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ACKNOWLEDGEMENTS

This manual is dedicated to the many volunteers who worked with overwhelming enthusiasm with the authors as the monitoring and training techniques were developed, implemented, and modified. The authors all hope to stimulate the interests of an army of citizen scientists who will actively move to assist, and even lead with the protection of the quality, as well as the quantity, of our coastal salt marsh systems.

A publication of the Massachusetts Office of Coastal Zone Management (CZM) pursuant to National Oceanic and Atmospheric Administration Award No. NA17OZ1125. This publication is funded (in part) by a grant/cooperative agreement from the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Environmental Protection Agency (EPA) under assistance agreement Grant No. CD99101001-2. The views expressed herein are those of the author(s) and do not necessarily reflect the views of NOAA, EPA, or any of their sub-agencies.

Prepared for:
Massachusetts Office of Coastal Zone Management (CZM) and Massachusetts Bays National Estuary Program (MBP)

251 Causeway Street, Suite 900
Boston, MA 02114-2136
(617) 626-1200

CZM Information Line: (617) 626-1212
CZM Website: www.massgov/czm
MBP Website: www.massbays.org

Citation for this document:
Carlisle, B.K., A.M. Donovan, A.L. Hicks, V.S. Kooken, J.P. Smith, and A.R. Wilbur. 2002. *A Volunteer's Handbook for Monitoring New England Salt Marshes.* Massachusetts Office of Coastal Zone Management, Boston, MA.

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A VOLUNTEER'S HANDBOOK FOR MONITORING NEW ENGLAND SALT MARSHES

Bruce K. Carlisle
Massachusetts Office of Coastal Zone Management, Chapters 3, 4, 8, and 9
Anne M. Donovan
Massachusetts Office of Coastal Zone Management, Chapters 1 and 2
Anna L. Hicks
Independent Consultant, Chapters 1 and 5
Vivian S. Kooken
Salem Sound 2000, Chapters 8 and 9
Jan Peter Smith
Massachusetts Bays National Estuary Program, Chapter 7
Anthony R. Wilbur
Massachusetts Office of Coastal Zone Management, Chapter 6

EDITOR AND GRAPHIC DESIGNER
Ethan J. Nedeau
BIODRAWVERSITY

ILLUSTRATORS
Ethan J. Nedeau and Mark A. McCollough

COMMONWEALTH OF MASSACHUSETTS
Jane M. Swift, Governor

EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
Bob Durand, Secretary

OFFICE OF COASTAL ZONE MANAGEMENT
Tom Skinner, Director

MAY 2002


Photo: Ethan Nedeau

Dear Salt Marsh Monitoring Volunteer,

Thank you for your interest in salt marshes, and your commitment to assessing, maintaining, and improving their health and condition. Salt marshes are incredibly productive ecosystems, important to the Commonwealth's biodiversity and economic vitality, as well as the community character of our coastal cities and towns. We have made great efforts in this state to preserve and protect these critical habitats, but, like all other states, have only begun to understand how to evaluate their basic health. Data collected by citizen volunteers like you will go a long way in helping us to advance our understanding of these complex and intriguing wetlands.

This manual provides a framework for volunteer monitoring groups to collect accurate data in a consistent fashion. By using this approach, volunteer data can be used by larger state and federal efforts to look at salt marsh condition. While developed for Massachusetts' salt marshes, we are confident the guide will be useful when assessing salt marshes elsewhere in New England, the Gulf of Maine, and south along the Atlantic seaboard. We encourage you to adapt this framework to your local area, and to make your data available to the state agencies and federal agencies working on these issues.

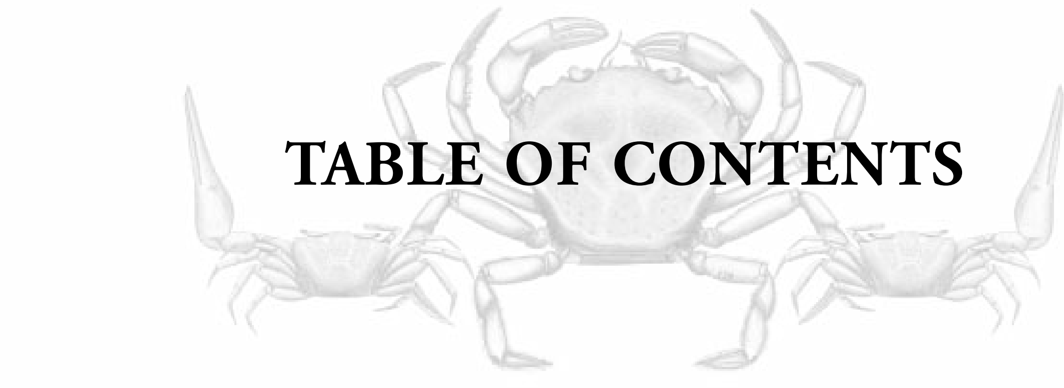
Again, thank you for all your efforts on behalf of Bay State salt marshes. We encourage and appreciate your involvement and look forward to working with you toward a better understanding of salt marsh health.

Very truly yours,

Bob Durand

Bob Durand
Secretary of Environmental Affairs
Commonwealth of Massachusetts


Photo: Ethan Nedeau



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chapter one

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, or fiddler crabs scurrying across the marsh is reason enough to be concerned about salt marsh health. Salt marshes are extremely important for a variety of reasons besides their beauty or the biological diversity they support. Salt marshes serve as nursery grounds for many economically important fish and shellfish such as crabs, mussels, and clams, and they 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.

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

Scientists and managers have developed a variety of tools to assess salt marsh health. Aerial photography and Geographic Information System (GIS) technology are used to determine wetland quantity by comparing recent versus historical maps and photographs, and to document changes that result from coastal development (i.e. houses, roads, etc.). However, wetland quality usually needs to be assessed by field measurements of biological, physical, and chemical **parameters**. Regulations help prevent further filling and fragmentation of wetlands, but they alone are not sufficient to adequately protect these habitats. Scientists are currently developing and employing tools to detect **biological impairment** in these habitats. Eventually, the information generated from these assessments will help to improve regulatory and other protection efforts.

A growing number of citizen and volunteer organizations are becoming involved in conservation programs aimed at restoring or protecting salt marshes. Many local citizens under the guidance of nonprofit volunteer organizations are collecting field data to document the condition of salt marshes and look for evidence of habitat degradation and biological impairment. Scientists refer to this effort as **monitoring**, which is the unbiased collection and precise recording of data over time. This publication advocates an integrated approach to monitoring that combines biological, physical, and chemical measurements; this approach provides a comprehensive and ecologically sound overview of salt marsh condition. Volunteer monitors provide a valuable service to their communities, to scientists who are trying to develop a better understanding of salt marshes with diagnostic **indicators** of wetland condition, and to managers who are trying to implement restoration projects and conservation plans to protect salt marshes.

CZM staff and volunteers conducting invertebrate monitoring. **Photo: Ethan Nedeau**

GOALS OF THIS MANUAL

This manual was developed by the Massachusetts Office of Coastal Zone Management (CZM), Massachusetts Bays Program (MBP), and several partners (see textbox on page 1-3) as a tool to help local volunteer groups collect and record data on salt marsh health in a consistent and scientifically sound manner. The goals of this manual are to:

- Encourage education and promote knowledge of salt marsh ecology.
- Promote stewardship of salt marshes, particularly in restoration and protection.
- Expand the number of qualified individuals who can help scientists learn more about the condition of the region's marshes.
- Generate quality data to be used in the assessment of the health of a marsh and in restoration or protection efforts.

RECENT SALT MARSH MONITORING IN NEW ENGLAND

The rationale and protocols contained in this manual are the culmination of nearly seven years of collaborative effort among the authors, other wetland scientists in the Northeast, and several state and federal agencies. These efforts focused on developing salt marsh bioassessment techniques, which are used to measure wetland health by examining resident plants, animals, and their habitat. While there has been decades worth of research and examination into salt marsh biology and processes, bioassessment of New England salt marshes was just beginning in 1995 when the authors of this manual began to develop scientific monitoring protocols in a series of pilot projects. Through these projects, the authors were able to develop, test, evaluate, and revise the sampling and analysis techniques for different biological, physical, and chemical parameters to examine how they reflected wetland condition. The goal was to first build a knowledge base for salt marsh monitoring, and then transfer this information to volunteer monitors via training workshops and a published manual.

Partners and Roles

Massachusetts Bays Program (MBP): MBP is one of 28 National Estuary Programs around the country. It has been the principal coordinator for the salt marsh volunteer training program and has coordinated the funding and development of this manual.

Massachusetts Office of Coastal Zone Management (CZM): This is a state program that is funded by the National Oceanic and Atmospheric Administration. CZM initiated research to develop a framework for assessing wetland condition and adapt these procedures for volunteer monitoring, and has played a key role in training volunteer monitors. In addition, CZM has contributed significantly to the development of this training manual.

Salem Sound 2000: This is a small non-profit organization, and through a partnership with MBP, helps coordinate and assist volunteer monitoring groups with fieldwork. In addition, Salem Sound 2000 has contributed to the development of several chapters of this training manual.

U.S. Environmental Protection Agency (US EPA): This federal organization provides base program funding to MBP through its Office of Water. In addition, US EPA has provided specific funding for the development of the salt marsh volunteer training program and the production of this training manual.

National Oceanic and Atmospheric Administration (NOAA): This federal organization provides funding for CZM and provided the initial funding for the salt marsh research. NOAA has continued to support CZM staff for all phases of this project, including the development of the training manual.

Anna Hicks: In her capacity as staff for the University of Massachusetts Cooperative Extension and as an independent consultant, Anna Hicks has contributed to the research and development of the volunteer training program and this training manual, particularly the sections on macroinvertebrates.

Salt marsh monitoring in the Northeast took several steps forward in 1999 when the Global Programme of Action Coalition for the Gulf of Maine (GPAC) held a workshop for resource managers and scientists to discuss standard protocols for salt marsh inventories and monitoring procedures. Participants were able to review, evaluate, discuss, and finally recommend regional standards for salt marsh monitoring protocols. Regional standards were then published in a workshop report entitled *Regional Standards to Identify and Evaluate Tidal Restoration in the Gulf of Maine* (Neckles and Dionne 1999). The approach and methods contained in this manual are consistent with those outlined in the GPAC report.

In 1997, the U.S. Environmental Protection Agency (US EPA) declared wetland monitoring a national priority and convened a national Biological Assessment of Wetlands Workgroup (BAWWG). In this workgroup, wetland scientists from federal and state agencies and universities collaborated to improve methods to evaluate the **biological integrity** of wetlands. A New England chapter of BAWWG was established in 1998 and has facilitated further development of techniques and methods for surveying or monitoring salt marshes.

In 1999, CZM, MBP, and Salem Sound 2000 began offering workshops to teach prospective volunteers how to monitor salt marshes. These workshops developed into the Wetlands Health Assessment Toolbox (WHAT) program. This program used a compilation of written guidance materials, workshops, and other technical assistance to provide volunteers and volunteer trainers with methods and practical advice to evaluate salt marshes in a way that is consistent, repeatable, and of maximum benefit to agency scientists and resource managers. This manual is the culmination of three years worth of development and refinement of training methods.

Salt marsh habitat. **Photo: Ethan Nedeau**

THE ROLE OF VOLUNTEER MONITORS

Some people may view the development of a volunteer monitoring project as a daunting task and ask questions such as, "What can I do?" "How can I help?" and "What will my contribution mean?" Volunteer monitoring is very important because it provides much-needed data to scientists and resource managers. You do not need a college degree in biology to be a volunteer monitor — all you need is enthusiasm and a willingness to learn.

Why Volunteer Monitoring Is Important

Coastal resource managers need better information about the condition of salt marshes and their potential threats to more effectively develop and implement protection and restoration strategies. In New England, significant momentum in the identification and inventory of salt marsh tide restrictions has given rise to numerous restoration projects. In addition, cities and towns, watershed organizations, and state agencies are actively working to address the adverse effects of stormwater pollution to wetlands and waters. Efficient use of resources is needed to accurately evaluate the impacts to salt marsh ecology, the feasibility of proposed mitigation projects, and the effects of restoration actions.

Volunteer monitors can play a pivotal role by providing resource managers with much needed field data. Volunteers, resource managers, and scientists all benefit from this type of partnership. Volunteer monitors receive training in wetland science and assessment and become active in local resource planning and decision-making. Agency scientists can monitor more projects and gather more data than would have otherwise been possible, and this can help them develop effective ways to protect or restore salt marshes. Volunteer groups should coordinate with state and regional groups to learn how and where monitoring efforts are needed.

The Role of Volunteer Data

Volunteer participation in government monitoring programs is not a new phenomenon. For many decades volunteers have been counting birds, taking Secchi disc readings in lakes, listening for breeding amphibians, and collecting stream invertebrates to provide valuable data to state and federal agencies. Counts, surveys, and simple tests are well suited for volunteers that do not have the scientific training or the time to devote to large-scale research projects. Historically, agencies were hesitant to encourage or train volunteers to undertake large-scale research projects for a number of reasons:

- Agencies lacked guidelines for study design and data collection particularly suited for volunteers.
- Agencies lacked resources to train volunteers.
- Agencies were concerned about the ability of volunteers to collect scientifically and legally defensible data that could directly influence conservation and management decisions.

Walking through salt marshes can be challenging! **Photo: Vivian Kooken**

MBP and CZM have invested a lot of time and resources to train volunteers to conduct salt marsh research so that volunteers can collect data that are as rigorous 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 to ensure data quality. Using this manual, volunteers can gather data that may directly influence the conservation and management of coastal resources.

Level of Technical Expertise

Volunteer monitoring requires only an interest in salt marshes and a willingness to devote time and energy toward their conservation. However, the use of technical language and terms of research methodology is unavoidable in this publication because you are being trained to think like a scientist and conduct careful monitoring. The authors of this manual have tried hard to find a suitable balance between user-friendliness and scientific rigor. The methods and techniques described are specifically designed for people who may not have direct training or education in salt marsh ecology or monitoring, yet are willing to learn techniques necessary for gathering important and credible information.

Practical Advice and Considerations for Volunteer Monitors

Volunteers following the methods outlined in this manual 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.

Safety Issues

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, thick mud, and potholes can combine to make an uncomfortable experience for unprepared volunteers. Do not work alone! It is important that volunteers be accompanied by at least one other team member when entering a marsh. Marshes are often intersected by ditches or dotted with potholes that are usually concealed by dense vegetation. Step carefully!

Estuarine streams and tidal flats are renowned for deep thick 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 crewmember. Mudflats 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.

Poison ivy is very common in the high marsh-upland transition zone, and it is important that sensitive individuals wear long clothing to protect themselves. In addition, ticks and biting flies can be both a nuisance and serious health threat, since deer ticks may carry Lyme disease. Long clothing and insect repellent are good 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 ensure that they will be comfortable and safe:

- Sunglasses
- Sunscreen
- Wide brim hat
- Water to drink
- First aid kit
- Insect repellent
- Appropriate clothing & footwear
- Cell phone (in case of emergency)

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, and the warmth is exacerbated by high humidity. In addition, light intensity is high because there is no shade and the marsh and surface water reflect sunlight. Sunscreen, sunhats, sunglasses, and water to drink will be among the most important items you will bring to the marsh. Volunteers may consider carrying waders and extra clothing so they do not overheat when walking to or returning from the sampling sites.

Care of the Salt Marsh

Salt marshes are fragile and sensitive ecosystems. Most types of monitoring require that volunteers enter the marsh, and they should be mindful of how their activities affect the marsh and take appropriate steps to minimize impacts. Vegetation trampling and substrate erosion are big concerns. Volunteers should minimize unnecessary trampling and follow paths at sites that they visit repeatedly. When entering estuarine streams and crossing ditches, select areas of bank that aren't too high or too steep; clambering up and down steep streambanks 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 sites during the nesting season. **Invasive species**, such as *Phragmites australis* (common reed), have become a huge problem in coastal wetlands. Most invasive plants have excellent dispersal abilities and rely on animals (or people) to transport them to new sites. You can help curtail the spread of invasive species and pathogens by thoroughly washing waders, footwear, and sampling equipment immediately after leaving one marsh and before moving to another. If you cannot make it to a hose, wash right there in the creek, pond, or bay at the site you just finished.

Naming Conventions for Plants and Animals

This manual uses both common English names and scientific Latin names. Different fields of study have different protocols for naming species. Plant and invertebrate specialists mostly use scientific names, while bird and fish specialists mostly use common names. This manual will use the most widely accepted types of names for each biological group.

A Word About Software

The "Data Entry" and "Data Analysis and Comparison" sections of this manual assume that volunteers and project leaders are familiar with spreadsheet software. Spreadsheets are especially useful for tabulating, sorting, and summarizing data. While many software products exist, the authors of this manual recommend Microsoft Excel because it is present on virtually all personal computers. Project leaders may also want to employ database software in their monitoring program, such as Microsoft Access. Database software is useful for storing large amounts of site-specific data (including digital photographs), querying the data, and generating lists and reports. Used together, database and spreadsheet software provide excellent means to store, manage, and analyze data.

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chapter two

NEW ENGLAND SALT MARSHES: ECOLOGY, IMPORTANCE, AND CONSERVATION

Salt marshes are one of the most productive natural ecosystems on Earth, and support a rich **diversity** of plants and animals that are uniquely adapted to inhabit **wetlands** that constantly change with the 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.

Despite their importance, New England salt marshes have been mistreated ever since the Colonial period because they were perceived as barren, unproductive, mosquito-filled wetlands that could only be improved by filling, draining, or dredging. In the last 350 years, humans have converted countless acres of salt marshes to roads, farms, parking lots, neighborhoods, and even cities. Large areas of Boston were once productive salt marshes! 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.

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 areas and wildlife **habitat**. This chapter also covers why salt marshes are important to humans, and the many ways that humans have destroyed, degraded, and polluted these valuable ecosystems. An understanding of salt marsh biology and ecology is imperative for anyone who is conducting environmental impact studies or 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 needs to be mindful of both.

> "*…There are at present about 3240 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
> From *Life and Death of the Salt Marsh*

Biology and Ecology of New England Salt Marshes

Life in coastal wetlands is characterized by extreme fluctuations 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 covered with seawater, exposed to the atmosphere, and experience salinities of 10 to 35 parts per thousand (ppt)! Normal seawater has a salinity of 35 ppt. Clearly, plants and animals must be highly specialized to deal with such extremes.

Salt Marsh Development

Coastal wetlands exist in areas that are periodically flooded by tidal waters. They develop along embayments, **barrier beaches**, islands, and especially 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 shores are examples of other coastal wetlands whose conditions are less hospitable to the establishment of plant communities.

Salt marshes develop in sheltered 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 are common along the Atlantic seaboard as far north as mid-coast Maine. In Massachusetts, there are some very large salt marshes along the North Shore and throughout Cape Cod.

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. Being able to identify plant and animal **species** from brackish and freshwater marshes is an important component to 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 and Zones

Salt marshes are comprised of three distinct zones called the **low marsh**, the **high marsh**, and the **marsh border** community. Scientists use vegetation to define these zones because the composition of the plant community reflects **hydrology**, salinity, and **substrate** conditions. Salt marsh zones and dominant plant species are illustrated in Figure 1; only the most common species are mentioned here and those interested in a complete description of salt marsh plant communities should consult Tiner (1987), Mitsch and Gosselink (1993), or Bertness (1999).

