exilis*) | LEBI |
| American Tree Sparrow (*Spizella arborea*) | ATSP | Least Sandpiper (*Calridris minutilla*) | LESA |
| Bank Swallow (*Riparia riparia*) | BANS | Least Tern (*Sterna albifrons*) | LETE |
| Barn Swallow (*Hirundo rustica*) | BARS | Lesser Yellowlegs (*Totanus flavipes*) | LEYE |
| Belted Kingfisher (*Ceryle alcyon*) | BEKI | Mallard (*Anas platyrhynchos*) | MALL |
| Black-capped Chickadee (*Parus atricapillus*) | BCCH | Marsh Wren (*Cisthorus palustris*) | MAWR |
| Black-crowned Night Heron (*Nycticorax nycticorax*) | BCNH | Mourning Dove (*Zenaida macroura*) | MODO |
| Blue Jay (*Cyanocitta cristata*) | BLJA | Nelson's Sharp-tailed Sparrow (*Ammodramus n. subvirgatus*) | NSTS |
| Blue-wing Teal *(Anas discors)* | BWTL | Northern Harrier (*Cricus caneus*) | NOHA |
| Bobolink (*Dolichonyx oryzivorus*) | BOBO | Osprey (*Pandion haliaetus*) | OSPR |
| Brown-headed Cowbird (*Molothrus ater*) | BHCO | Purple Martin (*Progne subis*) | PUMA |
| Canada Goose (*Branta canadensis*) | CAGO | Red-Winged Blackbird (*Agelaius phoeniceus*) | RWBL |
| Chimney Swift (*Chaetura pelagica*) | CHSW | Ring-billed Gull *(Larus delawarensis)* | RBGU |
| Clapper Rail (*Rallus longirostris*) | CLRA | Saltmarsh Sharp-tailed Sparrow (*Ammodramus c. caudacutus*) | SSTS |
| Common Grackle (*Quiscalus quiscula*) | COGR | Savannah Sparrow (*Passerculus sandwichensis*) | SAVS |
| Common Tern (*Sterna hirundo*) | COTE | Seaside Sparrow (*Ammodramus maritima*) | SESP |
| Common Yellow Throat (*Geothylpis trichas*) | COYE | Semipalmated Sandpiper (*Calidris pusilla*) | SESA |
| Cooper's Hawk (*Accipiter cooperii*) | COHA | Short-billed Dowitcher (*Limnodromus griseus*) | SBDO |
| Double-crested Cormorant (*Phalacrocorax auritas*) | DCCO | Snowy Egret (*Egretta thula*) | SNEG |
| Eastern Bluebird (*Sialia sialis*) | EABL | Song Sparrow (*Melospiza melodia*) | SOSP |
| Eastern Kingbird (*Tyrannus tryrannus*) | EAKI | Spotted Sandpiper (*Actitis macularia*) | SPSA |
| European Starling (*Sturnus vulgaris*) | EUST | Swamp Sparrow (*Melospiza georgiana*) | SWSP |
| Glossy Ibis (*Plegadis falcinellus*) | GLIB | Tree Swallow (*Tachycinets bicolor*) | TRES |
| Greater Yellowlegs (*Totanus melanoleucus*) | GRYE | Virginia Rail (*Rallus limicola*) | VIRA |
| Great Blue Heron *(Ardea herodias)* | GBHE | Willet (*Catoptrophorus semipalmatus*) | WILL |
| Great Egret (*Ardea alba*) | GREG | Willow Flycatcher (*Empidonax trailii*) | WIFL |
| Great Black-backed Gull *(Larus marinus)* | GBBG | Yellow-rumped Warbler (*Dendroica coronata*) | MYWA |
| Green-wing Teal *(Anas carolinensis)* | GRWT | | |
| Green Heron (*Butorides striatus*) | GRHE | | |

**For additional bird codes refer to http://www.pwrc.usgs.gov/BBL/manual/sname.htm**

# Chapter 8: Soil Characteristics

*Volunteers monitor the salinity of well samples.*

There are several types of water chemistry studies, including investigations of **ambient water quality** trends that typically involve several parameters, or specific investigations of suspected sources of pollution or parameters of interest. Ambient water quality sampling is usually conducted concurrently with the nekton monitoring methods described in this handbook, and the parameters of interest include salinity, dissolved oxygen, pH, and temperature. This chapter reviews methods for measuring two soil characteristics: soil salinity and sediment elevation.