Low Marsh: The low marsh is located along the seaward edge of a salt marsh. The low marsh is usually flooded at every high tide and exposed during low tide. It tends to occur as a narrow band along creeks and ditches, whereas the high marsh is much more expansive and is flooded less frequently. The predominant plant species found in the low

A salt marsh that has developed on the landward side of a barrier beach.
Photo: Paul Godfrey

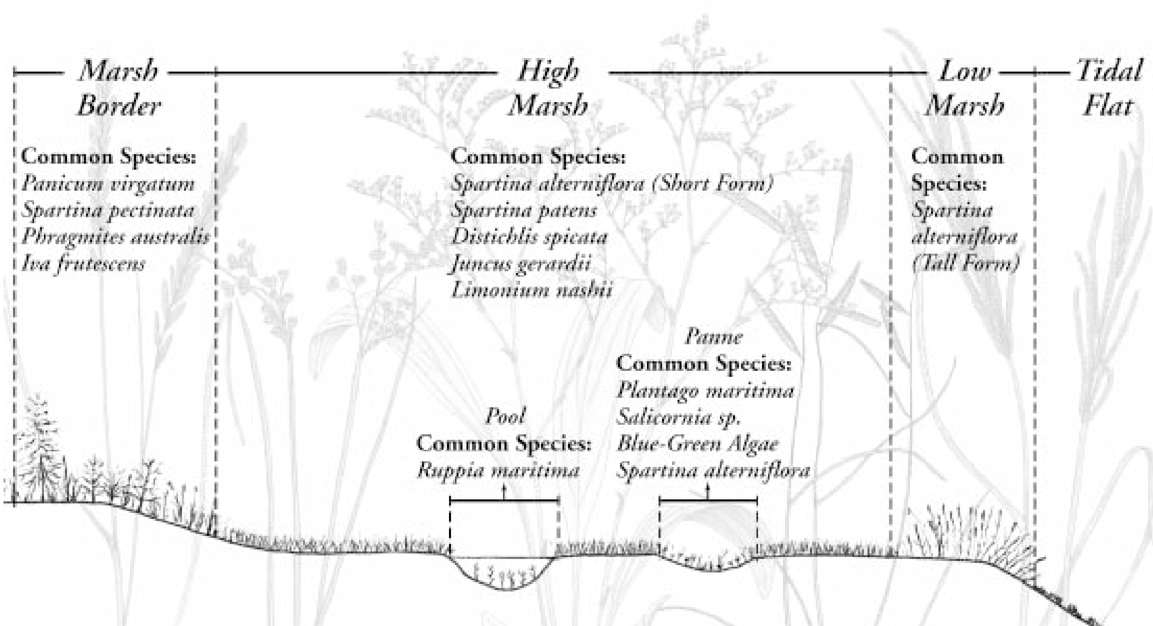

FIGURE 1. PLANT ZONATION IN NORTHEASTERN SALT MARSHES
This diagram shows the major plant zones and dominant species; see text for details and Tiner (1987), Mitsch and Gosselink (1993), or Bertness (1999) for a description of salt marsh vegetation patterns.

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.

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. Soils in the high marsh are mostly saturated, and the high marsh is generally flooded only during higher than average tides. Plant diversity is low (usually less than 25 species), with the dominant species being the grasses and rushes such as *Spartina patens* (salt hay grass), *Distichlis spicata* (spike grass), *Juncus gerardii* (black grass), and the short form of *Spartina alterniflora*. Other plant species commonly encountered on the high marsh are *Aster tenufolius* (perennial salt marsh aster), *Limonium nashii* (sea lavender), and *Agalinus maritima* (seaside gerardii). Within the high marsh are depressions, called **pannes**, that hold standing water and can 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* sp. (glassworts), *Plantago maritima* (seaside plantain), and the short form of *Spartina alterniflora*, as well as some blue-green **algae**. There are some deeper and more permanent pools in the high marsh that can be vegetated with submerged aquatic species such as *Ruppia maritima* (widgeon grass).

Marsh Border: The marsh border is located at the salt marsh's upland edge and other isolated areas on the marsh where elevations are slightly above the high marsh. The marsh border is usually only flooded at extreme astronomical tides and under irregular conditions such as storm surges or wind-driven tidal inundations, and does not experience waterlogged conditions or severe salt stress. A high diversity of herbs, shrubs, and even trees exists in the marsh border. *Iva frutescens* (high tide bush), *Baccharis halimifolia* (sea myrtle), *Agropyren pungens* (stiff-leaved quackgrass), *Solidago sempirvirens* (seaside goldenrod), and *Panicum virgatum* (switchgrass) are just some of the many marsh border plants.

Salt Marsh Succession

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 root system, called **rhizomes**, that 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 trapped by a growing stand of *Spartina alterniflora*. Over time, the accumulation of dead and decaying matter 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.


The seaward edge of a salt marsh is subject to intense wind and wave energy. **Photo: Paul Godfrey**

Higher than normal tides deposit large amounts of dead plant material or other **debris** 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* sp. and *Distichlis spicata* quickly colonize these open areas. Over time, typical high marsh plants may outcompete and replace opportunistic species.

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.


A pool located in the high marsh zone. **Photo: Ethan Nedeau**

Salt Marsh Food Web

Salt marshes support one of the most productive natural plant communities on Earth, rivaling productivity of some of the most fertile farmland in North America. With that much plant production, you might think that **herbivores** would be the most important consumers in salt marshes…not true! Salt marsh plants are too tough, salty, and nutrient-poor to support most herbivores. Flowers and seeds are more palatable, but regardless scientists estimate that only 10% of the plant productivity in salt marshes is consumed as living material. Insects, snails, crabs, and some vertebrates are common salt marsh herbivores. Some food web interactions in a typical salt marsh in northeastern North America are illustrated in Figure 2.

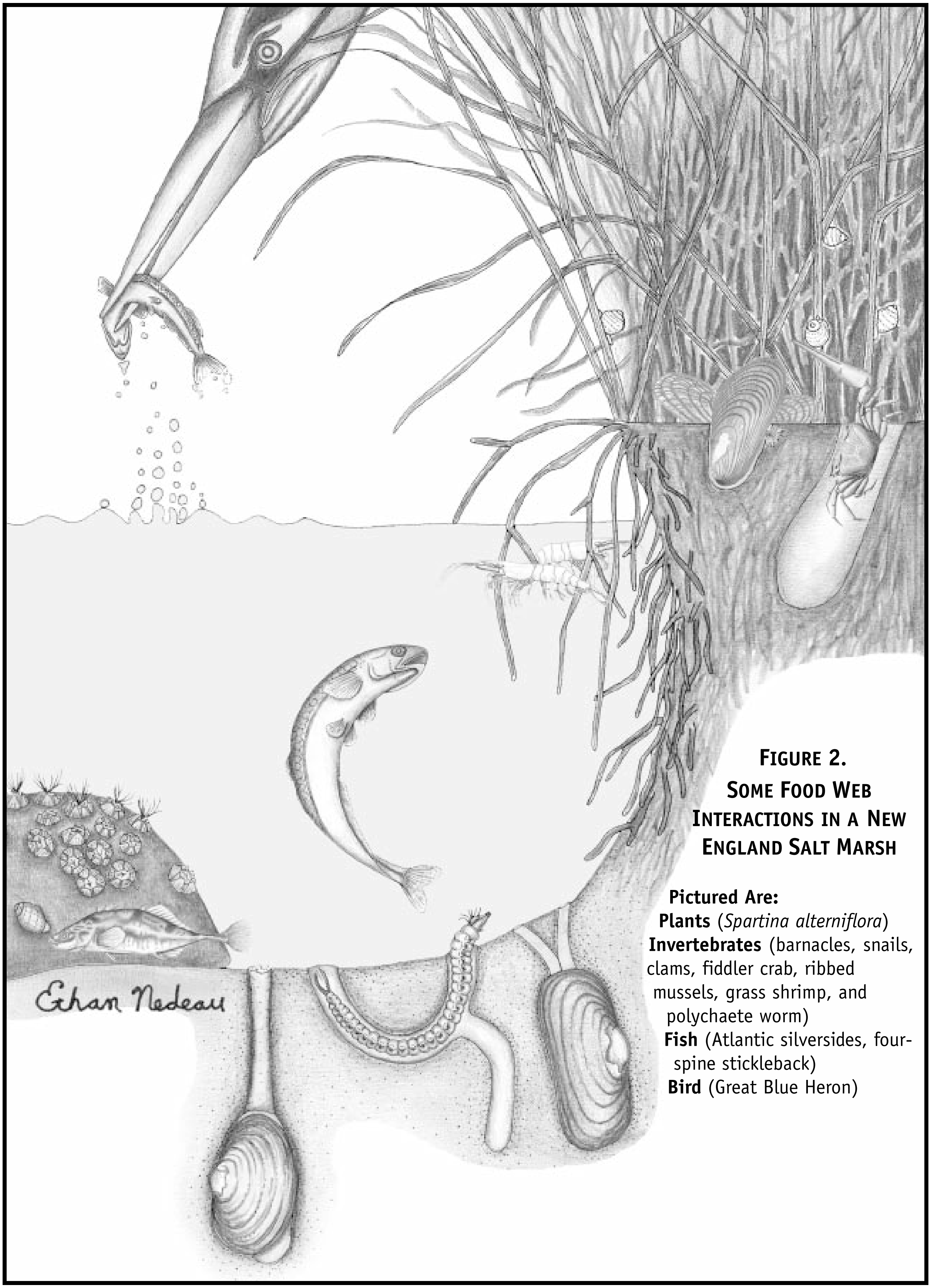

FIGURE 2.
SOME FOOD WEB INTERACTIONS IN A NEW ENGLAND SALT MARSH

Pictured Are:
Plants (*Spartina alterniflora*)
Invertebrates (barnacles, snails, clams, fiddler crab, ribbed mussels, grass shrimp, and polychaete worm)
Fish (Atlantic silversides, four-spine stickleback)
Bird (Great Blue Heron)

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 (think of detritus as a cracker and decomposers as peanut butter — its hard to eat one without the other); these invertebrates are called **detritivores**. Some detritivores eat detritus directly (some snails, crabs, and amphipods) whereas others eat sediment that contains detritus (fiddler crabs, snails, shrimp, and worms).

A nesting tern. **Photo: CZM Staff Photo**

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, grass 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 to one degree or another. Many invertebrates are well adapted to daily cycles of exposure and flooding, and the benefit of this adaptation is that they can spend their entire lives in a very 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, molluscs, and crustaceans) and few predators. Menhaden, flounder, sea trout, spot, and striped bass are just a few examples of game fish that use salt marshes at some point in their lives. Non-game fish such as killifish and mummichogs 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.

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 offshore areas are essentially transferring salt marsh-derived nutrients into marine food webs.

Many birds use salt marshes to nest, breed, feed, or rest during migration. Some of these birds are rare and protected, such as the Northern Harrier, Least Tern, King Rail, and American Bittern. Salt marshes are also critical habitat for the Massachusetts-listed Diamond-backed Terrapin and 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 reducing shoreline erosion. The roots and stems of salt marsh vegetation hold sediment — without vegetation, sediment could easily be transported away by wind and waves, and storms would cause severe erosion. Vegetation also absorbs waves and storm surges, temporarily stores floodwaters, and slows river currents. Waterfront homeowners and business owners that have marshes between their property and the ocean should feel fortunate because marshes provide a great line of defense against storm damage. Some states are even sponsoring costly 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

Streams, rivers, surface runoff, and subsurface flow all transport pollutants from uplands to marine environments. Salt marshes perform a natural filtration process that can help purify water that passes through before reaching the ocean. Salt marshes trap sediments, 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 coping with small amounts of pollution, excess amounts of certain pollutants such as nitrogen may have adverse effects on marsh productivity and food chains. Humans should not take the purification value of salt marshes for granted, and should try to minimize inputs of pollutants to maintain healthy marshes.

Recreation and Education

Salt marshes offer a wide variety of educational and recreational opportunities. They are unique "outdoor classrooms" well suited for coastal ecology lessons, and allow easy access to a rich diversity of plants and animals for natural history and marine biology study. They are perfect areas for wildlife viewing, and photographers and artists have long sought solace in their natural beauty. Salt marshes also provide opportunities for subsistence and recreational hunting and fishing, whether it is shellfish, fish, or waterfowl. Many kayakers and canoeists enjoy exploring bays, rivers, and creeks during high tide.

THREATS TO NEW ENGLAND SALT MARSHES

The outright destruction of salt marshes has been virtually halted in Massachusetts since 1963 when Massachusetts adopted the state's Wetlands Protection Act to protect inland wetlands and coastal salt marshes. Since then there has been other important state and federal legislation aimed at protecting salt marshes and other wetlands. However, 350 years of wetland destruction and pollution have left a lasting legacy on New England salt marshes. Today, some of the challenges facing wetland managers and scientists include the identification of imperiled salt marshes, the prioritization of sites for restoration, and the development of ways to measure the effectiveness of restoration efforts. Three current threats to salt marshes are changes to natural hydrology, pollution, and coastal development.

Coastal wetlands provide great opportunities for environmental education!
Photo: Paul Godfrey

Road crossings and ditching have had a dramatic effect on the hydrology of salt marshes along the Atlantic seaboard. **Photo: Ethan Nedeau**

Changes to Natural Hydrology

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. Called tidal restrictions, these road and railroad crossings have had enormous impacts on landward salt marshes by reducing or eliminating tidal flooding — the force that drives 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 *Phragmites australis* (common reed) or *Lythrum salicaria* (purple loosestrife).

Many local, state, and federal groups are working to address tidal restrictions and reclaim former salt marshes. The most common solution is to install larger culverts under roads and railways to restore tidal exchange. Mosquito control ditches also changed natural hydrology of salt marshes and efforts are underway to reverse these effects.

Increased surface 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

Humans, their machines, and their animals release enormous amounts of pollution to the air, water, and soil. The list of pollutants is virtually endless, and their effect on natural ecosystems is not well understood. Nutrients (such as nitrogen and phosphorus) from fertilizers, septic systems, and farm waste are common pollutants 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 lead to **eutrophication** (see textbox on this page). Industries and combustible engines release a variety of heavy metals (such as mercury, lead, and aluminum) that pose lethal and chronic health risks to wildlife and humans. Herbicides and pesticides are applied to lawns, gardens, forests, and ponds to kill "nuisance" species, but often affect non-target species.

It is beyond the scope of this publication to detail all the types of pollutants and their effect 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 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.

Coastal Development

Coastal New England has witnessed unprecedented population growth and urban development over the past three decades. Real estate value has 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. 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 anthropogenic pollutants and disturbances.

The upland buffer and marsh border are important nesting, breeding, perching, or feeding areas for a variety of wildlife that also utilize the adjacent salt marsh, such as many species of songbirds and mammals. Elimination or alteration of upland buffers will indirectly alter wildlife use of the salt marsh. Noise pollution (from cars, airplanes, lawn mowers, etc.) and light pollution (from street lights, vehicle lights, etc.) can affect wildlife behavior. As covered above, the introduction of pollutants through stormwater runoff, leaky septic systems, lawn chemicals, and other human activities can affect wetland organisms. Human disturbance of the landscape may encourage potentially damaging native, **introduced**, or opportunistic species such as *Phragmites australis*, *Lythrum salicaria*, starlings, house sparrows, raccoons, and opossums. Domestic cats are often a problem for birds in marshes near residential areas.

Clearly, by virtue 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, along with steps to improve or maintain their condition.

EUTROPHICATION

Eutrophication is the process of nutrient enrichment, typically by nitrogen and phosphorus. While some nutrients are essential to healthy ecosystems, excess nutrients that exceed the normal range for an ecosystem may have severe negative consequences. Among the adverse effects of eutrophication include an increased biomass of plants, proliferation of invasive species, loss of sensitive species, loss of biological diversity, and a reduction in the aesthetic and commercial value of a water body (Carpenter et al. 1998).

Garbage and bank erosion are two signs of a degraded marsh. **Photo: CZM Staff**

A barrier beach and its companion salt marsh converted to an urban landscape. **Photo: Paul Godfrey**

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chapter three

ELEMENTS OF STUDY DESIGN

In recent years, public awareness about the importance and plight of **salt marshes** has grown. Local citizens have become increasingly active in environmental **monitoring** of salt marshes to assist with preservation or 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, which incorporates project goals, specific objectives and methods to be used, and procedures to ensure data quality. A study design requires that investigators think through and describe how to conduct monitoring to achieve project goals, and it should be in the form of a document that is read and understood by everybody involved in the monitoring program (Dates et al., 1997).

Successful volunteer monitoring programs usually have at least one thing in common: someone to coordinate the various activities, forays, meetings, training classes, logistics, equipment, data sheets, and report preparation. The project leader 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 project leader usually develops the study design and helps to ensure data quality and consistency, no matter where, when, or by whom the data were collected. Established monitoring programs may be fortunate enough to have funds to compensate the project leader, though in many cases the project leader is participating as a volunteer. There are many sources of funding and support — groups should consult with other volunteer and nonprofit environmental groups, state agencies, or federal agencies to explore funding opportunities (see Appendix A).

WHY MONITOR SALT MARSHES?

Why do you want to begin monitoring a wetland? How do you intend to monitor that wetland? What are you going to do with the data you collect? These questions may sound simple enough, but they need to be answered completely before you put binoculars around your neck, slide on chest waders, or sink your net into a tidal creek. To help define a monitoring program, volunteers should follow a three-tiered framework that involves defining goals, objectives, and applications.

Goal

What is the motivation for initiating a monitoring program? In the broadest sense, what would you like to accomplish? Many government agencies, private organizations, and volunteer monitoring groups all share the same goals yet use different means to accomplish those goals. Establishing goals at the outset of a project will help guide you through the process of defining objectives and applications, and will also help you identify potential partners and funding sources. Contact other nonprofit organizations, state agencies, and regional planning groups to see if you may be able to fill an existing gap for monitoring priority salt marsh sites.

Objective

You know what you would like to accomplish, but how are you going to do it? What steps must be taken? Objectives are the specific steps that need to be taken to accomplish a goal. Often several tasks are required to complete a specific objective. In planning for specific steps, it is helpful to estimate how long it will take to complete a task, who will do it, and when it will be completed. This planning helps to keep a project on track.

Application

What specific things do you hope to achieve with the results of your project? How can your data be used, and why are the data important? Applications are specific aims that can be achieved with your objectives. Applications are usually more specific than goals. Data can often be used in several different ways, and often there may be important applications of your data that were not part of the original intent of the project. For example, a project designed to assess the effect of a tide restriction on a salt marsh might also yield valuable data on loss of biological **diversity** or other threats to the marsh. Volunteers with a good understanding of salt marshes and conservation issues will have an easier time listing a variety of potential applications for a project.

EXAMPLES OF GOALS, OBJECTIVES, AND APPLICATIONS

GOAL

- To describe the current condition of tide restricted salt marshes in Towns X and Y.

OBJECTIVE

- Contact state and regional groups.
- Collect background information, obtain ideas for possible sites.
- Hold kickoff meeting, invite interested locals.
- Select salt marsh sites, both **reference marshes** and study marshes.
- Determine **parameters** to sample, equipment needed, timing of sampling.
- Conduct **habitat assessment** of marsh **habitat** and surrounding landscape.
- Collect field data on selected parameters.
- Enter field data into spreadsheets.
- Analyze data.
- Hold community meeting to present results.
- Send results to state agency contact.

APPLICATION

- Select and prioritize marshes for conservation or restoration.
- Provide pre-restoration data on tide-restricted salt marshes in a certain area.
- Evaluate the effectiveness of a restoration project.
- Track the condition of a salt marsh over time.
- Document the plants and animals in a salt marsh.
- Assess the effects of **human disturbance** (i.e. pollution, development) on a salt marsh.

WHAT TO MEASURE, HOW, AND WHEN

This manual provides guidelines and methods for four biological parameters and two physical/chemical parameters. There are many factors to consider when choosing which of these parameters to measure. Project leaders should weigh the pros and cons of each (Table 1), their relative cost and resources available, and the level of effort and expertise required (Table 2).

The project leader, with advice from agency staff and other professionals, will be largely responsible for selecting parameters, arranging training sessions, and scheduling fieldwork. Expertise of volunteers might be an important consideration when choosing parameters to measure — for example, if a volunteer has a strong background in botany, a group may consider monitoring vegetation. 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! Volunteer data are more valuable to resource managers and scientists when groups have followed a study design and the guidelines and methods provided in the manual.

This manual emphasizes the use of metrics to represent wetland condition. Metrics, and the multimetric approach to assessing ecosystem health, are explained in the textbox on page 3-4.

TABLE 1. ADVANTAGES AND DISADVANTAGES OF MONITORING EACH PARAMETER COVERED IN THIS MANUAL

ADVANTAGES	DISADVANTAGES
TIDAL HYDROLOGY	
• Easy to take readings • Tidal restriction is easily observed and documented • Low level of effort	• Time-consuming as readings must be taken over tidal cycle
SALINITY	
• Relatively easy to take readings • Samples from pore water and surface water • Important chemical parameter	• Samples should be taken at multiple sites and times • Equipment must be calibrated • Affected by rainfall and seasonality
PLANTS	
• One or two surveys per season • Plants are relatively easy to identify • Plants integrate wide array of stressors such as salinity, hydrology, and substrate conditions	• Mobility on marsh surface may be difficult • Late/early season ID can be difficult • Difficult to isolate specific stressor
INVERTEBRATES	
• Wide range of organisms covering all trophic levels • Large number of organisms per sampling effort • Organisms complete their life cycle within the marsh, and reflect ambient and past habitat conditions • Well documented biology and ecology	• Sampling can be challenging in mud substrates • Sorting organisms from debris is time consuming • Identification of some taxa (especially polychaete worms) is difficult • Equipment costs are fairly expensive
FISH	
• Fish represent a higher trophic level than plants or invertebrates • Composition of marsh residents may reflect environmental conditions • Fun to collect, and thus foster an appreciation for these animals and their habitat • Salt marsh fishes are generally easy to identify	• Many samples (over several years) are often needed to accurately evaluate a fish population or community • Mobility of fish presents unique collection challenges • Sampling method often dictates which species are collected • Manpower (3 people minimum) • Equipment cost (i.e., bag seines)
BIRDS	
• Birds are popular with both the public and scientists and a large pool of proficient data collectors exists • The life history, ecology, and geographic distribution of birds is very well known • Easy and inexpensive to survey due to their visibility • Birds can indicate the integrity of landscapes since they can fly and easily move from one site to another • Birds are sensitive to habitat conditions and disturbance by noise, human visitation, and predatory animals (cats, dogs, raccoons, etc.)	• Birds present at a site will vary daily, seasonally, and randomly, and several visits are required to get accurate & representative data on wetland use by birds • Some sites are important for migration, feeding, or breeding, so surveys should be scheduled to capture all uses • Most bird identification is done by sound so surveyors need to be proficient with bird calls

TABLE 2. COSTS AND TIME COMMITMENT FOR EACH PARAMETER

PARAMETER	EQUIPMENT COST	TIME COMMITMENT
Tidal Hydrology	Low	Low
Salinity	Moderate	Moderate
Plants	Low	Low
Invertebrates	High	High
Fish	Moderate	Moderate
Birds	Low	Moderate

SITE SELECTION AND SAMPLING LOCATIONS

Where are you planning to conduct your research? How many sites should you monitor? Should you monitor the entire marsh or just a portion of the total area? How do you decide what areas to monitor? Deciding which marshes to monitor and where to sample within these marshes are important tasks that should be resolved during the development of a study design. Some guidelines are provided below, and Chapters 4-9 provide more specific instructions on selecting sample locations.