## Soil Salinity

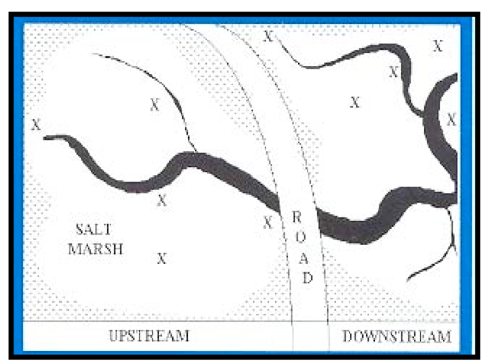
Tidal inundation and freshwater sources control **salinity regimes** in salt marshes. Salinity is highest in areas of estuaries closest to the ocean and in pools or pannes within salt marshes, and gradually declines in a landward direction as the effects of tidal inundation diminish. Rainfall is another source of verification and can reduce salinity in pools substantially. Perhaps the most recognizable consequence of salinity regimes in salt marshes is the vegetation zonation patterns.

Measurements of salinity can help to explain the diversity, distribution, and abundance of plants and animals in a salt marsh. Salinity is also a critical parameter to measure when investigating any type of tidal restriction (or man-made alteration to marsh hydrology). Careful measurements before and after the removal of a tide restriction can provide an excellent indication of the success of restoration efforts. Most often, the primary goals of programs that seek to restore tidal flow are the reestablishment of natural salinity regimes for the restoration of communities.

### When Should Salinity Be Monitored?

Soil salinities should be obtained throughout the entire area to be restored and at an appropriate reference marsh. Sampling should be performed at low tide every three weeks between the beginning of the growing season (April or May) to late-season (September or October) including both spring and neap tides. Soil salinity monitoring may continue at post-restoration sites for several years until results of the restoration activity can be determined. If annual assessments show positive results from the restoration, it can be omitted in some years (for example: pre-restoration, year 1, 2, 4, 5, 7 post-restoration).

### Where Should Salinity Be Sampled?



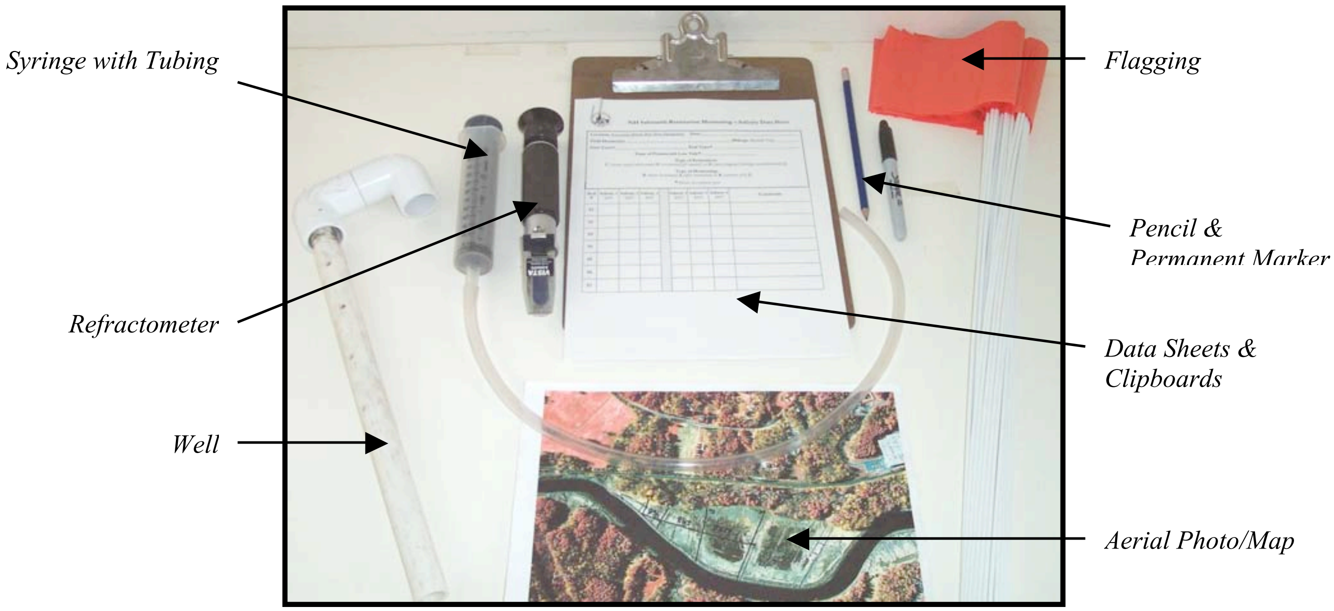

*Example of a salinity monitoring layout; X's mark salinity wells*

A simple layout of at least five stations per marsh unit (i.e. upstream and downstream of tidal restriction or scattered) will be established as a minimum for sampling soil salinity. Along the axis of the main channel one station would be placed close to the restriction, one near the predicted head of tide (after restoration) and one equidistant between the two. These three stations would be located in high marsh approximately 3 to 4m from the tidal channel. Two more stations would be placed between the central station and the upland in high marsh. Soil water should be collected from 5 to 20cm depths (0 to 5cm samples are not practical except with soil cores).

## How Should Salinity Be Monitored?

### Equipment

Soil salinity is a relatively inexpensive parameter to incorporate into a monitoring program. Wells to obtain soil salinity are constructed from 19mm diameter CPVC plastic pipe with 7 pairs of 4mm holes at sediment depths between 5 to 20cm. The base of the 35cm pipe is sealed and the top is capped with two right angles in sequence. This prevents rain or floodwaters from entering the well while maintaining ambient air pressure.




### Sampling Method

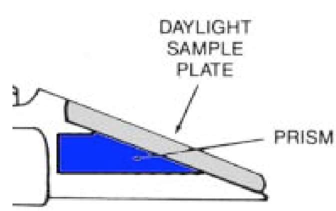
1. Remove the elbow-shaped cap from the well and insert the syringe tubing to the base of the well.

2. Lift the tubing about an inch away from the base to minimize the presence of mud and silt in the sample.

3. Extract a sample from the well by pulling the circular knob at the top of the syringe and drawing as much water into the syringe as possible.

4. Shake the syringe to reduce stratification (layering) in the water.

5. Open the daylight sample plate. Place the end of the tubing onto the refractometer prism and gently push the plunger until a few drops of water fall onto the refractometer.




6. Close the daylight plate so the plate comes into contact with the prism surface. The sample should spread completely over the prism surface. Air bubbles or an insufficient sample will be hard to read. If this occurs, repeat the procedure, applying more of the liquid sample.

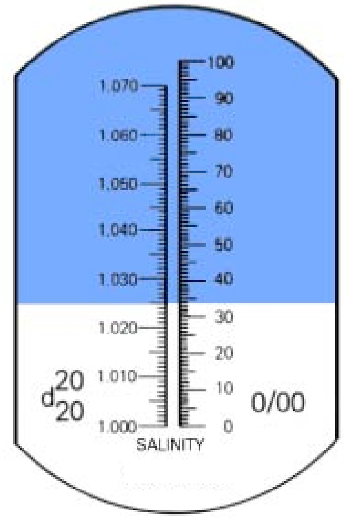
7. Hold the refractometer by the rubber grip and point the prism end of the refractometer to a light source and observe the field of view through the eyepiece. Focus the eyepiece by turning the cross-striped portion of the rubber eyepiece guard either clockwise or counter-clockwise until the scale becomes clearly visible.

8. A horizontal boundary line separating the blue field of view (top) and white field of view (bottom) will appear in the field of vision. Adjust the angle of unit to the light source until line is sharp and distinct. The values on the scale are specific gravity and parts per thousand (ppt).

9. Measure the sample to the nearest parts per thousand (ppt). Record the information in the space provided on the data sheet for "sample 1".

10. Wipe the refractometer prism surface dry and repeat steps 5 and 6 two more times for a total of <u>three</u> salinity readings.

11. Do not allow saltwater to remain anywhere on the unit. When through, wipe clean with damp cloth (fresh water) then wipe dry.