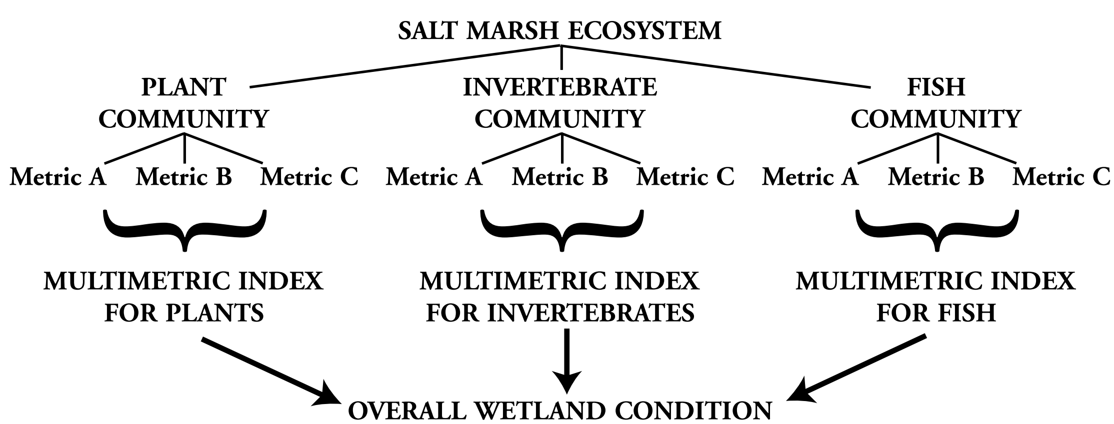
The Comparative Approach

The guidelines and methods described in this manual are based on a comparative approach. The basic premise of the comparative approach is that to understand how a **stressor** (such as a tide restriction or pollution) is affecting a salt

METRICS

Karr and Chu (1999) define a **metric** as an attribute expected to change in value along a gradient of human disturbance. Metrics have been tested for individuals, populations, communities, and ecosystems. This manual focuses primarily on population and community attributes such as taxonomic richness, relative abundance, species composition, and trophic structure. Metrics can be combined into a single **multiple metric index** for different biological communities, and these indices can be combined to provide a comprehensive measure of ecosystem health. The schematic diagram below illustrates this point.

Although this manual focuses on metrics, investigators may also want to explore descriptive or inferential statistics to analyze their data. Good sources of information on statistical treatment of biological data are Green (1979), Krebs (1985), Ott (1993), and Hayek and Buzas (1997).



Comparative Approaches

Example: Your group would like to study the effects of a tide restriction on a marsh, and you suspect that the tide restriction will be removed in two or three years. Your group may consider two different study approaches:

BEFORE-AFTER COMPARISON

Definition: Study a salt marsh before and after a stressor is added or removed.
Application: Study the restricted marsh for one or two years before the removal of the tide restriction and for a year or two afterward. Compare how salt marsh parameters change following the removal. Keep in mind that many natural processes respond slowly to change, and in many cases restored salt marshes will continue to evolve and respond for a long time.

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 (seaward side) of the salt marsh is a suitable reference site. Compare important parameters from the restricted side to the unrestricted side of the salt marsh. Your group can complete a meaningful comparison between the study site and reference site in one sampling season. This study will provide a lot of 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 trajectory to help evaluate how the study site is responding.

marsh, the characteristics of the marsh in the absence of the stressor must be understood. There are two primary ways to establish this comparison, including the Before-After Comparison and Reference Site-Study Site Comparison.

When it is feasible, volunteer groups should try to incorporate both a Before-After Comparison and Reference Site-Study Site Comparison into their monitoring program. Monitoring programs that are able to combine the two comparative approaches will provide much greater insight into the overall effects of a 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 Site Comparison allows groups to understand restoration targets and provide information and guidance for designing the restoration project.

The Before-After Comparison is not always possible, especially in instances where a group is interested in studying the effects of a disturbance that is already present and for which there is no restoration or remediation plan. For example, a group may want to know how an urban area (such as a large parking lot) is affecting a nearby salt marsh. The parking lot was built 20 years ago, and there are no plans to remove it. In this instance, the volunteer group has no choice but to compare the salt marsh to a nearby reference marsh.

Reference sites are salt marshes that lack some or all of the disturbances of the study sites. Reference sites are important because many of the impacts to salt marshes have occurred over relatively long periods of time, and it is usually not known what these sites were like prior to disturbance. Therefore, reference sites are used as reasonable approximations of conditions in the absence of a particular stressor. The selection of suitable reference sites is an extremely important part of the study design. The characteristics of reference sites will vary depending on the purpose, scope, and location of the investigation (Brinson and Rheinhardt, 1996). The limits of using reference sites are described in the next paragraph and in the section “Data Quality and Limitations.”

One note of caution is that 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. Project leaders should be aware of natural differences between study sites and reference sites, and address these differences when analyzing and presenting data.

When selecting reference sites, try to find sites in the same estuary or bay, perhaps even in the same salt marsh but in an area isolated from the stressor of interest. You should consider selecting at least two reference sites, such as one nearby the study site (for example, the unrestricted portion of a tide restricted salt marsh) and a second, more pristine marsh in your region. Throughout coastal New England, federal and state parks, town conservation areas, and nonprofit land trusts hold large areas of protected salt marsh that are practically void of human presence and therefore represent the least disturbed conditions at this time.

Three Common Study Areas

Volunteers will usually investigate one of three categories of salt marshes: marshes with tide restrictions, regional reference sites, and marshes affected by pollution or land use.

1. Salt Marshes with Tide Restrictions

A tide 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 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 tide restriction studies, volunteers can use the unrestricted side as the reference site and the restricted side as the study site, because in the absence of the restriction it is assumed that the two sides would resemble each other. Volunteer groups that want to include another reference site can also select a regional reference site.

2. 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 residential, commercial, and industrial development. Ideally, they lack linear or grid ditches that resulted from the Works Project Administration of the 1930s and other ill-begotten mosquito control or drainage projects. Certain recreational activities are permitted, such as bird watching, walking, or kayaking, but in general, these marshes experience little human disturbance. Regional reference sites represent the best achievable condition for salt marshes in a given region.

3. Salt Marshes Affected by Pollution and Land Use

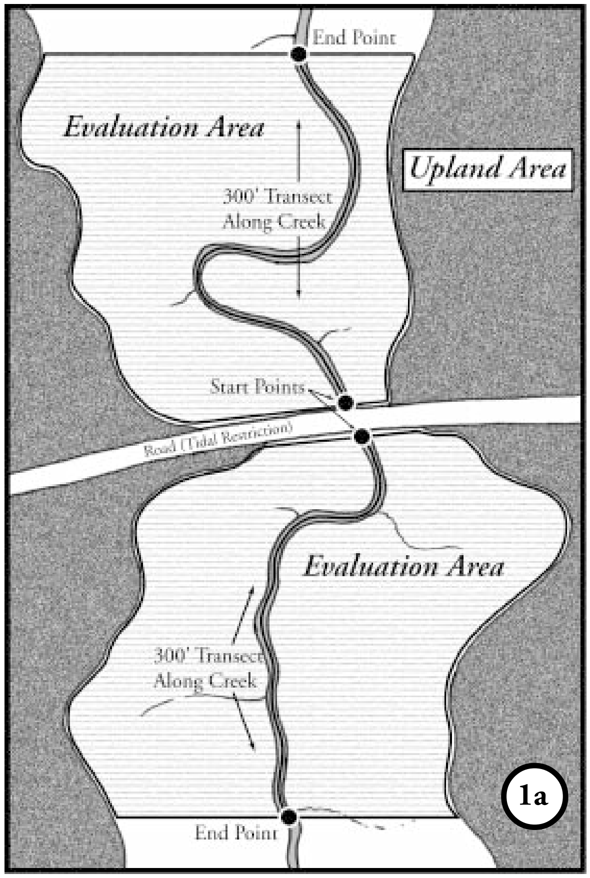
The types and intensity of surrounding land uses will affect the types and amounts of pollutants that enter coastal wetlands. Many people are interested in studying the effects of pollution and land use on salt marshes. It is difficult to choose reference sites for these types of study sites. One approach 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. Project leaders should consult with agency scientists or other professionals when selecting reference areas for this category of study sites.

The Evaluation Area

Once you choose study sites and reference sites, you need to decide where to sample. Where should you put your vegetation **transect**? From what part of the tidal creek, bay, or salt pond should you collect invertebrates? This task may sound easy for a small salt marsh, but it can daunting in a 400-acre salt marsh! The study design needs to account for the wide variation in the sizes of salt marshes, reference sites and study sites that are different sizes, and environmental differences at different locations in a salt marsh (see textbox on page 3-8).

To address size variability, the authors have designed an approach to examine comparable portions of reference sites and study sites, called **evaluation area(s)**. The evaluation area is delineated as follows (Figure 1):

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 feet (92 meters).
2. At both the start point and the end point, create another line (called a transect) that runs from the salt marsh banks to the upland edges.



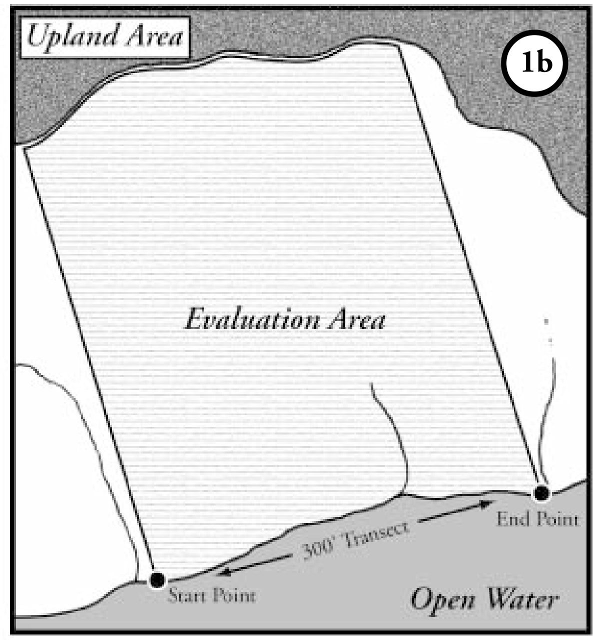


FIGURE 1. DELINEATING EVALUATION AREAS
Figure 1a shows the evaluation area on both sides of a tide restriction, and Figure 1b shows the evaluation area along an open-water feature. See text for details.

3. The habitat (salt marsh and creek channel) that falls between the two transects makes up the evaluation area.

Chapters 4-9 each provide specific instructions on selecting sampling locations for the different parameters.

DATA QUALITY AND LIMITATIONS

Throughout this manual, the authors emphasize how important volunteer monitoring can be and how volunteer data can affect conservation and management of natural resources. However, groups should also understand potential limitations of volunteer data and the importance of ensuring data quality. Quality assurance and quality control are of utmost importance for successful volunteer monitoring projects.

Cause and Effect

You have done everything right. You wanted to find out if a tide restriction was affecting a salt marsh in your community. You set up a sound study design and were very careful to select suitable reference sites. You collected excellent data on three parameters using procedures outlined in the manual. Your data clearly showed that the study site had poor habitat quality, a low diversity of plants and animals compared to the reference sites, and a higher proportion of **non-indigenous** and **invasive species**. You write up a report for your study and conclude that the tide restriction is to blame for degradation of the salt marsh. Does this mean you have correctly assessed the effect of the tide restriction on the salt marsh? Perhaps not…

It is important to understand that every study has its 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. In the above example, the tide restriction is most likely a major cause of the reduced diversity and increased **abundance** of invasive species, but other factors may be at work. For example, there may be a major **groundwater** seep in the study area causing substantial flows of fresh ground water, which naturally reduces the salinity. The expanse of *Phragmites australis* (common reed) that you measured may have been there

WHAT IS THE EVALUATION AREA AND WHY USE IT?

Your group is interested in examining the effects of a tide restriction (roadway and culvert) that has bisected a salt marsh into two parts — a six-acre restricted area and a 280-acre unrestricted area. You 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, the authors of this manual 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 differences between different 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.

for decades and expectations for removing this invasive species by eliminating the tide restriction may be overly optimistic. Other natural factors that you have not measured, such as the extent and duration of flooding and soil and water chemistry, strongly influence salt marsh biology. Finally, the confounding effects of other stressors such as commercial land use and stormwater discharges will make an accurate diagnosis more difficult.

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. However, volunteer monitoring groups often do not have the time or resources needed to conduct a study that is intensive enough to build an irrefutable case. We would all like to be the dazzling detective that presents our evidence to the speechless jury and wins the case handily, but the reality is environmental scientists are rarely 100% confident about their findings.

So why bother? 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 a closer examinations, 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 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 concerned citizens, groups, communities, and professional scientists.

Quality Assurance and Quality Control

One of the most difficult issues facing volunteer monitoring programs is data credibility. Decision makers and managers may be skeptical about volunteer data — they may have doubts that a group of concerned individuals can get together and collect scientifically sound data on a resource. The best way to address these concerns is to discuss issues of quality assurance and quality control during the study planning process. The terms quality assurance and quality control sound intimidating, but they are simply terms that refer to attentive and rigorous work. In any study, it is important that consistent protocols are used to complete data collection, storage, analysis, and reporting. With consistent procedures, volunteer monitoring groups will be able to confidently compare one site to another and compare sites over time. Groups will be able to stand behind their work with conviction and satisfaction, knowing that they have been thorough in its completion.

In some cases, a state or federal agency may require or strongly suggest that your group develop a separate document called a quality assurance project plan, or QAPP. A QAPP outlines the procedures a monitoring project will follow, and includes methods of data collection, data validation, storage, and analysis. The authors have federal and state-approved QAPPs for the study design, methods, and procedures outlined in this manual. Several organizations provide assistance to volunteer groups who are developing a QAPP. The U.S. Environmental Protection Agency has a document called *The Volunteer Monitor's Guide to Quality Assurance Project Plans* (Hunt et al., 1996). Also, the Massachusetts Waterwatch Partnership offers hands-on support for volunteer groups engaged in developing a QAPP or study design, and their website is http://www.umass.edu/tei/mwwp/. Finally, there are many different individuals and organizations that can be contacted with questions or request for support (Appendix A).

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chapter four

PLANTS

Plants are the primary food source for **salt marsh** ecosystems, and most plant material is consumed as **detritus** by decomposers and **invertebrate** consumers. A salt marsh is physically dependent on its plants — plant roots and stems anchor the **substrate** and enable the gradual build up of peat. The plants, along with physical **parameters** such as tides and geology and chemical parameters such as salinity, create the template for salt marshes and enable invertebrates, fish, birds, and even humans to benefit from these resources.

Salt marshes can be extremely difficult places to live because of wide daily fluctuations in salinity, water, temperature, and oxygen. Few plants have evolved adaptations to cope with the extreme conditions of salt marshes, and by examining healthy marshes, scientists have become familiar with these plants and their environmental requirements. Plant **zonation** (see: Chapter Two) in a salt marsh results from **species**-specific adaptations to physical and chemical conditions. Looking out on a healthy 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 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.

Plant communities respond to **human disturbances** and subsequent changes in salinity, natural **hydrology**, **invasive species**, or pollutants. Volunteer groups may compare a disturbed marsh with an undisturbed marsh to see how vegetation has responded to the disturbance. For example, a volunteer group may study the plant **communities** in two salt marshes on either side of a railroad bed to try to understand how the restriction altered what was once a contiguous ecosystem. A volunteer group may also study plant communities in one salt marsh over time and watch how vegetation may change in response to the introduction and proliferation of invasive species such as *Phragmites australis* (common reed) 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, and compete with native species.

Plants are an important and easy parameter for volunteer monitors to measure. Equipment cost is very low compared with other parameters and volunteers only need to sample once or twice a year. Many people are familiar with wetland plants, and those who are not will find numerous field guides with excellent illustrations and photographs. Volunteer groups may want to measure salinity and tidal influence concurrently with vegetation because the three are closely linked.

EQUIPMENT

Salt marsh vegetation surveys require minimal equipment, listed in Table 1. Much of this equipment is also required to monitor other parameters, such as flagging, stakes, and a tape measure. Therefore, the only equipment

Phragmites australis

"COMMON REED"

Non-Native? Invasive?

Recent research on *Phragmites australis* using advanced DNA genotyping tools demonstrates that there are native and non-native strains present in North America. In the last 40 years, one of the non-native strains has proliferated throughout the country, altering native plant communities and wetland ecosystems (Saltonstall, 2002). This type appears to be aggressive and competitively superior to the native strains. Throughout this document, the authors will refer to *Phragmites australis* as "invasive" rather than "non-native" to reflect our current understanding of this species.

Photo by Paul Godfrey

that volunteer groups need to purchase or construct that is unique to plants is a $1m^2$ square **plot sample** frame and a reliable field guide to wetland plants. The $1m^2$ plot frame can be constructed from ½ inch PVC material. Although stakes come in a variety of materials, PVC is good because it is durable and lasts for a long time.

TABLE 1. PLANT SAMPLING EQUIPMENT

EQUIPMENT
1 100-meter field tape measure with wind-handle
24 Stakes (5 ft. lengths of ½ or 1 in. diam. PVC)
$1m^2$ plot
Compass (and/or GPS)
Field guide to coastal wetland plants
Clipboard
Pencils
Field data sheet
Large Ziploc bags

SAMPLING METHODS

At each site, you will survey vegetation according to a standard protocol. It is important that the plant survey follows the methodology outlined in Chapter Three for using a comparative approach and establishing **evaluation areas**.

Establishing Evaluation Areas, Transects, and Plots

Establish the evaluation areas for the salt marshes your group will be **monitoring.** The project leader usually does this using the steps outlined in Chapter Three. NOTE: If a creek or river channel bisects the salt marsh (this is the case for most tide restricted sites), your group may want to survey the plants on both sides — your leader will help to decide this. If so, your group will be establishing two sets of **transects** as explained below, one set on each side of the channel.

1. Stratify the evaluation area into three sections as follows (Figure 1a,b):
    a. Section 1 is the area between the starting point of the evaluation area (0') and a point 100' along the creek, bay, or salt pond.
    b. Section 2 is the area between 100' and 200' along the creek, bay, or salt pond.
    c. Section 3 is the area between 200' and 300' along the creek, bay, or salt pond.