## Sediment Elevation

Measuring the surface elevation of the marsh may assess net balances in critical soil processes that allow salt marshes to persist over time. Loss in elevation indicates peat degradation, whereas gains may be due to accretion at the surface or peat development below the surface. Standard survey techniques are unable to measure short-term changes in the sediment elevation (2 to 3 years), but are adequate for documenting long-term change (10 years or greater). Short-term changes in the sediment elevation of salt marshes around the world are being monitored using Sediment Elevation Tables (SET). Installation of the SETs is difficult and requires professionals. In New England, more than 30 stations exist in several salt marshes. Data are collected to provide baseline information, assess projects to restore hydrology, and assess sea level rise.

# Chapter 9: Hydrology

The presence, type, and potential hydrologic effects of tide restrictions are critical information for salt marsh monitoring and assessment. Tidal influence is an important parameter to measure, and along with salinity can provide a very good understanding of the effect of tide restrictions on the physical and chemical nature of salt marshes.

## Tidal Flow

As discussed earlier, tide restrictions usually result from the construction of a travel route over a salt marsh, particularly where a bridge or culvert is installed on the tidal creek. Tidal crossings are restrictive if they block or inhibit water from flowing freely from one side of the marsh to the other, resulting in a reduction of tidal influence on the landward, or restricted side of the estuary. The seaward, or unrestricted, side of the estuary is a good indication of what the restricted side would resemble in the absence of the tide restriction. In tidal influence studies, the unrestricted marsh is usually the reference marsh and the restricted marsh is usually the study marsh. A comparison of tidal ranges between the reference site and study site provides a good indication of the effect of the tide restriction on tidal hydrology.

There are two types of restrictive tidal crossings. One occurs when the opening of the culvert or bridge is too small or has started collapsing and does not allow natural amounts of water to pass through during each tidal cycle. The most common effect of this type of restriction is a decrease in salinity and especially flooding at high tide in the restricted marsh. The second type of restrictive crossing occurs where a culvert is elevated too high in relation to the creek bed. In this case, sufficient amounts of water may enter the restricted marsh during an incoming tide, but with a delayed effect since the tidal level in the unrestricted side must reach the height of the culvert before passing through it. Elevated culverts may prevent complete drainage of the restricted side because water cannot leave once water levels drop below the culvert, and even during low tide, there is standing water in the restricted marsh. Bank erosion may be evident on either side of the culvert with both types of tidal restrictions. Bank erosion resulting from tide restrictions is often described as "round-shaped pools," which form on either side and directly next to the culvert.


*Little River, North Hampton, NH: pre–restoration (above) and post-restoration (below)*

### Why Should Tidal Flow Be Monitored?

A reduction in tidal flow can have numerous adverse effects on salt marshes, the most important of which is a change in natural salinity regimes. Many plants and animals that exist in salt marshes are adapted to a specific range of physical and chemical conditions, and large-scale alterations such as tide restrictions can cause intolerant species to perish. When salinity levels fall below 20 ppt, the invasion of opportunistic brackish plants such as *Phragmites australis* becomes a problem. Tide restrictions may also block the passage of estuarine invertebrates and fish into the upper estuary, thereby reducing the export of organic matter from the salt marshes. A reduction in tidal flushing may result in the accumulation of detritus, nutrients, and pollutants in the restricted marsh.

## How Should Tidal Flow Be Monitored?

Automatic water level recorders will be installed and operated by project coordinators for a minimum of two weeks, i.e., one lunar cycle of spring and neap tides (one month, or two lunar cycles is better) near the source of tidal influx. For tidally restricted marshes, recorders will be installed both upstream and downstream of the tidal restriction. When automatic data collection gauges are unavailable, volunteers can be used to collect 10-minute measurements over 13-hour periods using a simple tide staff (a vertical ruler fixed in the tidal channel) for three spring and three neap tides would provide adequate information. Using either method, the elevations of the upstream and downstream devices are required, preferably referenced to NGVD (National Geodetic Vertical Datum).

Knowledge of the tidal current in the main channel can be useful when designating the tidal conduit for a tidal restoration and to assess the function of the current structure. Tidal current should be assessed over several tidal cycles and can be measured with a recording current meter.

# Groundwater Levels

Healthy salt marshes depend on high groundwater levels to maintain pool and panne water depth. Groundwater drainage increases in proximity to manmade ditches, resulting in surface subsidence, soil compaction, and dry peat. These conditions can alter natural marsh hydrology, reduce plant productivity, and create opportunities for non-native invasive species to colonize the site.

## Why Should Groundwater Levels Be Monitored?

Under circumstances where an important goal of the restoration project is to increase tidal flooding in order to reduce invasive plant species or increase open water habitat, water table depth monitoring is recommended.

## Where Should Groundwater Levels Be Monitored?

Wells should be placed according to recommendations given for soil salinity stations along the upland edge of the marsh, or in sections of marsh potentially affected by the restoration action.

## When Should Groundwater Levels Be Monitored?

Sampling will occur at low tide about 6 times a year in the early to mid growing season and include neap and spring tides.

## How Should Groundwater Levels Be Monitored?

### Equipment

Piezometers are used to monitor groundwater levels. Piezometers are wells that are open only near the base to allow water into the well. They can be constructed from PVC pipe with a screened, perforated interval that intersects the water table. Changes in water table can be monitored with piezometers placed deep enough in the soil to intersect the water table during drier periods.

### Sampling Method

1. Measuring the height in centimeters of the well above the marsh surface and record the information on the data sheet.

2. Insert a dowel marked at 1cm intervals into the well.

3. Observe the length of the dowel that is wet and record the information on the data sheet.

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# Appendix B. Glossary

**abundance:** The amount — by count, weight, or other measure — of a given group in a given area. Generally, abundance refers to the number of individuals of a species (genus, family) within an area of survey.

**alga/algae:** Very simple, often one celled, plants that are either attached or unattached in aquatic (marine or freshwater) environments; can be used as a term to cover simple seaweed. Floating clumps of algae are called alga mats.

**ambient water quality**: The conditions of a water body (or wetland) generally taken as a whole (e.g. the average pH of Pleasant Bay in 1999), contrasted with site source specific or episodic measurements.

**analyze**: To study and examine critically.

**biological impairment:** Diminished quality, strength, or value of the condition of an individual, group, habitat, and/or function of living organisms.

**biological integrity:** Ability of an ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of pristine habitats within a region.

**coastal/back barrier marshes**: Marshes associated with back barrier beaches that are located adjacent to and have direct access to the Atlantic Ocean and are dominated by high marsh.

**community:** A group of species inhabiting a given area, where organisms interact and influence one another's distribution, abundance, and evolution.

**detritus:** Dead and decomposing plant and animal material.

**diversity:** Variety or heterogeneity in taxonomic groups.

**environmental stressor:** Any material or process (physical, chemical, or biological) that can adversely affect a salt marsh, includes both natural and human disturbances.

**estuary:** Region of interaction between rivers and near-shore ocean waters, where tidal action and river flow mix fresh and salt water. Such areas include bays, mouths of rivers, salt marshes, and lagoons. These brackish water ecosystems shelter and feed marine life, birds, and wildlife.

**eutrophication:** The process by which a body of water becomes enriched with nutrients, particularly nitrogen and phosphorus, which usually changes ecosystem properties and functions.

**evaluation:** Area A comparable and representative portion of a reference or study salt marsh.

**finger marshes**: Marshes having an elongated shape that follows the long axis of a channel where the area of high marsh is large compared to the size of the channel

**food web:** The linkage of organisms based on their feeding relationships sources.

**fringe marshes**: Marshes found along protected shoreline in estuarine reaches and rivers where there is limited development of the high marsh.

**generalist:** A species (genus, family) that is able to exist or thrive in a variety of habitats or conditions.

**Global Positioning System (GPS):** Technology that utilizes communication between orbiting satellites and ground receivers to pinpoint exact locations on the earth.

**groundwater:** The water found beneath the Earth surface, frequently used in reference to aquifers and drinking water wells.

**habitat:** The sum of the physical, chemical, and biological environment occupied by individuals or a particular species, population, or community.

**high marsh:** The area of a New England salt marsh that is flooded by higher than average tides and dominated by the grasses *Spartina patens* and *Distichlis spicata*. The high marsh lies between the low marsh and the marsh's upland border.

**human disturbance:** Activity or state caused, directly or indirectly, by humans that intrudes, interrupts, or perturbs the natural state of ecological relationship and function.

**hydrology:** The [study of] water of the earth, its occurrences, distribution, and circulation with particular emphasis on the chemistry and movement of water.

**indicator:** An attribute or measure that is strongly suggestive of the condition or direction of an ecological system.

**interpret**: To explain meaning according to one's understanding.

**introduced species:** See Non-Indigenous.

**invasive species:** Non-indigenous organisms that may threaten the diversity or abundance of native species or natural ecological relationships and functions by spreading and out-competing native species.