2. Randomly generate numbers for the location of two transects within each section (six per evaluation area). Transect locations can be determined using a calculator that has a function for generating random numbers, or Microsoft Excel can generate random numbers between two numbers (in this case 0 and 100) using the command: =RAND( )*100. You can

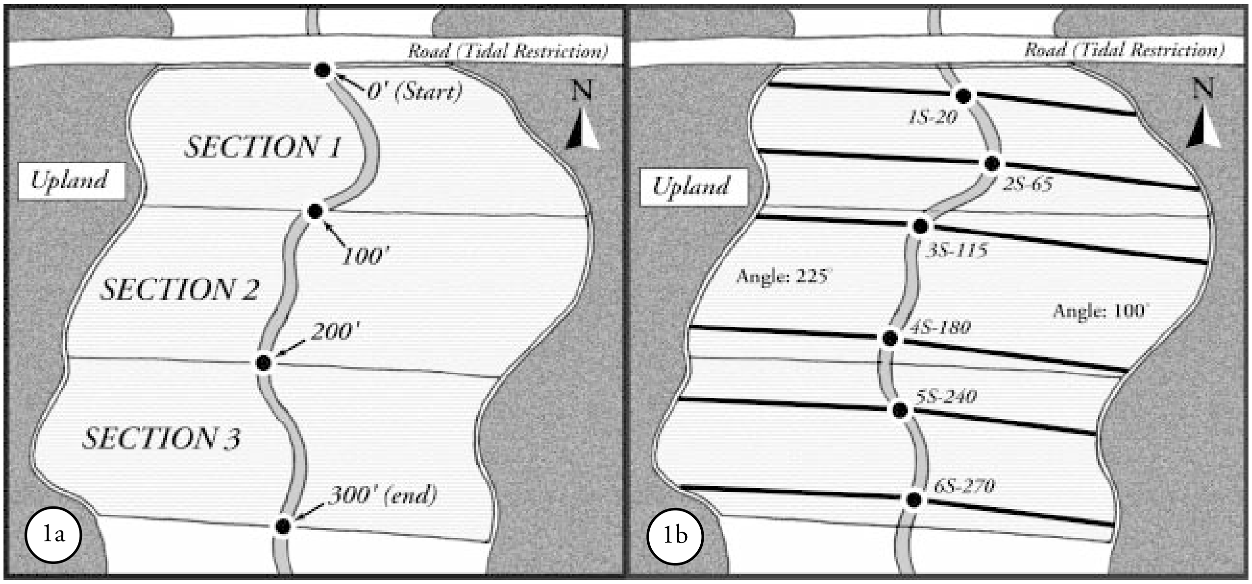


FIGURE 1. EVALUATION AREA AND TRANSECT PLACEMENT
Figure 1a shows the three sections within a wetland evaluation area on one side of a tidal restriction. Figure 1b shows transect placement within each section. See text for details.

generate random numbers in the office before going out to the marsh. The random number is the distance in feet from the beginning of each section and marks the starting location of each transect. If the location of a transect places it on a ditch, within 3 feet of another transect, or some other unworkable location, then use another number/location.

3. Transects run from the bank to the upland edge, according to a consistent compass bearing (for example, all six transects will be laid on a bearing of 225 degrees from the bank to upland edge) (Figure 1b). One member should stand at the creek with a compass and one end of the measuring tape. Another group member should walk toward the upland edge with the measuring tape and move until their position matches the compass reading.

4. For groups monitoring both sides of a river or channel, establish a second set of transects in the same manner as the first. If the location or compass bearing for the second set of transects yield awkward or unworkable transect locations, such as transects falling directly on channels or excessively long transects, then use a new compass bearing for the second set. As a rule and to ensure consistency, always label the two sides of the marsh. You may use the cardinal directions of the compass — for example, the northwest side and the southeast side of the channel. Figure 1b shows transect placement within a wetland evaluation area, and Table 2 shows how to label plots and transects.

5. Secure a stake at each end of the transect and label it according to the protocol shown in Table 2. Be sure to solidly plant the stake into the ground. The stake will enable your group to find the same transects next season, and the labeling will avoid confusion.

STRATIFIED RANDOM SAMPLING

In vegetation monitoring, six transects are established within each evaluation area using a stratified random design. This terminology sounds intimidating, but it is quite simple when broken down. The random assignment of transects helps to eliminate bias and the intentional targeting of a certain species or community. Stratified means layered or segmented, and in this case, it means that the evaluation area is divided into three segments. Stratifying the sampling area helps avoid the situation whereby all six transects happen to be clustered together and do not provide adequate spatial coverage of the evaluation area. This approach allows the investigator to use statistical tools to analyze data and draw conclusions about the evaluation areas.

TABLE 2. AN EXAMPLE OF TRANSECT LABELING

SITE CODE	DISTANCE (random number)	TRANSECT # AND EVALUATION AREA	TRANSECT LABEL
HW-Study	19.9	1-North	1N-19.9
HW-Study	74.4	2-North	2N-74.4
HW-Study	184.2	3-North	3N-184.2
HW-Study	199.9	4-North	4N-199.9
HW-Study	263.9	5-North	5N-263.9
HW-Study	291.4	6-North	6N-291.4

6. Place $1m^2$ plots every 60 feet along each transect, starting at the bank and progressing toward the upland edge. Plots should be located every 30 feet if the transect length is less than 120 feet. The first plot is always placed at the beginning of the transect and the last plot is placed in the salt marsh border regardless of whether or not the 30 or 60 foot interval falls there. For example, your group finished the 240 foot plot and is following the transect out to position the next plot at 300 feet. The salt marsh ends at about 285 feet, so that a plot at 300 feet would be located in the upland. In this case, you should establish the last plot at 280 feet in the salt marsh border and make sure this location (280') is recorded on the field data sheet.

Collecting Data

1. Always walk on the left side of the tape measure and place the plots on the right side. This way you are not trampling plants you intend to survey and you know that plot position is consistent. Also, position the plots so that the bottom left-hand corner of the frame is always located at the designated distance on the measuring tape (e.g. at 120 feet).

2. Starting at the first plot on the first transect, identify every plant that falls within the $1m^2$ plot frame. Use your field guide to identify any plant in question. Record the plant community type within each plot, (**low marsh**, **high marsh**, or marsh border).

3. Record the scientific name (genus and species) of each species on the field data sheet.

4. Estimate the **abundance** of each species. Using the worksheet in Appendix 2 of this chapter, select the cover class that most accurately portrays the abundance of each species in the plot. Include all leaves, branches, and stems that fall within the vertical column made by the plot frame extended upwards. It is fine if the total abundance for all the species in the plot is over 100%, as plants will overlap each other.

5. Plot coverage estimates should include areas within the plot frame that are not occupied by living vascular plants, called "Other." This category includes duff, old dead leaves, bare ground, and open water. During the data analysis stage, you can adjust abundance values to account for the "Other" category.

6. If the management or control of *Phragmites australis* (or another species) is an objective of your study, then it is important to document the relative health and vigor of this plant. In at least three plots where *Phragmites australis* occurs, your group should measure the height of the tallest 10 living individuals. Measure from the ground to the very tip of the inflorescence (flowering part of the plant), or if no inflorescence is present, measure to the tip of the highest leaf. The field data sheet in Appendix 1 of this chapter contains a section for this information.

Plant Identification

Proper identification of wetland plants is an important skill for salt marsh vegetation monitoring. 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 gain experience with plant **morphology** and plant ecology to become competent with species identification. Several books integrate key information on identification, ecology, and distribution and are 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* (Tiner 1987). 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.

If you have trouble identifying a specimen using Tiner (1987) or a different field guide, you should call the specimen "Unknown Species A" in your field data sheet and place the plant and part of its roots into a resealable plastic bag (along with a label) for later identification. Once you identify the plant, you can go back and adjust your spreadsheet or database accordingly. It may also be a good idea to keep specimens of plants that you are *pretty sure* you identified properly, but still need some confirmation from someone with more experience. Getting hands-on instruction and spending time in the field with someone with expertise in wetland plant identification is a great way of learning to identify plants. Your project leader may have such experience, or may be able to arrange for a training session, or get a commitment from a wetland professional to join your group for an afternoon.

DATA ENTRY

You should use one field data sheet for each transect. Number the transects as shown in Table 2. The field data sheet requires basic information such as the name of the investigator(s), the survey date, site name, transect ID, and compass bearing of each transect. The rest of the field data sheet is divided into plot-by-plot sections, and at the end there is a section to record target species height (i.e. *Phragmites australis*). A blank standard field data sheet is provided in Appendix 1 of this chapter.

In the field, you should take the time to thoroughly fill out basic information and make sure that site-specific information is recorded in the proper location so that you do not confuse data sheets from different transects or even different sites! Always spend time reviewing each data sheet, double-checking that you have entered all the necessary information — an extra minute in the field could save hours later.

In the office, investigators should transfer information on field data sheets into a computer spreadsheet such as Microsoft Excel or perhaps a database such as Microsoft Access. Each site should have its own table, spreadsheet, or worksheet. The primary objective is to enter raw data into the spreadsheet and then use functions and tools available in the software to consolidate all of the numerous plots into a cumulative list and to compute the total abundances of species for the evaluation area.

Juncus gerardii
Black Grass

Spartina patens
Salt Hay Grass

Steps in Data Entry

The following section outlines the steps volunteers should take when entering data into a spreadsheet. The text includes figures that show spreadsheet format and use real data to illustrate key aspects of data entry. Tables 3, 4, and 6 are set up similar to a spreadsheet with column and row identifiers (letters for columns and numbers for rows), so that any cell in the figure can be identified. For example, cell D12 is located in column D and row 12.

1. For each evaluation area, set up a table or spreadsheet with five columns for Site Code, Plot ID, Community Type, Genus Species, and Plot Cover. The plot ID is the transect number and location of the plot on that transect. The example provided in Table 3 is for one transect (1N) with four plots (0', 60', 120', 166'). Your spreadsheet will be much longer because it will include data for all transects at the study site (six or twelve transects, depending on your study).

TABLE 3. EXAMPLE DATA ENTRY SPREADSHEET, STEP ONE

	A	B	C	D	E
1	**SITE CODE**	**PLOT ID**	**COMMUNITY**	**GENUS SPECIES**	**PLOT COVER**
2	HW-Study	1N0	Low	Spartina alterniflora	76
3	HW-Study	1N0	Low	Salicornia europaea	1
4	HW-Study	1N0	Low	Other	25
5	HW-Study	1N60	High	Distichlis spicata	55
6	HW-Study	1N60	High	Spartina patens	38
7	HW-Study	1N60	High	Other	15
8	HW-Study	1N120	High	Phragmites australis	38
9	HW-Study	1N120	High	Distichlis spicata	38
10	HW-Study	1N120	High	Other	25
11	HW-Study	1N166	Border	Phragmites australis	76
12	HW-Study	1N166	Border	Solidago sempirvirens	15
13	HW-Study	1N166	Border	Juncus gerardii	15
14	HW-Study	1N166	Border	Other	7

TABLE 4. EXAMPLE DATA ENTRY SPREADSHEET, STEPS TWO AND THREE

	A	B	C	D	E	F
1	**SITE CODE**	**PLOT ID**	**COMMUNITY**	**GENUS SPECIES**	**PLOT COVER**	**TOTAL PLOT COVER**
2	HW-Study	1N60	High	Distichlis spicata	55	
3	HW-Study	1N120	High	Distichlis spicata	38	93
4	HW-Study	1N166	Border	Juncus gerardii	15	15
5	HW-Study	1N0	Low	Other	25	
6	HW-Study	1N60	High	Other	15	
7	HW-Study	1N120	High	Other	15	
8	HW-Study	1N166	Border	Other	7	62
9	HW-Study	1N120	High	Phragmites australis	55	
10	HW-Study	1N166	Border	Phragmites australis	76	131
11	HW-Study	1N0	Low	Salicornia europaea	1	1
12	HW-Study	1N166	Border	Solidago sempirvirens	15	15
13	HW-Study	1N0	Low	Spartina alterniflora	76	76
14	HW-Study	1N60	High	Spartina patens	38	38

2. Copy Table 3 to a new spreadsheet (this will enable you to go back and look at the raw data). On the new spreadsheet, select all cells in the table, go to Data → Sort, select the column "Genus Species" (column D), and select "Sort Ascending." This results in a sheet similar to Table 4 with plant species in alphabetical order.

3. Sum the plot cover values for each species, using the SUM function (under Insert → Function → Math & Trig). For example, in Table 4 the value in cell F3 is computed using the equation "=SUM(E2:E3)" and represents the total plot cover value of *Distichlis spicata* at transect 1N. This summation should be done for all species in the transect and all transects at the site.

TABLE 5. EXAMPLE DATA ENTRY SPREADSHEET, STEP FOUR

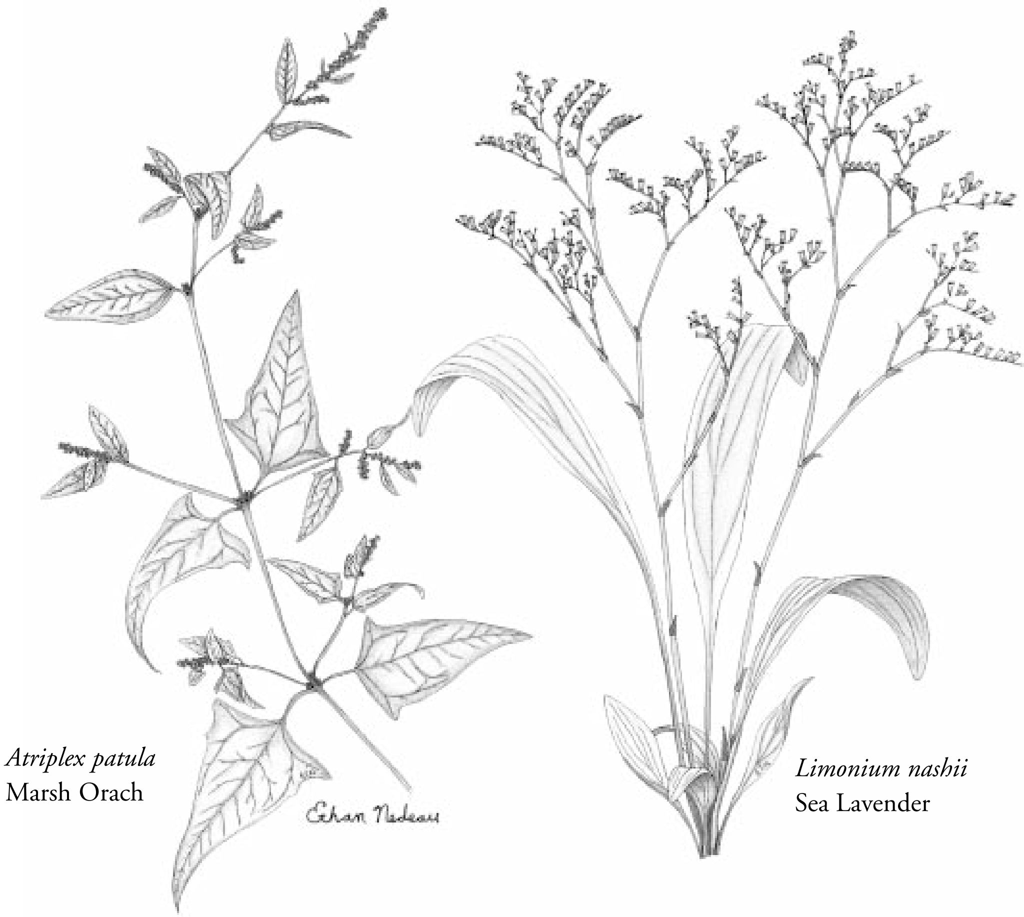
SITE CODE	GENUS SPECIES	TOTAL PLOT COVER
HW-Study	Atriplex patula	9
HW-Study	Distichlis spicata	585
HW-Study	Iva frutescens	159
HW-Study	Other	1202
HW-Study	Phragmites australis	869
HW-Study	Salicornia europaea	31
HW-Study	Scirpus pungens	20
HW-Study	Solidago sempirvirens	24
HW-Study	Spartina alterniflora	1349
HW-Study	Spartina patens	382
HW-Study	Typha angustifolia	47
	Total Abundance	4677

4. Create a new table with three columns for Site Code, Genus Species, and Total Plot Cover (Table 5). Table 5 represents data for all transects at the study site. You should combine data for all six or twelve transects at the study site when completing Table 5. Notice that the "Other" category remains in the column "Genus Species." This category is important because it indicates the relative amount of non-vegetated marsh in the survey plots, though you will generally analyze results without this category. Copy Table 5 to another worksheet and delete the "Other" category.

5. Add a fourth column to Table 5 called "Percent Abundance" (Table 6). Sum column C in Table 6 by typing the formula "=SUM(C2:C11)" in cell C12. This represents Total Abundance. To compute Percent Abundance, divide Total Plot Cover for each species by Total Abundance of all species and multiply by 100. For example, the Percent Abundance of *Distichlis spicata* is computed using the formula "=(C3/3475)*100." The sum of column D should equal 100. Complete this step for both the study site and **reference site**. You will work with this set of compiled data for many of the data comparisons suggested in the following section.

TABLE 6. EXAMPLE DATA ENTRY SPREADSHEET, STEP FIVE

	A	B	C	D
1	SITE CODE	GENUS SPECIES	TOTAL PLOT COVER	PERCENT ABUNDANCE
2	HW-Study	Atriplex patula	9	0.26
3	HW-Study	Distichlis spicata	585	16.83
4	HW-Study	Iva frutescens	159	4.58
5	HW-Study	Phragmites australis	869	25.01
6	HW-Study	Salicornia europaea	31	0.89
7	HW-Study	Scirpus pungens	20	0.58
8	HW-Study	Solidago sempirvirens	24	0.69
9	HW-Study	Spartina alterniflora	1349	38.82
10	HW-Study	Spartina patens	382	10.99
11	HW-Study	Typha angustifolia	47	1.35
12		**Total**	3475	100



Atriplex patula
Marsh Orach

Limonium nashii
Sea Lavender

DATA ANALYSIS AND COMPARISON

Once you enter and compile data into a spreadsheet, your group can begin to analyze and compare the data. Many different tools and techniques exist to analyze biological data. This chapter provides a detailed description of five types of **variables**: species richness, species abundance, community composition, target species, and occurrence frequency. Project leaders may decide to explore other types of analysis, such as descriptive statistics or other community metrics and indices. For this section, two sample data sets are used to illustrate key concepts; these data are from a tide restricted site (HW-Study) and its unrestricted reference counterpart (HW-Ref).

Species Richness

Description: Species richness is the number of different species (or genera) that were documented at a particular site.

Calculation: Simply count the number of species at each site. In addition, you can compute a ratio of species richness at the study site and reference site. In Table 7, species richness is 10 and 14 for the study site and reference site, respectively. The ratio is 10/14 = 0.71, or 71%, meaning the study site has 29% fewer species than the reference site.

Interpretation: Species richness is an important variable because in general pristine salt marshes will generally support more species than disturbed salt marshes; that is, high species diversity is usually associated with favorable conditions. Disturbance often eliminates sensitive species, and favors the proliferation of a few **generalist** or **opportunistic** species. The ratio of species richness at the study site and reference site is informative, but it's meaning is somewhat subjective. Table 8 (page 4-10) provides general guidelines to make a qualitative interpretation of this ratio. These guidelines should be considered in the context of other attributes of the plant community or other parameters.

One of the best ways to appraise the condition of a salt marsh in terms of species diversity is to look at species diversity over time. Data sets from different years at the same site (including evaluation area and transects) may

TABLE 7. SPECIES RICHNESS AND RELATIVE ABUNDANCE

SITE CODE	GENUS SPECIES	PERCENT ABUNDANCE
HW-Study	Spartina alterniflora	38.82
HW-Study	Phragmites australis	25.01
HW-Study	Distichlis spicata	16.83
HW-Study	Spartina patens	10.99
HW-Study	Iva frutescens	4.58
HW-Study	Typha angustifolia	1.35
HW-Study	Salicornia europaea	0.89
HW-Study	Solidago sempirvirens	0.69
HW-Study	Scirpus pungens	0.58
HW-Study	Atriplex patula	0.26
HW-Ref	Spartina patens	63.64
HW-Ref	Spartina alterniflora	18.94
HW-Ref	Distichlis spicata	13.41
HW-Ref	Phragmites australis	1.52
HW-Ref	Atriplex patula	0.58
HW-Ref	Pluchea purpurascens	0.49
HW-Ref	Aster tenuifolius	0.38
HW-Ref	Solidago sempirvirens	0.29
HW-Ref	Salicornia europaea	0.27
HW-Ref	Juncus gerardii	0.18
HW-Ref	Limonium nashii	0.15
HW-Ref	Plantago maritima	0.06
HW-Ref	Agalinis maritima	0.06
HW-Ref	Agropyren pungens	0.04

indicate a trend. A marked increase of species richness over time may be strong evidence of improving conditions and successful restoration.

Relative Abundance

Description: Relative abundance is the proportion of a community comprised of a certain species or group of species. In this chapter, volunteers compute relative abundance using plot cover values.

Calculation: You calculated percent abundance values during data entry (Step Five, Table 6). For data analysis and comparison, it is useful to sort the percent abundance values from high to low. To do this, select the entire table, go to Data → Sort, select the column "Percent Abundance," and select "Sort Descending." Do this for the study site and reference site (Table 7). Beginning at the top of the third column, sum relative abundance values until you reach 75% and record the number of species it takes to reach 75%. In Table 7, it takes three species to reach 75% in the study site and two species to reach 75% in the reference site.

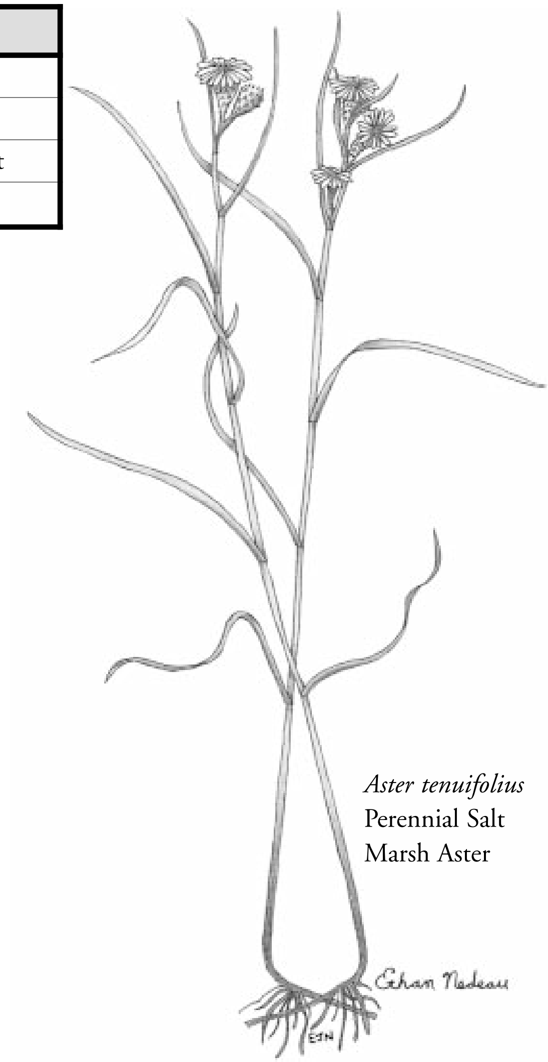
Interpretation: There are several different ways to interpret relative abundance values, and particularly how relative abundance relates to species richness. One way to look at relative abundance is to look at the relative abundance of particular species. For example, a salt marsh may have high species richness but one species may account for over 80% of the total biomass; an extraordinarily high abundance of one species would greatly affect the variety and quality of habitats in the marsh. A second way to look at relative abundance is the 75% rule, which is the number of species that comprise at least 75% of a plant community.

Dominant species may indicate certain characteristics of the marsh. For example, a great abundance of *Spartina alterniflora* indicates that a low marsh community is a dominant feature in a marsh, and investigators may want to explore possible explanations for this observation. Two possible explanations are that tidal restriction caused compaction of the marsh surface or that water levels are locally higher — either of these explanations would create favorable conditions for a low marsh community. Low marsh habitat is more available to sub-tidal foragers and predators like fish and crabs, as it is more frequently flooded than high marsh.

One of the best ways to appraise the condition of a salt marsh is to look at changes over time. Data sets from different years at the same site (including evaluation area and transects) may indicate a trend. Significant shifts in species abundance from one year to another can indicate changes in local conditions. For example, increasing abundance of brackish or freshwater species can indicate a "freshening" of the marsh, possibly due to the effects of a tidal restriction.

TABLE 8. GUIDELINES TO INTERPRET RATIOS

RATIO	INTERPRETATION
0.76 - 1.00	High similarity, no assumed impairment
0.51 - 0.75	Fair similarity, assumed minimal impairment
0.26 - 0.50	Poor similarity, assumed moderate impairment
0.0 - 0.25	Dissimilar, assumed severe impairment



Aster tenuifolius
Perennial Salt
Marsh Aster

Community Composition

Description: Community composition refers to the types of species that occur in a community, and particularly the similarity or difference between two different communities. The previous two variables focused on the number of species and the abundance of species. Two sites may have similar species richness and relative abundance, but support entirely different species. Since different species have different environmental requirements, the types of species in a community provide clues about salt marsh condition.

Calculation: One way to examine community composition is to compare the species lists of two or more sites and see how many unique species exist at each of the sites. Generate a species list for each site, sort the species alphabetically, and place the lists side-by-side to compare them. Table 9 demonstrates how this looks in a spreadsheet. From Table 9, you can see that the two sites share seven species, the reference site has seven unique species, and the study site has three unique species. You can calculate a community similarity ratio by dividing the number of species that the study site and reference site share (in our example, 7) by the number of species at the reference site (in our example, 14). The ratio is 7/14 = 0.50, or 50%.

Interpretation: When interpreting community composition data, it is important to have an understanding of the environmental tolerance and ecology of the plant species. If a study site has five unique species, you should ask yourself, “What traits do these five species share that might help explain why they are not also found at the reference site?” Perhaps they are brackish or freshwater species, and their occurrence in the study site indicates a tidal restriction or freshwater intrusion. Alternatively, perhaps they are invasive or opportunistic species that are known to colonize disturbed habitats.

The community similarity ratio is a quick way to judge the how similar two wetlands are in terms of plant communities, but the interpretation of this ratio is somewhat subjective. Table 8 provides some general guidelines to make a qualitative interpretation of this ratio. These are only guidelines, and it is more important to look at actual species composition rather than relying on this simple ratio.

Target Species

Description: Target species are species whose presence and abundance is particularly relevant to the goals or objectives of a monitoring project, or provide important clues about ecosystem processes and health. Volunteer groups may want to track the presence, abundance, and growth of these species. Examples include *Phragmites australis* because it is invasive and usually detrimental to wetlands, certain brackish or freshwater species such as *Typha latifolia* or *Lythrum salicaria* (purple loosestrife) because they provide clues about hydrology, or even common salt marsh species to show how they respond to restoration projects.

TABLE 9. COMMUNITY COMPOSITION EXAMPLE

HW-STUDY	HW-REF
Agalinis maritima	
Agropyren pungens	
Aster tenuifolius	
Atriplex patula	Atriplex patula
Distichlis spicata	Distichlis spicata
Juncus gerardii	
	Iva frutescens
Limonium nashii	
Phragmites australis	Phragmites australis
Plantago maritima	
Pluchea purpurascens	
Salicornia europaea	Salicornia europaea
	Scirpus pungens
Solidago sempirvirens	Solidago sempirvirens
Spartina alterniflora	Spartina alterniflora
Spartina patens	Spartina patens
	Typha angustifolia

Salicornia europaea
Common Glasswort

Calculation: One way to track a target species is to simply document its presence and abundance at each site. In Table 7, you can see that *Phragmites australis* is present at the study site and reference site, but its abundance is 25% at the study site and only 1.5% at the reference site. In other words, *Phragmites australis* is nearly 17X more abundant in the study site.

Your group also may have taken measurements of the height of the 10 tallest individuals of *Phragmites australis* (or other target species) at a number of plots (three minimum recommended). If so, compute the average height of all plants measured at each site. Table 10 shows the results of from the tidally restricted HW-Study and its unrestricted reference counterpart, HW-Ref (Note that *Phragmites australis* heights were measured in three plots at the study site, but since it occurred in only one plot at the reference site, only 10 plants were measured).

Interpretation: Tracking target species can be an important part of volunteer monitoring. In salt marshes, **populations** of the invasive *Phragmites australis* have greatly increased over the past several decades. Resource managers are concerned about this species because it aggressively colonizes new habitats, and alters natural habitat functions and values. The presence of large and increasing stands of *Phragmites australis* usually indicates some type of disturbance or environmental stress, including altered hydrology, filling, stormwater discharge, road salts, or other water pollution. There are no established criteria to judge when the abundance of *Phragmites australis* (or another target species) is a problem, but in general when *Phragmites australis* is a dominant species or its population is increasing, there is probably some underlying reason as to why conditions in the marsh are changing to favor this species. Use paired or regional reference sites for indications of what might be natural and stable populations of *Phragmites australis.*

TABLE 10. *PHRAGMITES* HEIGHT MEASUREMENTS

Phragmites MEASUREMENT	HW-REF	HW-STUDY
Average Height	5.6	9.2
Number Measured	10	30

Compare the average height of your target species at the study site and reference site. How do these average heights compare? Is one much larger? How great is this difference? You may explore other descriptive statistics such as minimum, maximum, range (maximum-minimum), standard deviation, and standard error (functions for these statistics are found in Insert → Function → Statistical). Average height and standard deviation can be plotted on a simple bar graph to provide a nice visual representation of your data. If you have a good background in statistics, you may perform a statistical test to determine if the two sets of plant heights are significantly different.

Collectively, the presence, abundance, and growth of target species may provide important information about salt marsh condition. However, be cautious when drawing conclusions about the meaning of these data, since there are several possible explanations for different plant communities at different sites. Groups may want to explore other parameters such as tidal hydrology and salinity to understand underlying causes for vegetation patterns.

Occurrence Frequency

Description: Occurrence frequency is simply how often a species appears in your plots. This can be expressed as a percentage, and along with relative abundance provides information about the spatial distribution of a species.

Calculation: Examine the data table you created in Step Two of the data entry section (example shown in Table 4). Count the number of times that each species occurs in the list to determine its occurrence frequency (include all plots and transects at a site). This should be easy because the species are arranged alphabetically. Divide each species' occurrence frequency by the number of plots your group surveyed and multiply by 100 to express it as a percentage.

Interpretation: Occurrence frequency and relative abundance go hand-in-hand, and when used together tell about the spatial distribution of a species. A species with a high frequency of occurrence but a low total abundance will be distributed well over the marsh but with only small numbers of individuals. A low frequency of occurrence with a high abundance would indicate that the species occurs in larger isolated patches. Occurrence frequency and relative abundance are helpful for comparing plant communities in different marshes, or tracking changes in vegetation communities in a single marsh over time (such as before and after removal of a tidal restriction).

References and Other Suggested Reading

Bertness, M.D. and A.M. Ellison. 1987. Determinants of pattern in a New England salt marsh plant community. *Ecological Monographs* 57(2): 129-147.

Bertness, M.D. 1999. *The Ecology of Atlantic Shorelines*. Sinauer Associates, Sunderland, MA.

Gleason, H.A. and A. Cronquist. 1991. *Manual of Vascular Plants of Northeastern United States and Adjacent Canada*. The New York Botanical Garden, Bronx, NY.

Niering, W.A. and R.S. Warren. 1980. Vegetation patterns and processes in New England salt marshes. *BioScience* 30(5): 301-307.

Saltonstall, K. 2002. Cryptic invasion by a non-native genotype of the common reed, Phragmites australis, into North America. *Proceedings of the National Academy of Sciences* 99(4): 2445-2449.

Tiner, R.W. 1987. *A Field Guide to Coastal Wetland Plants of the Northeastern United States*. The University of Massachusetts Press, Amherst, MA.

Tiner, R.W. 1993. *Coastal Wetland Plants of the Southeastern United States*. The University of Massachusetts Press, Amherst, MA.

Distichlis spicata
Spike Grass

chapter four

APPENDICES

APPENDIX 1. PLANT SURVEY FIELD DATA SHEET
APPENDIX 2. COVER CLASS WORKSHEET

NOTES

PLANT SURVEY FIELD DATA SHEET

Investigators: ______________________________

____

Site Name: ______________________________

Date: ______________________ **Reference or Study (circle)**

Transect Number: ______________________

Distance from Origin Point: ______________________

Compass Bearing of Transect: ______________________

Plot ID: ______________________
Location on Transect (feet): ______________________
Community Type (low, high, border):

GENUS	SPECIES	% COVER (MIDPOINT VALUE)
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
OTHER	OTHER	

Plot ID: ______________________
Location on Transect (feet): ______________________
Community Type (low, high, border):

GENUS	SPECIES	% COVER (MIDPOINT VALUE)
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
OTHER	OTHER	

Plot ID:
Location on Transect (feet):
Community Type (low, high, border):

GENUS	SPECIES	% COVER (MIDPOINT VALUE)
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
OTHER	OTHER	

Plot ID:
Location on Transect (feet):
Community Type (low, high, border):

GENUS	SPECIES	% COVER (MIDPOINT VALUE)
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
OTHER	OTHER	

Plot ID:
Location on Transect (feet):
Community Type (low, high, border):

GENUS	SPECIES	% COVER (MIDPOINT VALUE)
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
OTHER	OTHER	

Plot ID:
Location on Transect (feet):
Community Type (low, high, border):

GENUS	SPECIES	% COVER (MIDPOINT VALUE)
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
OTHER	OTHER	

Plot ID:
Location on Transect (feet):
Community Type (low, high, border):

GENUS	SPECIES	% COVER (MIDPOINT VALUE)
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
OTHER	OTHER	

Plot ID:
Location on Transect (feet):
Community Type (low, high, border):

GENUS	SPECIES	% COVER (MIDPOINT VALUE)
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
OTHER	OTHER	

Plot ID:
Location on Transect (feet):
Community Type (low, high, border):

GENUS	SPECIES	% COVER (MIDPOINT VALUE)
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
OTHER	OTHER	

Plot ID:
Location on Transect (feet):
Community Type (low, high, border):

GENUS	SPECIES	% COVER (MIDPOINT VALUE)
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
OTHER	OTHER	

OPTIONAL: HEIGHT OF TALLEST 10 LIVING PHRAGMITES IN PLOT

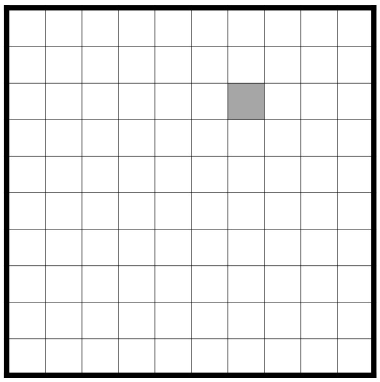
Plot ID:
Location on Transect (ft):

PLANT	HEIGHT (cm)	PLANT	HEIGHT (cm)
#1		#6	
#2		#7	
#3		#8	
#4		#9	
#5		#10	

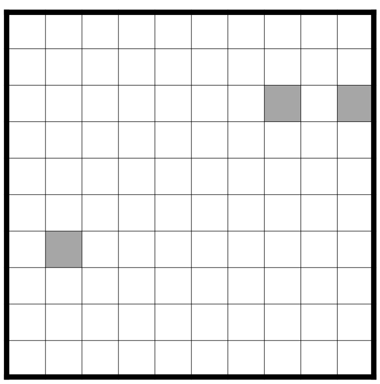
Average Height of 10 Individual Plants:

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

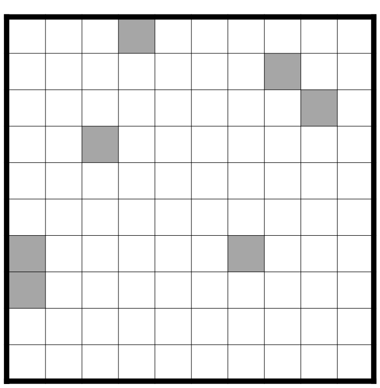
One method for obtaining abundance values is to estimate the percent of a plot occupied by the target plant. To assess percent cover, one estimates the area of the plot frame ($1m^2$) that is covered by all of the leaves, branches, and stems of the target species. Since visual estimates may vary from 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.



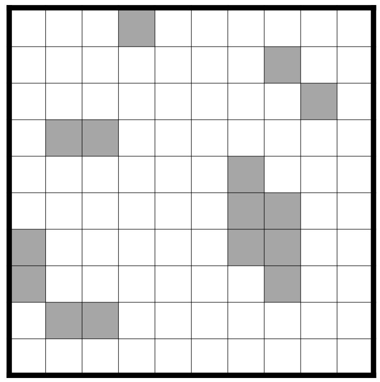
(Trace to 1%)
Use 1%



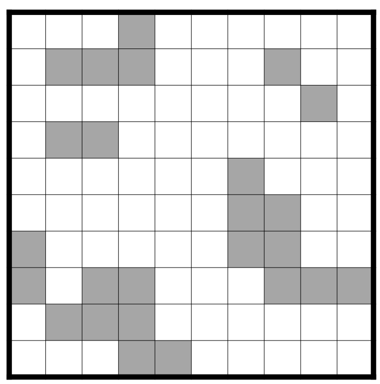
(2% to 4%)
Use midpoint 3%



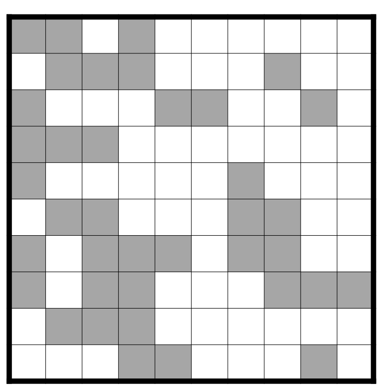
(5% to 10%)
Use midpoint 7%



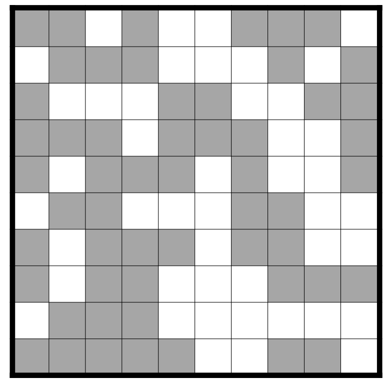
(11% to 19%)
Use midpoint 15%



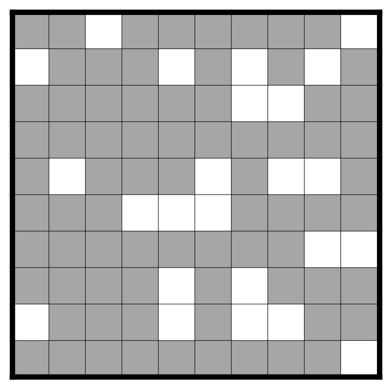
(20% to 30%)
Use midpoint 25%



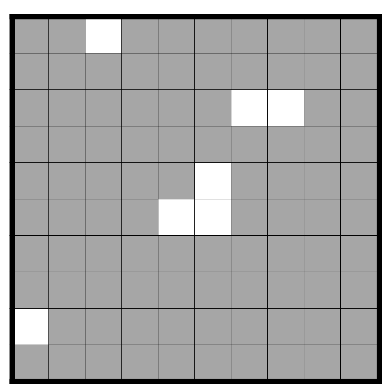
(31% to 45%)
Use midpoint 38%



(46% to 64%)
Use midpoint 55%



(65% to 87%)
Use midpoint 76%



(88% to 100%)
Use midpoint 94%

chapter five

INVERTEBRATES

Coastal **wetlands** play host to a rich **diversity** of **invertebrates** that scurry, burrow, or swim in tidal creeks, mudflats, and **salt marshes**. Snails, mussels, crabs, and shrimp are the most conspicuous animals in tidal areas, and together often comprise the greatest proportion of animal biomass in these ecosystems. You can look under vegetation, turn over rocks, and wade in water to observe less conspicuous animals such as insects, mites, spiders, amphipods, isopods, and worms. Salt marshes also support a rich diversity of tiny (often microscopic) and reclusive animals that we rarely ever see.

Just like plants, salt marsh invertebrates display a wide range of tolerance for physical and chemical conditions such as salinity and tidal influence. **Species** will occupy different areas of the marsh depending on their tolerance for local conditions, and unlike plants, can migrate between different habitats with the ebb and flow of the tide. The **low marsh** and permanently flooded areas support species that require almost constant inundation, including most mussels, clams, shrimps, crabs, and bristle worms. The **high marsh** and marsh border support a variety of marine and terrestrial invertebrates. During high tide, terrestrial invertebrates either migrate toward the marsh border or crawl up vegetation, and many crustaceans migrate from the low marsh or tidal creek into the high marsh to forage.

Invertebrates perform the critical task of converting tough salt marsh grasses into a form more palatable for other organisms, allowing animals (including other invertebrates, fish, birds, and mammals) to benefit from the rich productivity of salt marsh grasses. Thus, invertebrates are largely responsible for providing the food resources that help fuel salt marsh and marine ecosystems. The condition of the invertebrate community will ultimately influence the health of all salt marsh dependent animals.

Scientists recognize invertebrates as good **indicators** of changes in tidal flow, vegetation cover, **salinity regime**, nutrients, and dissolved oxygen. A number of invertebrates are also sensitive to pesticides and heavy metals. Many marine invertebrates are sedentary (stay in one place for their entire lives), and their populations reflect past and present environmental conditions at a particular location. In contrast, fish and birds are highly mobile and since they can leave an area if conditions become unfavorable, they are not as useful in documenting historical conditions.

Invertebrate communities may provide information as to how impacted a site may be, but often cannot reveal the source of that impact. A thorough **habitat assessment** will usually help pinpoint the reasons for an impaired invertebrate community. This chapter provides guidelines and methods for conducting a habitat assessment as part of an invertebrate **monitoring** program.