**invertebrate(s):** Animals without internal skeletons and backbones. Marine invertebrates live in ocean-derived salt water, freshwater invertebrates live in freshwater for at least part of their life cycle, and terrestrial invertebrates are associated with uplands and fringes of aquatic habitats.

**low marsh:** The seaward area of a salt marsh, generally flooded daily by the tides, and dominated by the tall form of *Spartina alterniflora*.

**macroinvertebrate:** An animal without an internal backbone that is large enough to be seen by the naked eye.

**marsh border:** The zone of a salt marsh that is only flooded during extreme high tides or coastal storms, and sustains a variety of upland and wetland plants that are not well adapted to periodic flooding or salt stress.

**monitoring:** Periodic or continuous survey or sampling to determine the status or condition of various media and systems, including water bodies, groups of plants and animals, or ecological systems.

**morphology:** The [study of] form and structure of an organism.

**nekton:** Any organisms that actively swim in the water column.

**non-indigenous:** A species transported intentionally or accidentally from another region, allowing it to occur in areas beyond its normal range. Synonym: introduced species.

**panne:** A depression on the surface of a salt marsh. This term is used variably in the literature and field to include both vegetated and un-vegetated, as well as permanently or temporarily flooded depressions.

**parameter:** A measurable property whose value determines characteristics of an ecosystem (e.g. salinity is a measurable attribute of estuarine waters).

**plot sample:** A field sample technique gathering information from an area enclosed by a frame of a standard size.

**pool:** A depression on the surface of a salt marsh generally permanently flooded depressions.

**population:** A group of interbreeding organisms occupying a particular space or area; all of the organisms that constitute a specific group or occur in a specified habitat.

**pore water:** The shallow groundwater occupying the interstitial areas (or pores) of marsh substrate.

**quadrat sample:** See plot sample.

**qualitative:** Involving distinctions based on standards, traits, or value.

**quantitative:** Expressible as, or relating to, a measurable value.

**reference marsh/site:** A marsh that exhibits a typical "minimally disturbed" condition, or maximum functional capacity; and represents other marshes in a specific region sharing the same water regime, topographic setting, and climate zone.

**refractometer:** A device used to measure salinity (or the concentrations of certain dissolved minerals). Prisms send light through a very small water sample and the bend of the light is consistent with the concentration (amount) of salts.

**rhizomes:** A horizontal, usually underground stem that generally sprouts roots and shoots from its nodes.

**salinity regime:** The measured, normal fluctuations in salinity over tidal and seasonal cycles.

**salt marsh:** Low-lying, vegetated coastal wetlands, influenced by the tidal estuary or marine waters.

**sample station:** A specific location within the salt marsh site selected to conduct field sampling.

**sensitive:** Organisms that have a low tolerance of pollution and disturbance. Numbers tend to decrease with impact.

**spawning:** The release of gametes or eggs into the water.

**specialist:** An organism with very specific requirements for some aspects of its ecology or phases of its life cycle.

**stressor**: A single agent or condition constituting a stress for an organism.

**substratum:** The various materials that collectively make up the exposed or submerged surfaces of wetlands and aquatic environments, which may include sand, silt, peat, algae, logs, wood, debris, bank surface, sediments, leaf packs, mud, rock, and sometimes solid waste such as tires.

**surface runoff:** Water from precipitation or snow melt that flows over a land area into streams and rivers.

**taxonomy:** The study of the relationships and classification of organisms.

**tidal restriction:** A structure or landform that restricts natural tidal flow, such as a culvert, bridge, dam, or causeway.

**tolerant:** Organisms that have a high tolerance of pollution or disturbance, whose numbers tend to increase with impact.

**transect:** A method for environmental sample or survey using a straight line to delineate the area of analysis.

**vagile:** A species that easily disperses over large distances.

**wetland:** Areas where water covers the soil, or is present either at or near the surface of the soil for at least part of the growing season.

**zonation:** The observed occurrence of New England salt marsh plants to organize into apparently discrete areas, due to flooding, salinity, and other forcing factors. A classic zonation pattern is (progressing across a marsh from estuarine water to the upland) low marsh, high marsh, and border or fringing marsh. In many marshes, the classic pattern does not hold, and the plant communities would be better described as a patchwork or mosaic.