EQUIPMENT

You will need equipment to conduct the habitat assessment and collect, sort, and identify invertebrates. Table 1 lists the equipment you will need for each of these tasks, as

TABLE 1. INVERTEBRATE SAMPLING EQUIPMENT

FIELD EQUIPMENT		
D-Net (500 micron mesh size)	Spatula	Permanent Marker
Quadrat Frame, 18" x 18"	Baster	Ziploc Bags
Auger	Forceps	Labels
2 Buckets	Trowel	Clipboard and Pencils
# 30 (500 micron) Sieve	Magnifying Lens	Form 1: Field Sheet
Flagging Tape	Protective Gloves	Topographic Map
Flagging Stakes	Cooler	Aerial Photographs (if available)
300' Measuring Tape	Alcohol (ethyl or isopropyl, >90%)	Camera and Film
SORTING EQUIPMENT		
Bagged and Labelled Samples	Squeeze Bottle	Magnifying Lamp
Alcohol (ethyl or isopropyl, 70%)	Small Glass Jars (Baby Food Jars)	Forceps
	40 mL Vials and Caps	Form 2: Invertebrate Samples Record Sheet
#30 (500 micron) sieve	Plastic Bucket	
Small Glass Beaker	White Sorting Tray	
IDENTIFICATION AND COUNTING EQUIPMENT		
Vials with preserved samples	Petri Dish	Dissecting Microscope (10x-40x)
Alcohol (ethyl or isopropyl, 70%)	Ice Cube Container	Form 2: Invertebrate Samples Record Sheet
	Probe	
Small Glass Beaker	Forceps	Form 3: Laboratory Bench Sheet
Squeeze Bottle	Pencils	Identification Manuals
Small Glass Jar (Baby Food Jar)		
DATA ENTRY AND ANALYSIS EQUIPMENT		
Form 1: Field Sheet (completed)	Form 4: Invertebrate Data Sheet	Calculator
Form 3: Laboratory Bench Sheet (completed)	Form 5: Habitat Assessment Sheet	Computer with spreadsheet software

well as the necessary data sheets. Although the equipment list is extensive, resourceful people should be able to gather the materials they need at relatively low cost. The most expensive items are the D-net, auger, sieve, magnifying lamp, and dissecting microscope. Volunteer groups should try to seek an arrangement with local biological laboratories (such as high school, university, or state research labs) so that they do not have to purchase expensive items. Many of the materials required are common household items and can be donated from volunteers or the community.

SAMPLING METHODS

At this point, take the time to read the "Overview of Invertebrate Monitoring" text box that accompanies this section. Salt marsh invertebrate monitoring is more complex than the other monitoring techniques described in this manual and may require considerable preparation. It is wise to have a full understanding of your commitment before going into the field. At times, you will not be able to follow the instructions exactly as they are described below. You may encounter unexpected conditions such as dangerous mud flats where you want to sample, or steep banks that make access into the stream difficult. Use common sense to modify the procedures if necessary, but try to conduct your sampling in the prescribed manner.

Habitat Description

The ability of a salt marsh to withstand the effects of various **environmental stressors** depends upon **hydrology**, substrate, the shape and size of the marsh, and its resident **biological community**. Volunteers should fully describe habitat conditions and potential stressors to the marsh, and the best way to do this is by making careful field observations. Volunteers should conduct the habitat description during the growing season after the vegetation has become established, and preferably at the same time as the invertebrate sampling. The instructions below will guide you

Overview of Invertebrate Monitoring

- **Set Goals and Objectives.**
- **Choose a Study Site, Reference Site(s), and Sampling Stations**: Visit the study site and reference site(s) well before conducting the invertebrate sampling.
- **Set Date for Field Work**: Marine invertebrates are always present, but the presence and abundance of some species changes throughout the year. Late summer is a good time to sample because invertebrate size, diversity, and abundance are maximum then. If you are planning a second collection effort, spring is good because certain taxa are present that are scarce in the summer.
- **Borrow or Purchase Equipment and Materials.**
- **Organize the Support Team**: A field team should consist of a team leader with experience in salt marsh ecology or invertebrate taxonomy, and field assistants to help with equipment, sampling and recording. For safety reasons, single individuals should never undertake invertebrate sampling alone.
- **Conduct the Habitat Assessment.**
- **Conduct the Invertebrate Sampling**.
- **Sort the Invertebrate Samples**: Ideally, volunteers will work in a laboratory environment equipped with at least one deep sink and workbench. A university or local high school biology laboratory is a perfect setting for sorting and identification.
- **Identify and Count Invertebrates.**
- **Perform Data Entry and Analysis.**
- **Complete the Habitat Assessment Score.**
- **Submit All Completed Forms and Invertebrate Samples to the Project Leader**: Be sure that the project leader has all the necessary contact details so that if questions arise they can be resolved expediently.

through the field data form and provide explanations as you go. Maps, aerial photographs, and accurate field observations are your "tools" for completing Form 1, and later Form 5, to compute a habitat condition score.

Complete the site identification section at the top of Form 1 (Appendix 1 of this chapter). List the names of all team members conducting the assessment. Use a **GPS** to record latitude and longitude of your site or estimate coordinates from topographic maps. Before leaving the marsh site, double check Form 1 to ensure you have recorded all information. Record observations on the following variables:

1. **Weather:** Tick the appropriate boxes to describe weather conditions in the 24 hours before invertebrate sampling, and on the day of the invertebrate sampling. Stormy weather or heavy rains can affect sampling conditions, turbidity, dissolved oxygen, and conductivity.

2. **Hydrology:** Tick the appropriate boxes to list the sources of water. Use tidal charts to determine the average tidal range during the year. Document any tidal restrictions and record any impediment to water movement.

3. **Marsh Vegetation:** Categorize the **abundance** of different types of marsh vegetation in the **wetland evaluation area (WEA)** using the following abundance descriptors: N = None, R = Rare, C = Common, and A = Abundant. Abundant vegetation usually indicates a healthy marsh, and marshes with a rich variety of vegetation types provide more habitats and feeding opportunities.

4. **Abundance of Food for Invertebrates:** Follow the same method as for the marsh vegetation. Aquatic invertebrates generally prefer to consume softer vegetation. The hard stemmed plants, such as *Spartina alterniflora* (smooth cordgrass) and *Phragmites australis* (common reed), provide good habitat even though they are a poor food source. Record the presence of fish because they prey on invertebrates and can affect their densities.

5. **Substrate:** Follow the same method as for the vegetation to record the relative abundance of the different substrate types, and record other observations such as oil slicks. Most water-dependant salt marsh invertebrates favor sandy and muddy substrates, though some (snails, barnacles) prefer solid surfaces. Solid substrates are often colonized by seaweed that in turn provides food and habitat for invertebrates.

6. **Impacts to Salt Marsh:** Record all observed and known impacts to the salt marsh WEA. Mark their location on the sketch or take photographs.

7. **General Water Quality:** *(Optional, but recommended)* Using a water quality analyzing system (see: "Salinity" chapter), record the water quality parameters indicated in the table. Measure water quality at each of three sampling stations, and if necessary, record other water quality observations. Tick the appropriate boxes if suspended materials or water odors are observed.

8. **Record Invertebrate Samples:** After completing the invertebrate sampling, ensure that there is a record of all collected, bagged, preserved, and labeled samples ready for return to the laboratory. Also, be sure to record all of the live invertebrates you identified and counted in the **quadrat samples**.

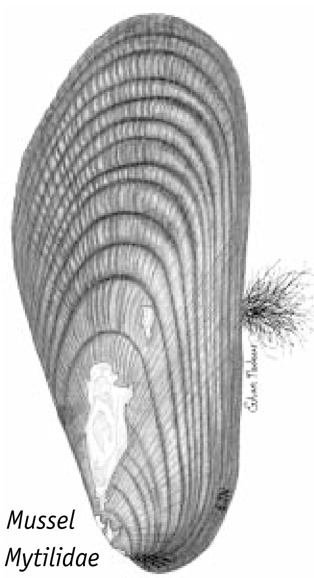
9. **Sketch of Marsh:** Use a topographic map and aerial photographs to assist you with the sketch. Include all of the elements listed at the top of the sketch area. Drawing the map will familiarize you with the surrounding land uses and roadways, the size and shape of the marsh and the related WEA, the stream pattern, ditches, vegetation types, location of restrictions, and other disturbances. It is important to mark the three sampling stations at each sampling site. Take photographs of the WEA to complement your sketch.

Collecting Samples

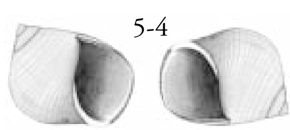
At this point, you have already selected your study site, reference site(s), and WEA using guidelines in Chapter Three and previous sections of this chapter. The WEA should be representative of the marsh condition and meet the overall goals and objectives of your study. Within the WEA, you must choose three locations to collect invertebrates, called **sample stations**. Here are some general recommendations for choosing sample stations and collecting samples:

- Be sure that your invertebrate sampling coincides with low tide.
- Flag a 300' transect along the primary tidal creek if you are studying an estuarine marsh, or a 300' transect along the bank if you are studying a salt marsh that borders an embayment.

Two volunteers conducting invertebrate sampling in a quadrat.
Photo: Ethan Nedeau



Ribbed Mussel
Family Mytilidae



- Choose three sample stations near the beginning, middle, and end of the transect. Be sure to choose sample stations that are representative of local conditions. Place flags at each location so that you will remember where you took the samples.
- If you are working along a tidal creek, first check the direction in which the water is flowing. Begin sampling at the downstream location against the flow of water and work "upstream" against the flow so that you do not disturb other unsampled stations above. If you are working along an embayment, it does not matter what order you collect samples.

Three types of samples are collected at each station: quadrat (or plot) samples at the top of the bank, **D-Net samples** in the stream or bay, and **auger samples** in the stream or bay (Figure 1). These three methods will later form one composite invertebrate sample for each station. Use the instructions below to collect these samples.

Quadrat Sampling

Quadrats are used to sample invertebrates that exist on the upper edge of the estuarine stream bank or seaward marsh edge. You should expect to find crabs, mussels, barnacles, amphipods, isopods, flies, spiders, grasshoppers, and mites in this habitat. It is useful to have one person do the sampling while another person records the results on Form 1. You should use protective gloves for this sampling technique.

Use the following procedure:

1. Place the quadrat on the bank near the water's edge at a location that is typical of the bank condition.
2. Methodically work the hands backwards and forwards across the surface of the ground within the frame, and identify, count, and record every living invertebrate that you encounter. Since barnacles are usually too numerous to count, record their abundance with the following notation: + = rare, ++ = common, and +++ = abundant.
3. Repeat this procedure at the other sampling stations.

D-Net Sampling

D-Nets are used to collect invertebrates from shallow water environments at low tide, either in tidal creeks or embayments. Using this method, you should expect to collect molluscs, polychaete worms, amphipods, isopods, and other organisms requiring constant inundation with seawater. At least two people (ideally three) are needed to conduct D-Net sampling. Use the following procedure:

1. If working in a tidal creek, note the direction of the tidal movement, and face against the flow.
2. Before entering the water, look for all the different habitat types, such as banks and vegetated margins, different substrate types, **woody debris**, and floating **alga mats**, and try to collect from each of these habitats. Enter the water gently so that you do not frighten and disperse swimming organisms.

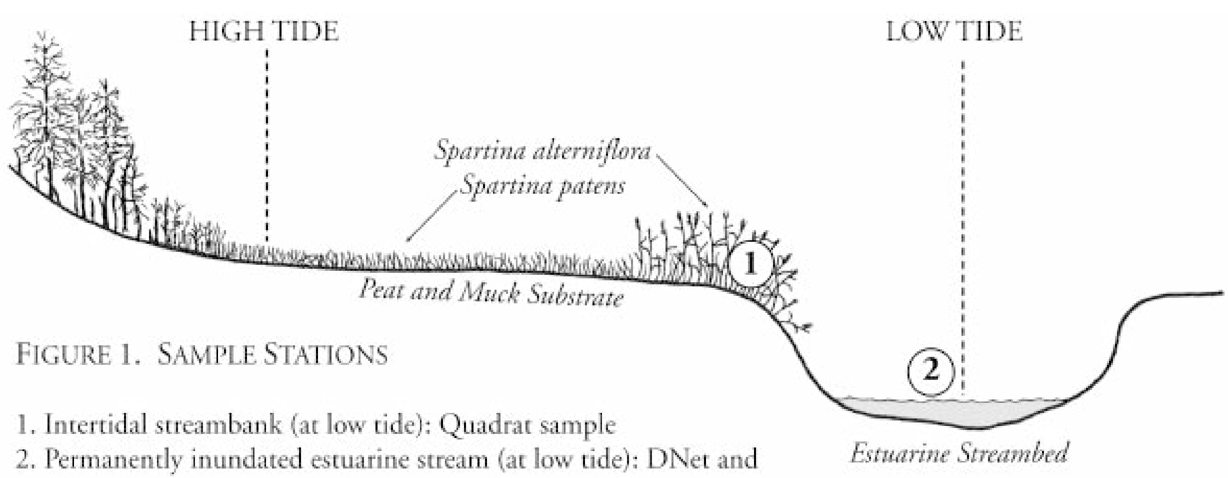
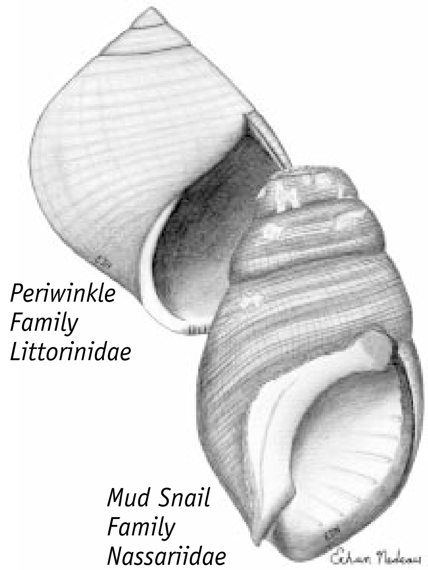


FIGURE 1. SAMPLE STATIONS

1. Intertidal streambank (at low tide): Quadrat sample
2. Permanently inundated estuarine stream (at low tide): DNet and auger samples

Collecting a D-Net sample in a tidal creek. **Photo: Ethan Nedeau**

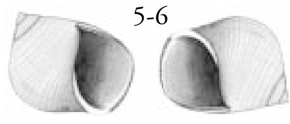


3. Place the flat side of the D-Net on the surface of the substrate in approximately 0.3 meters (14 inches) of water, and hold the net perpendicular to the substrate as you walk 10 strong and even paces toward the water flow, pulling the D-Net through and over different habitats. If working in an embayment, you will not have the current to contend with and it is important that you maintain your momentum as you collect the sample. Many invertebrates are good swimmers and try to escape the net.
4. Bring the net containing the sample to the surface for retrieval. Gently swish the net back and forth in the stream to allow fine silt and sand to pass through the mesh, being careful not to lose organisms.
5. Place the contents of the inverted net over a bucket half filled with water and wash all debris and invertebrates off the net and into the bucket.
6. Use forceps to remove any organisms that remain on the net, and place these in the bucket.
7. Pour the contents of the bucket through a standard US No. 30 brass sieve to remove the water.
8. Place the contents of the sieve into a resealable plastic bag, and make sure that no invertebrates are left on the sieve.
9. If you have a large number of snails and crabs in your sample, you should identify them in the field, record the numbers of each **family** (and if possible, species) on the field sheets, and then return them back to the water alive.
10. Label the resealable plastic bag (see instructions below) and record the sample information on the field sheet.
11. Once you complete a sample, wash out the D-Net to remove all remaining debris.
12. Repeat the procedure at the two other sample stations, placing each sample into a separate resealable plastic bag. It is important that you collect all samples in a consistent manner.

Auger Sampling

An auger, or corer, is used to collect a sediment or substrate sample from the stream or embayment. Using this method, you should expect to collect a variety of worms, snails, clams, amphipods, isopods, and other organisms that live on or within the substrate. You should collect the sample in a location that was not disturbed by D-Net sampling. Use the following procedure to collect auger samples:

1. Hold the auger perpendicular to the water surface above the point from which the sample will be taken.
2. Push the auger downward into the sediment until the bucket of the auger is half embedded in the substrate. Turn the auger handle to help force the auger into the substrate.
3. Carefully pull the auger out of the sediment and quickly place the sieve beneath the auger so that none of the sample is lost. Keep the sieve under the auger as you return to the bank, where you should empty the remaining auger contents into the sieve.



4. Remove fine sediment from the sieve by carefully placing it face up in the water (being careful that the water does not cover the top!) and gently swirling the contents so that the fine sediment passes through the sieve. This important step will greatly decrease sorting time.
5. Place sieve contents into a resealable plastic bag, seal, label (see instructions below), and record the sample information on the field sheet.
6. Clean the auger by swishing it back and forth in the water.
7. Repeat the procedure at the other two sampling stations, placing each sample into a separate resealable plastic bag. It is important that you collect all samples in a consistent manner.

Sample Bagging and Labeling

You must properly bag and label all samples so that everybody knows how, where, and by whom a sample was collected. A sample without a label is worthless, and it would be unfortunate if valuable field time were wasted because of improper bagging or labeling procedures. Use the following procedures to label samples:

1. Using a permanent ink marker, label all samples with the following information: sample number, field site identification, sampling station number, date, names of collectors, sampling method, and the **preservative** used (Figure 2). This can be done before going into the field.
2. Flood all bagged samples with 90% or higher concentration alcohol or similar preservative and seal carefully.
3. Record the sample numbers on the field sheet (See: Form 1).
4. Place bagged samples in a cooler with ice to prevent heating in hot weather.
5. Store samples in an air-conditioned laboratory (or similar workspace) or a refrigerator for no longer than two weeks before sorting.

Sample Sorting

After you collect samples and return to your indoor working area or laboratory, you must begin the painstaking process of removing invertebrates from the sand, silt, and peat substrate. Many invertebrates are less than 5mm long and pale in color, making them difficult to see among the sediment. Sample sorting is a very important part of your study, and it is imperative that you remove all of the organisms in your sample (or sub-sample — see #4 below) so that your data are not biased and your conclusions are reliable. You might have to be patient and thorough, but the data you generate will be well worth the effort. Use the following guidelines for sorting samples:

Sample Number: *#4*
Field Site Identification: *WEA MSBP-R*
Sampling Station: *#2*
Date: *April 20, 2002*
Names of Collectors: *Tom Hopkins, Bev O'Halloran*
Sampling Method: *D-Net*
Preservative Used: *90% ethyl alcohol*

FIGURE 2. SAMPLE LABEL

1. Empty the contents of a sample into the standard US #30 sieve. You should place the sieve over a bucket so that sediment is not washed down the drain.
2. Gently rinse the sample under tap water to remove fine organic detritus, silt, and clay. Place the sieved sample into a white sorting tray (one small handful at a time, if necessary). You must be careful to remove any organisms that may be stuck on the sieve.
3. Place the sorting tray under a desk light or magnifying lamp, and using the magnifying lens and forceps, remove invertebrates from the sediment and place them into a large (40mL) vial two-thirds filled with 70% or higher concentration of alcohol.

Volunteers sorting and identifying invertebrates. **Photo: Anna Hicks**

Rapid Bioassessment Subsampling Protocol

(100-Organism Count Technique)

1. Thoroughly rinse sample in a 500-micron screen or the sampling net to remove fine sediments. Any large organic material (whole leaves, twigs, algal or macrophyte mats) should be rinsed, visually inspected for invertebrates, and discarded.

2. Place sample contents in a large flat pan with a light-colored (preferably white) bottom. The bottom of the pan should be marked with a numbered grid pattern, each block in the grid measuring 5 x 5 cm. (Sorting using a gridded pan is only feasible if the organism movement in the sample can be slowed by the addition of club soda or tobacco to the sample. If the organisms are not anesthetized (or preserved), 100 organisms should be removed from the pan as randomly as possible.) A 30 x 45 cm pan is generally adequate, although pan size ultimately depends on sample size. Larger pans allow debris to be spread more thinly, but they are unwieldy. Samples too large to be effectively sorted in a single pan may be thoroughly mixed in a container with some water, and half of the homogenized sample placed in each of two gridded pans. Each half of the sample must be composed of the same kinds and quantity of debris and an equal number of grids must be sorted from each pan, in order to ensure a representative subsample.

3. Add just enough water to allow complete dispersion of the sample within the pan; an excessive amount of water will allow sample material to shift within the grid during sorting. Distribute sample material evenly within the grid.

4. Use a random numbers table to select a number corresponding to a square within the gridded pan. Remove all organisms from within that square and proceed with the process of selecting squares and removing organisms until the total number sorted from the sample is within 10 percent of 100. Any organism that is lying over a line separating two squares is considered to be in the square containing its head. In those instances where it is not possible to determine the location of the head (worms for instance), the organism is considered to be in the square containing the largest portion of its body. Any square sorted must be sorted in its entirety, even after the 100 count has been reached. In order to lessen sampling bias the investigator should attempt to pick smaller cryptic organisms as well as the larger more obvious organisms.

5. After 100 or more organisms have been removed, check the entire contents for any taxonomic group that has been missed. Pick out one representative of each previously missed group. This ensures a complete record of taxa richness.

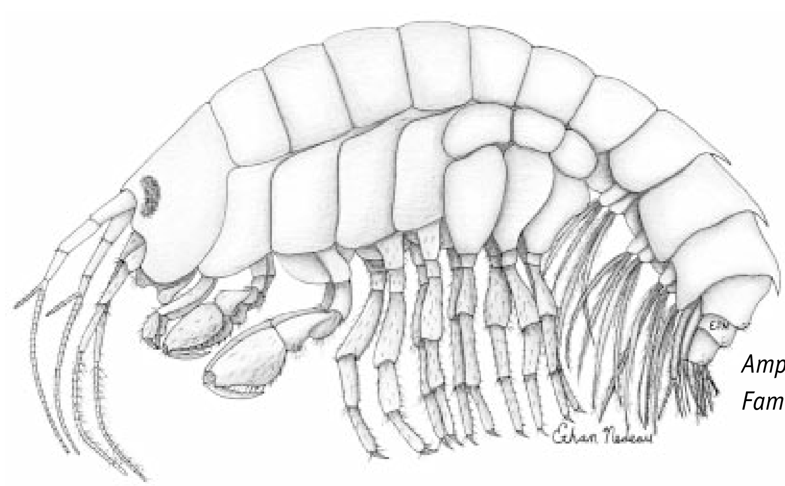
Source: Plafkin et al., 1989, modified from Hilsenhoff, 1987. #5 is a modification made by the authors of this manual.

4. If you think there are approximately 100 or less organisms in the sample, then remove all organisms. If you think there are well over 100 organisms, you may use the 100-organism **sub-sample** procedure (see textbox above). This sub-sampling method is appropriate for volunteers with limited time and financial resources. If time and resources are available, volunteer groups should conduct a full count.
5. After you have finished sorting, have a second person scan the debris in the sorting tray to double check your work. Tightly seal and label each vial (two for each sampling station: one for D-Net and one for auger), and register the sample on the Invertebrate Samples Record Sheet (Form 2, Appendix 2 of this chapter).
6. Samples can be identified and counted any time after the sorting has been completed, but should not be left for more than six months because alcohol in the vial sometimes evaporates and ruins the sample.

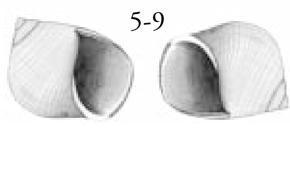
Identifying and Counting Samples

Identification can be enjoyable because you get the chance to look closely at organisms, observe their fascinating shapes, and spend time looking through identification guides and learning about each organism and its close relatives. It is very satisfying to know the difference between Capitellidae, Spionidae, and Nereidae — all different types of marine worms — especially considering that you probably did not even know these words existed before you became a volunteer monitor! Identification takes practice, and people working in the Northeast are fortunate to have two outstanding identification manuals for marine invertebrates entitled *Marine Animals of Southern New England and New York* (Weiss, 1995) and *A Practical Guide to the Marine Animals of Northeastern North America* (Pollock, 1998). Use the following guidelines to identify and count invertebrates:

1. Create a **composite sample** for each station by pouring the vial contents of the D-Net sample and auger sample into one petri dish. Make sure that no organisms remain in the vials.
2. Place the petri dish under the dissecting scope set at 10X magnification, and in a deliberate, systematic manner, scan back and forth, identifying organisms as you go. You may need to increase the magnification to see finer details.
3. Using Weiss (1995), Pollock (1998), and other references, identify the invertebrates to family level.
4. Record and count each **taxon** on the Laboratory Bench Sheet (Form 3, Appendix 3 of this chapter).
5. Immediately after you identify and record a specimen, return it to a labeled vial two-thirds filled with 70% or higher concentration alcohol. There should be one vial per sample station per sample date.
6. Label and safely pack the vials for return to your project coordinator so that someone can reexamine specimens or identify them to a lower level of taxonomy at some future date.
7. If you have doubts about an organism's identity, consult with a marine invertebrate specialist. Place the specimen in question in a separate vial with alcohol and a complete label. Send the specimens to a specialist for verification, and add to your records later. Alternatively, arrange to have a **taxonomist** present during an identification session to provide assistance.
8. Record the completion of this process for each sample on the Invertebrate Sampling Record Sheet (Form 2). Form 2 traces the sample collection, sorting, and identification to this stage.
9. On the Laboratory Sheet (Form 3), add the data from the quadrat sample taken from the same sampling station. Enter the total number of organisms for each family or **taxonomic group**, the number of different types of taxa you identified, and the resulting total abundance for the completed composite sample.
10. Repeat this process for the remaining two sample stations, using a separate Form 3 for each station.
11. Once volunteers have finished collecting, sorting, and identifying samples for a site, there will be three completed copies of Form 3 (one for each sample station).
12. Samples and the registration sheet (Form 2) are to be returned to the project leader for **archival action**. Similarly, return Forms 1, 3, 4, and 5 to the project leader once they are completed. Project leaders should keep copies (hard or floppy disk) for their own records and as a safety backup.



Amphipoda
Family Gammaridae



DATA ENTRY

Even though the project scientist or leader usually analyzes the data, volunteers can perform a number of tasks associated with data entry. If you followed the sampling, identification, and counting procedures outlined above, you will have three completed copies of Form 3 for each site, which will then be combined into a single Invertebrate Data Sheet (Form 4, Appendix 4 in this chapter) for each site. Volunteers should transfer invertebrate data onto Form 4 using the instructions below. Data entry and analysis is ideally suited for a spreadsheet program such as Microsoft Excel. The instructions below include figures that show spreadsheet format and use real data to illustrate key aspects of data entry. Figure 3 is set up similar to a spreadsheet with column and row identifiers (letters for columns and numbers for rows), so that any cell can be identified. For example, cell D12 is located in column D and row 12.

Data Entry Instructions

1. Record all pertinent information (site identifiers, processing dates, names of volunteers) on Form 4.
2. Transfer the number of organisms in each taxonomic group for each composite sample (the last column of Form 3) into columns D(1), D(2), and D(3) of Form 4. For example, if 23 individuals of the family Hydrobiidae were collected at Station 1, then you would enter 23 into cell C6 in Figure 3.
3. Sum D(1), D(2), and D(3) for each taxonomic group (class, order, or family), divide by three, and enter this value into column $\overline{D}$. This is the Taxa Average. For example, the value "6.7" in cell F3 of Figure 3 represents the average number of Acteonidae collected at the three sampling stations.
4. For each order, sum column $\overline{D}$ to compute Order Subtotal (Figure 3). For example, the value "21.7" in cell F16 of Figure 3 represents the average number of Isopoda collected at the three sampling stations.
5. Transfer each Order Subtotal into the second column of the box "Composition of Major Groups" on page two of Form 4 (see Table 2). The sum of the column "Number" represents the Average Number

	A	B	C	D	E	F	G
1	**TAXA**	**FG**	**D(1)**	**D(2)**	**D(3)**	$\overline{D}$	**%**
2	**GASTROPODA**						
3	Acteonidae	G	5.0	12.0	3.0	6.7	6.2
4	Cerithiidae	G	0.0	0.0	0.0	0.0	0.0
5	Columbellidae	G	1.0	5.0	1.0	2.3	2.2
6	Hydrobiidae	DF	23.0	12.0	6.0	13.7	12.6
7	Littorinidae	G	7.0	4.0	34.0	15.0	13.9
8	Melampodidae	G	0.0	0.0	0.0	0.0	0.0
9	Nassariidae	G	9.0	4.0	6.0	6.3	5.8
10					**Subtotal**	44.0	40.6
11	**ISOPODA**						
12	Idoteidae	DF/C	31.0	8.0	14.0	17.7	16.3
13	Janiridae	DF/SC	0.0	0.0	0.0	0.0	0.0
14	Limnoriidae	DF	3.0	7.0	2.0	4.0	3.7
15	Other	DF/SC	0.0	0.0	0.0	0.0	0.0
16					**Subtotal**	21.7	20.0
17	**SPIONIDA**						
18	Spionidae	DF	24.0	17.0	81.0	40.7	37.6
19	Other	DF	2.0	3.0	1.0	2.0	1.8
20					**Subtotal**	42.7	39.4

FIGURE 3: EXAMPLE DATA ENTRY SPREADSHEET

The numbers along the side (1-20) and letters along the top (A-G) are used to identify individual cells within the spreadsheet. For instance, cell "F6" refers to the average value of the family Hydrobiidae, which is 13.7. This figure only shows partial data, and a realistic spreadsheet would include several additional taxonomic groups.

Column labels are as follows:
Taxa: Class, Order, or Family
FG: Feeding Group (see Table 3 for abbreviations)
D(1): The number of organisms in sample station #1
D(2): The number of organisms in sample station #2
D(3): The number of organisms in sample station #3
$\overline{D}$: Taxa Average
%: Taxa Percent Composition

of Organisms for the site (stations 1-3 combined). In Table 2, the value "108.3" represents the average number of organisms collected at the three sampling stations.

6. In the box "Composition of Major Groups" (Table 2), divide each Order Subtotal by the Average Number of Organisms, multiply by 100, and enter this value into the column "Percent." This represents the percentage of the entire sample comprised by each Order, and the sum of the column should be 100%. In Table 2, to compute the percent contribution of the order Isopoda, divide 21.7 by 108.3 and multiply by 100 to reach 20.0%.

7. In Figure 3, divide Taxa Average by Average Number of Organisms (from Table 2) and multiply by 100 to compute Taxa Percent Composition for the entire sample. Enter these values into the column "%." For example, in Figure 3 the percent composition of the family Idoteidae is determined by dividing its taxa average (17.7; Cell F12) by the Average Number of Organisms (108.3, from Table 2) and multiplying by 100 to reach 16.3% (Cell G12).

8. Sum column "%" for each order to compute Order Percent Composition for the entire sample, which is entered as "Subtotal" in column "%" of Figure 3. The Order Percent Composition in Figure 3 should be the same as the percent composition in Table 2. For example, the percent Gastropoda in Table 2 and Figure 3 (Cell G10) are both 40.6.

9. Complete the box "Composition of Feeding Groups" by summing the Taxa Percent Composition for each **feeding group** (see Table 3). Feeding group is indicated in column FG of Figure 3. The **Mixed Feeding Group** is used for families that have more than one feeding group (e.g. SF/DF). For example, in Figure 3 the **deposit feeders** (DF) are the Hydrobiidae (12.6), Limnoriidae (3.7), Spionidae (37.5), and Spionida Other (1.8), for a combined percentage of 55.6%. This value is entered into the appropriate line on Table 3. If you have counted correctly, the sum of percentages should be 100.

10. Locate the summary box "Introduced Species" on Form 4. You may not be able to complete this box because it requires species-level identification of three common introduced species — the green crab (*Carcinus maenas*), common periwinkle (*Littorina littorae)*, and Japanese crab (*Hemigrapus sanguineaus*). Remember that this chapter has recommended family-level identification. If you have identified and counted these species, you can record the average number of individuals and percent composition in the sample following the same procedure you did for the box "Percent Composition of Feeding Groups."

11. Complete the box "Percent Insects, Spiders, and Mites" on Form 4 by summing Taxa Percent Composition for the Insecta (insects), Aranea (spiders), and Acarina (mites).

12. Fill out the box "Summary" (see Table 4) using the following instructions:

    Line 1: Enter the Average Number of Organisms (Table 2, value = 108.3).
    Line 2: Count the number of different taxonomic groups present in the samples (whether to class, order, or family) and enter that figure into line two. Using data in Figure 3, there are nine different taxonomic groups.
    Line 3: Find the highest value in the third column of the box "Composition of Major Groups" and enter the value into line three (Table 2, value = 40.6 [Gastropoda]).

TABLE 2. COMPOSITION OF MAJOR GROUPS

ORDER	NUMBER	PERCENT
Gastropoda	44.0	40.6
Isopoda	21.7	20.0
Spionida	42.7	39.4
Total	108.3	100.0

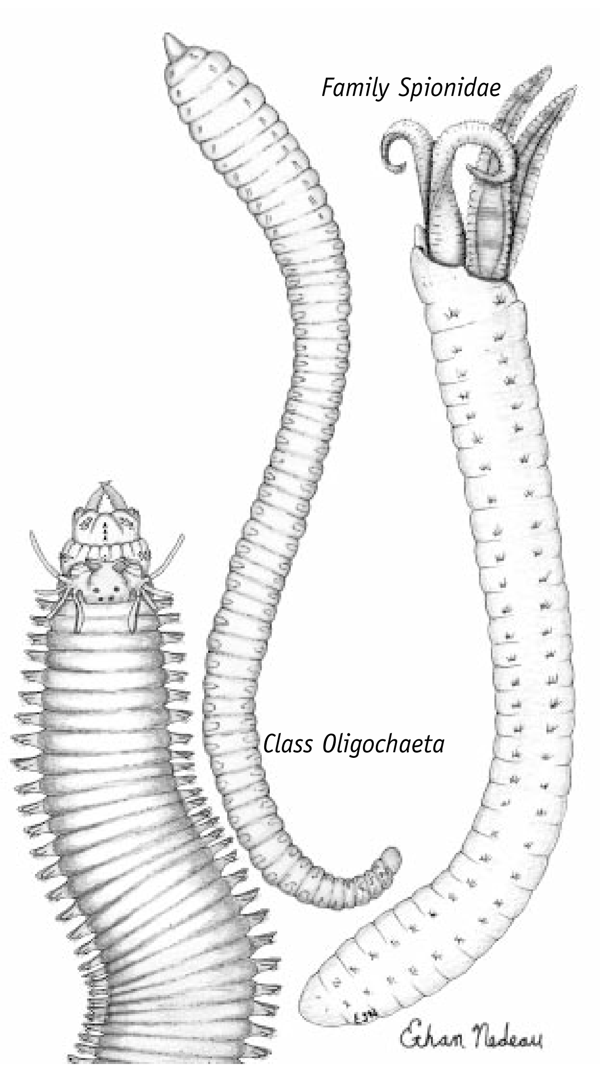
TABLE 3. COMPOSITION OF FEEDING GROUPS

FEEDING GROUP	PERCENT
Predator (PR)	0.0
Deposit Feeder (DF)	55.6
Grazer (G)	28.0
Omnivore (OM)	0.0
Scavenger (SC)	0.0
Suspension Feeder (SF)	0.0
Mixed (M)	16.3
Total	100%

TABLE 4. SUMMARY

METRIC	VALUE
Average Number of Organisms	108.3
Taxonomic Richness	9
% Contribution of Dominant Taxonomic Group	40.6%
% Contribution of Dominant Feeding Group	55.6%
% Insects, Spiders, and Mites	0%

Line 4: Find the highest value in the second column of the box "Composition of Feeding Groups" and enter the value into line 4 (Table 3, value = 55.6 (Deposit Feeder).
Line 5: Enter the combined percentage of Insects, Spiders, and Mites.



Family Nereidae

DATA ANALYSIS AND COMPARISON

You have completed Data Entry and by doing so you have computed some important community **metrics** for your study site and reference site. This section discusses what each of these metrics means and how they are used to compare a study site with a reference site.

Average Number of Organisms

This is the average number of organisms that were collected in three composite samples from a site. This is sometimes called "average abundance" or "average density." This is not a very meaningful value. Scientists have found that the average total number of organisms, or abundance, usually does not respond in a consistent way to environmental impact. The results are always highly variable. Some impacts, such as an increase in nutrients, may promote an increased abundance of organisms, whereas other impacts, such as heavy metals, may cause a decreased abundance of organisms. Even though this figure is not very useful as a metric, it is needed to calculate other more reliable metrics.

Taxonomic Richness

This is the number of different types of organisms that were collected at the site. If you identified all taxa to the family level, then this would be the number of families. It is more likely that you only identified some difficult organisms to the class or order level. Taxonomic richness usually represents the number of groups that were identified to the lowest possible level. For example, if the final taxa list looked like this:

Class Insecta
Class Turbellaria
Unknown Polychaeta
Family Spionidae
Family Capitellidae
Family Gammaridae
Family Idoteidae

then the taxonomic richness for your sample would be seven, even though you could only identify four of these to the family level. High taxonomic richness is usually associated with favorable conditions with various types of microhabitats. Taxonomic richness is usually lower in disturbed areas because sensitive species are lost and certain habitats are eliminated. The exception occurs with a mild disturbance that can create more habitats or niches than previously existed. In this case, taxonomic richness is likely to increase.

Percent Composition of Taxonomic Groups

The types of organisms and the percent composition of major groups of organisms can reveal important information about the health of a community because groups respond differently to environmental pollution and disturbance. Some species are very sensitive to disturbance, and a community with large numbers of **sensitive** organisms is probably very healthy. Other species are extremely **tolerant** of pollution and often increase in abundance in polluted habitats. For example, studies have shown that the abundance of the families Palaemonidae, Spionidae, Nereidae + Nephtyidae, and Capitellidae increase with eutrophication. Table 5 suggests that the study site is more eutrophic than the reference site, even though Nereidae + Nephtyidae did not respond as expected.

TABLE 5. COMPOSITION OF TAXONOMIC GROUPS

TAXA	PERCENT COMPOSITION REFERENCE	STUDY
Palaemonidae	2	5
Spionidae	0	15
Nereidae + Nephtyidae	4	1
Capitellidae	3	30
Percent Abundance	12	48

Percent Composition of Dominant Taxonomic Group

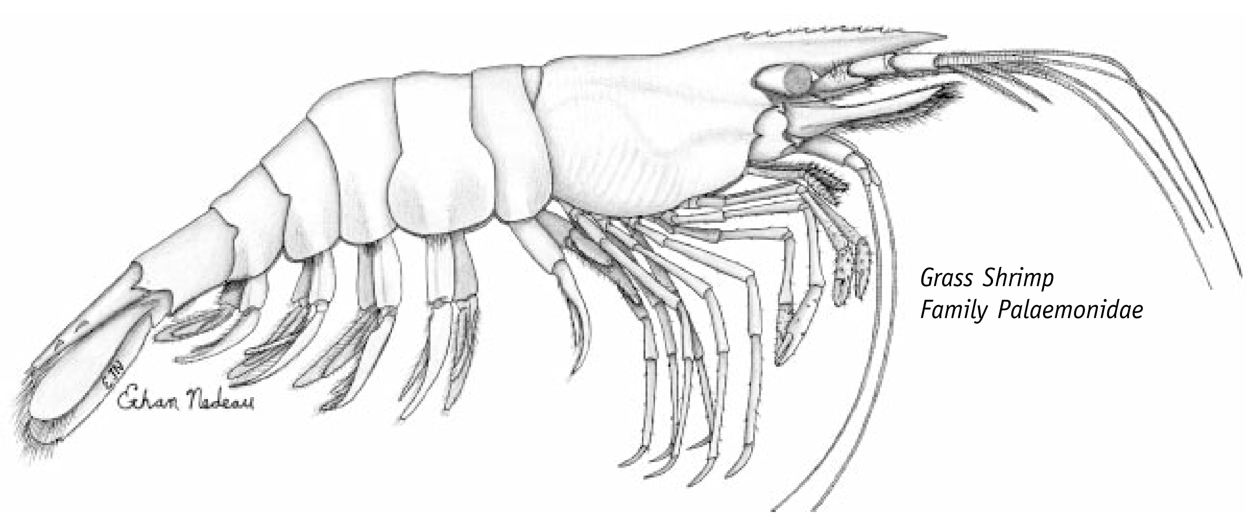
A healthy community should have a balanced composition of taxa consisting of at least three co-dominant groups. Usually no single group should greatly dominate the rest of the community. One or two groups usually dominate stressed communities, either because sensitive species are eliminated or because certain groups respond in a positive way to pollution or disturbance. If the percent composition of the dominant taxonomic group is 36% in the reference site and 78% in the study site, then it is possible that conditions at the study site favor one type of organism that out competes the others.

Percent Composition of Trophic Groups

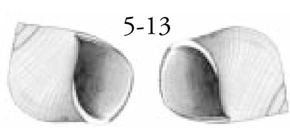
This metric is very similar to the one above except that it indicates the balance between different feeding groups in a community. A healthy community should have a well-balanced composition of different trophic groups, although **detritivores** and **suspension feeders** are usually dominant in salt marshes. Many invertebrate **predators**, such as the blue crab and the clamworm, live a long time and their presence in a water body usually indicates good water quality, especially because predators are subject to the effects of **biomagnification** — the increasing concentration of a pollutant in body tissues as food passes along a food chain. With increasing impact, the proportion of predators is expected to decline and the proportion of detritivores to increase.

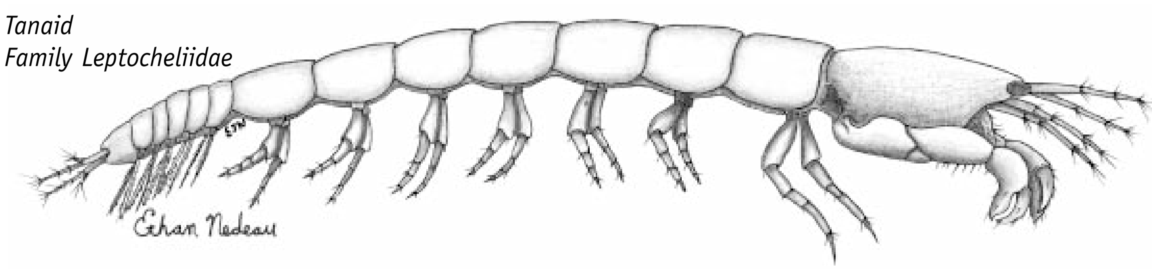
Percent Contribution Dominant Trophic Group

A healthy community should have a balanced composition of trophic groups, and no single group should greatly dominate the community. The percent contribution of the



Grass Shrimp
Family Palaemonidae





dominant trophic group can be a reliable indication of the feeding opportunities that exist in a community, and provide insight about wetland condition.

Introduced Species

There is a growing concern that species introduced from other areas of the world find ideal conditions in New England. Often they do not have natural predators or diseases that were present in their native habitats, and can often out-compete native species and spread very quickly throughout the ecosystem. The green crab (*Carcinus maenas*), common periwinkle (*Littorina littorae)*, and Japanese crab (*Hemigrapus sanguineaus*) are three common introduced species. High numbers of these species might not indicate other environmental problems associated with the salt marsh, but should be cause for concern. In some cases, careful monitoring or **mitigation** measures might be appropriate.

Percent Insects, Spiders, and Mites

The presence of aquatic freshwater insects (such as chironomid midges, beetles, true bugs, mosquitoes, and dragonfly **larvae**) in salt marshes might indicate low salinity regimes possibly caused by excessive stormwater runoff from the surrounding landscape, the influence of groundwater springs, or the lack of tidal flushing due to a tidal restriction. The presence of terrestrial organisms such as spiders, mites, flies, aphids, and grasshoppers very close to the water edge can indicate a reduction in flooding by tidal salt water. For example, if you found 28% of Insects, Spiders, and Mites in the study site and only 4% in the reference site, then it is likely that the two sites have a different salinity and/or hydrological regime(s). You would probably want to measure salinity or tidal hydrology to support these findings.

ADVANCED ANALYSIS

You can now see how to use metrics to make comparisons that may suggest health problems for different aspects of the invertebrate community at a study site. The information you have obtained to this point is very important. It forms the basis for the final step in the invertebrate community health analysis, the calculation of the **Invertebrate Community Index (ICI)**. Volunteers are not asked to take this step because it requires special expertise. Volunteers should complete the **Habitat Assessment Score (HAS)**, and by reading the section "Summary of ICI and HAS" volunteers can see how the invertebrate data and habitat evaluation can be graphically displayed and presented to decision makers and managers.

Invertebrate Community Index (ICI)

Project leaders use invertebrate data to calculate an ICI with assistance from a professional biomonitoring scientist. The ICI is a summary of the multiple metrics and **indices** that have been selected for each site. The ICI summarizes the degree of impact to the invertebrate community at the study site as compared to a reference site(s) by comparing all of the invertebrate metrics that were calculated. The study site is given a score between 0% and 100%. A score of 100% means that the invertebrate community at the study site is the same as that of the reference site(s). A score of 0% means there is no resemblance at all with the reference site. Scores will nearly always fall in between 20% and 90%. For example, a score of 72% means that the invertebrate community from the study site differs by 28% from that sampled at the reference marsh.

Habitat Assessment Score (HAS)

Invertebrate community health is reliant on both habitat quality and water quality. It is important to document habitat quality and water quality variables in order to put invertebrate results into context. Form 1 and Form 5 provide a means to express habitat and water quality in a way that is comparable to the invertebrate community metrics and the ICI. This manual uses 10 important **variables** of habitat condition to compute an overall score, called the HAS. The HAS is expressed as a percentage of a theoretical optimal condition. Follow the procedure below to compute the HAS:

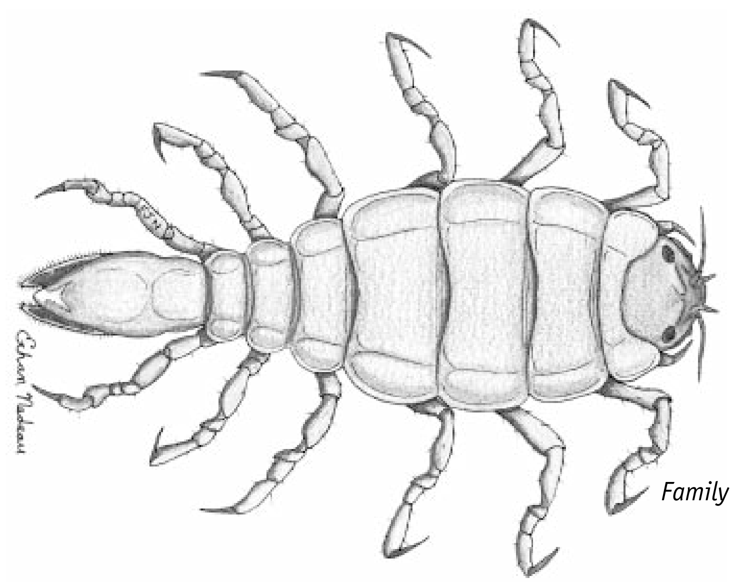
1. Use the information recorded on Form 1 and your best judgment to determine a score for each of the variables on Form 5. Scores range from zero to five, with zero = poor and five = excellent. You may use partial numbers (i.e. 3.5). Record the score in the appropriate column on Form 5.
2. Sum the scores for each variable and convert the total to a percentage. Conversion to % = total score for attributes/50 x 100

Reference marshes may or may not score 100%. Reference marshes are selected because they are minimally disturbed or because they are less disturbed than other salt marshes within a region — not because they are perfect. Most of the best marshes in New England show some signs of historical disturbance such as ditches or tidal restrictions. Similarly, study sites sometimes receive a higher HAS than reference sites. Some types of disturbance may seem important but may have little influence on overall habitat quality in a salt marsh — for example, the odor of sulfur that is natural. Investigators should examine both the overall HAS and the individual variables to fully understand how habitat may affect invertebrate communities.

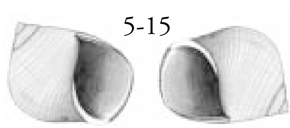
Summary of ICI and HAS

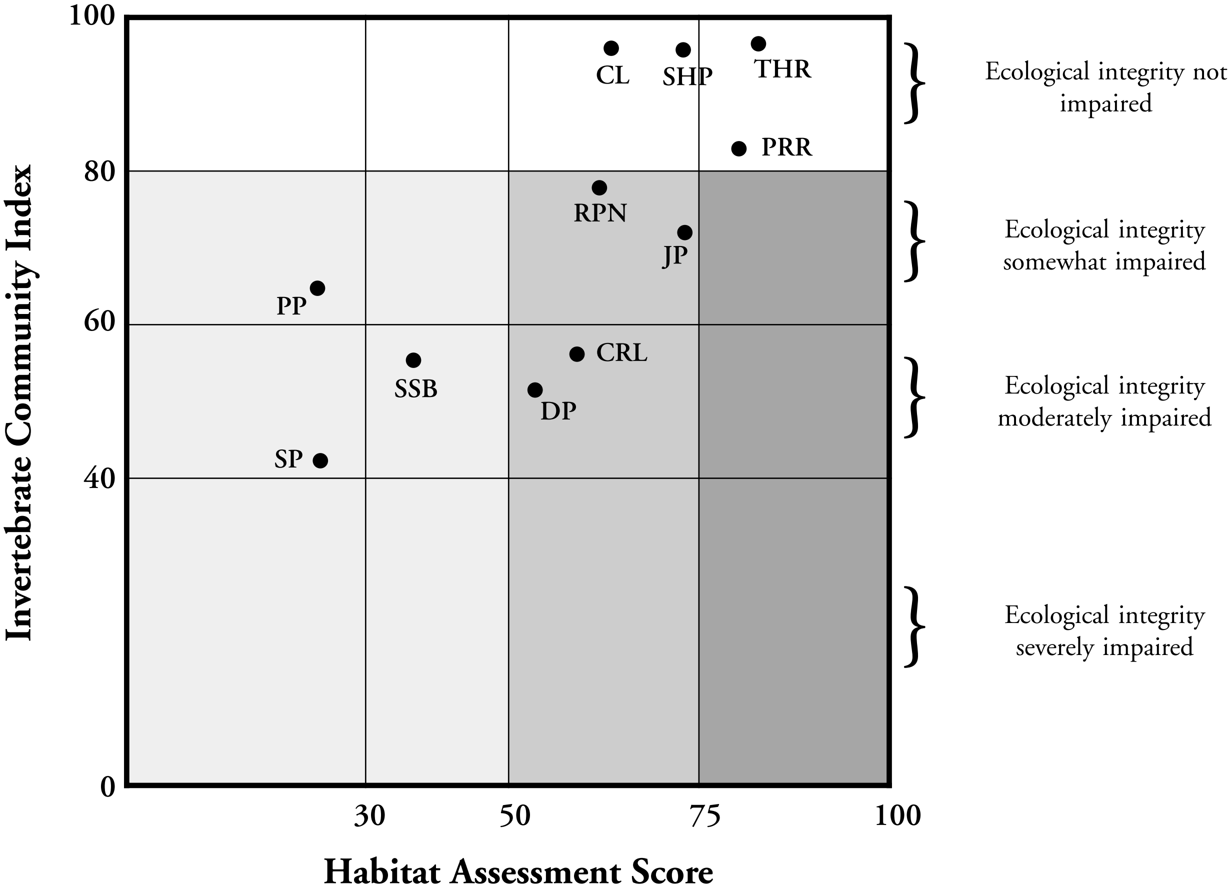
The Salt Marsh Invertebrate and Habitat Summary Graph (Figure 4) is a graphical representation of the HAS and the ICI. The vertical axis of the graph represents the ICI and the horizontal axis represents the HAS. The graph provides a visual representation of salt marsh invertebrate community condition and provides some indication about the relative importance of habitat quality when marshes are plotted against the two axes. This graph is a valuable **evaluation tool** and has implications for planning and management in light of the rapid rate of development that is threatening many of New England's salt marsh habitats.

Typically, reference sites will be near the upper right hand corner of the graph and impacted sites will be closer to the lower left hand corner of the graph. If the ICI is very low (indicating impairment) yet the HAS is high (indicating good habitat), then it is likely that something other than the habitat variables you measured are causing **biological impairment** (for example, toxic pollution). Any anomalies — such as poor invertebrate communities and excellent habitat, or excellent invertebrate communities and poor habitat — should be followed with a more intensive investigation. This manual provides instructions on measuring tidal influence, salinity, and three other biological parameters — all of this information can complement your invertebrate study. Other types of information that may be helpful include **land use analysis**, a more detailed habitat assessment, measurements of water quality and sediment quality, and **toxicity tests** such as **Microtox** and **bioassays**.



Family Idoteidae





Legend	
	Condition due primarily to poor habitat
	Condition due to poor habitat and other stressors
	Condition due to stressors other than poor habitat

FIGURE 4. ICI & HAS SUMMARY GRAPH
The abbreviations on the graph represent different wetlands and are meant for illustrative purposes.

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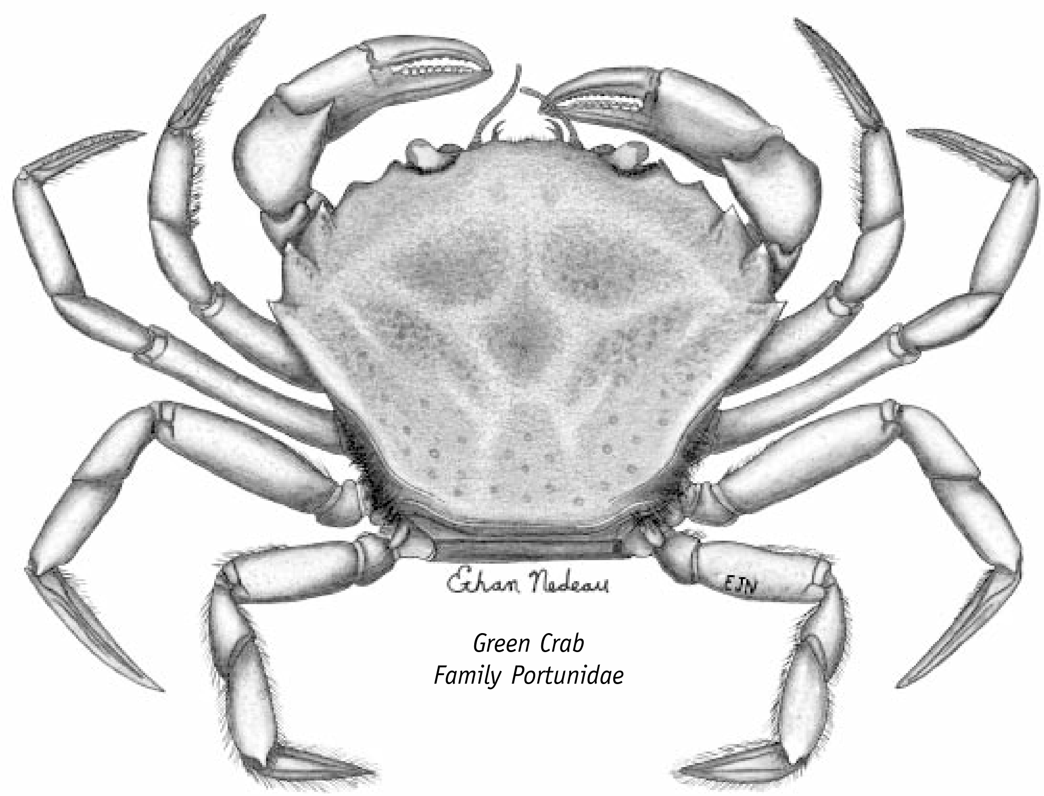


Green Crab
Family Portunidae

NOTES

chapter five

APPENDICES

APPENDIX 1. FORM 1: SALT MARSH INVERTEBRATE FIELD SHEET
APPENDIX 2. FORM 2: INVERTEBRATE SAMPLES RECORD SHEET
APPENDIX 3. FORM 3: INVERTEBRATE LABORATORY BENCH SHEET
APPENDIX 4. FORM 4: INVERTEBRATE DATA FORM
APPENDIX 5. FORM 5: HABITAT ASSESSMENT SCORE SHEET
APPENDIX 6. FORM 6: ICI AND HAS SUMMARY GRAPH

Form 1: Salt Marsh Invertebrate Field Sheet

Monitoring Team: ______________________________

Site #: ____________________ Date: ____________________

Site Name: ____________________ Latitude: ____________________

Topo Map Series: ____________________ Longitude: ____________________

Photographs Taken?: ______________________________

Estimated size of Wetland Evaluation Area (WEA): ____________________

Approximate distance from site to seacoast: ____________________

Percent of Wetland Buffer at least 100' Wide (Circle One):

0 - 30%   30 - 50%   50 - 80%   80 - 100%

WEATHER (check appropriate boxes)

WEATHER IN PAST 24 HOURS	
Storm (Heavy Rain)	
Rain (Steady Rain)	
Showers (Intermittent Rain)	
Overcast	
Clear/Sunny	

WEATHER NOW	
Storm (Heavy Rain)	
Rain (Steady Rain)	
Showers (Intermittent Rain)	
Overcast	
Clear/Sunny	

HYDROLOGY

1. Water Sources to the Marsh: (Circle those that apply) Precipitation   Runoff   Freshwater Stream/River   Groundwater   Tidal Influence
2. Average Tidal Range During Year:
3. Tidal Restrictions (number and describe each one, including dimensions for tidal movement)

VEGETATION Note approximate abundance: N = Absent, R = Rare, C = Common, A = Abundant

VEGETATION - MARSH	
Salt Marsh Grasses	
Non-persistent Salt Marsh Plants	
Phragmites australis	
Scrub/Shrub Vegetation	

VEGETATION - STREAM	
Algae and Seaweed Attached to Banks	
Submerged Algae and Seaweed	
Floating Algae Mats	
Bare Substrate	

Evidence of Disturbance: ______________________________

Evidence of Eutrophication: ______________________________

ABUNDANCE OF FOOD FOR, AND PREDATORS OF, INVERTEBRATES

Note the approximate abundance:
N = Absent
R = Rare
C = Common
A = Abundant

FOOD / PREDATOR	
Green Slime on Banks	
Unattached Surface Floating Algae	
Attached Filamentous Algae and Other Seaweed	
Organic Detritus	
Soft-Stemmed Macrophytes	
Hard-Stemmed Macrophytes	
Macroinvertebrates	
Fish	

SEDIMENT TYPE AND QUALITY
Note approximate abundance and provide a short explanation if necessary.
N = Absent, R = Rare, C = Common, A = Abundant

SUBSTRATE TYPE	
Bedrock	
Boulders	
Cobble	
Gravel	
Sand	
Mud	
Peat	

SEDIMENT ODOR	
Normal	
Sewage	
Petroleum	
Sulfur	
Other	

Notes: ______________________

____

IMPACTS TO SALT MARSH
Check appropriate boxes and provide a short description.

FEATURE	check	DESCRIPTION
Drainage / Channelization		
Dredging		
Filling		
Bank Modification		
Bank Erosion and Slumping		
Vegetation Removal		
Invasive Species		
Dumping		
Hard Wall Structures		
Tracks through Marsh		
Recreational Activities		
Litter		
Other Impacts		

WATER QUALITY AND ODOR
Check boxes as appropriate, and provide a short explanation if necessary.

SUSPENDED MATERIAL	
None	
Algae	
Silt/Clay	
Fine Pariculate Organic Matter	
Other	

WATER ODOR	
Normal	
Sewage	
Petroleum	
Sulfur	
Other	

Evidence of Eutrophication and Other Notes:

WATER CHEMISTRY

		MEASUREMENT	
VARIABLE	STATION 1 at 0'	STATION 2 at 150'	STATION 3 at 300'
Depth			
Temperature			
pH			
Dissolved Oxygen			
Conductivity			
Salinity			
Total Dissolved Solids			
Color			

INVERTEBRATE SAMPLES RECORD CHECK

Preservative Used (type, concentration):

Did you complete labeling and seal bags tightly?

Station	Sample	Sample #
Station 1	D-Net	
	Auger	
Station 2	D-Net	
	Auger	
Station 3	D-Net	
	Auger	

SKETCH OF MARSH

Include: approximate scale, WEA shape and dimensions, location of streams, direction of coastline, ditches, restrictions, surrounding land uses (including roads and storm drains), north direction, and any other relevant information. Include a legend if useful. Indicate the three sampling stations.

QUADRAT SAMPLES RECORD SHEET

SITE #:

FAMILIES / GROUPS	STATION 1 at 0'	STATION 2 at 150'	STATION 3 at 300'
Amphipods			
Talitridae			
Other			
Isopods			
Oniscidae			
Other			
Mussels			
Mytilidae			
Barnacles			
Balanoidae			
Other			
Crabs			
Portunidae (Green)			
Ocypodidae (Fiddler)			
Other			
Snails			
Melampodidae (Marsh)			
Littorinidae (Periwinkle)			
Other			
Orthoptera (Grasshoppers)			
Delphacidae (Planthoppers)			
Collembola (Springtails)			
Aranea (Spiders)			
Acari (Mites)			
Diptera (Flies)			
Homoptera (Aphids, Leafhoppers)			
Other:			
Other:			
Other:			
Other:			
Other:			
Other:			

FORM 2: INVERTEBRATE SAMPLES RECORD CHECK

Project Name: ______________________________

Project Coordinator: ______________________ Coordinator Phone Number: ______________

Names and Phone Numbers of Volunteers:

Sample #	Collection Date	Site Name	Site #	Preserved & Labeled	Received Condition	Sorted (Initial/Date)	Sample Preserved & Labeled	Identified & Counted (Initial/Date)	Archive Location

FORM 3: INVERTEBRATE LABORATORY BENCH SHEET

Site Number: ______________________ Sample Number: ______________________

Technician: ______________________ Phone Number: ______________________

Date: ______________________

D-Net Number: ____________ Auger Number: ____________ Quadrat Number: ____________

PHYLUM/CLASS	ORDER	FAMILY	FG	TALLY	TOTAL
Turbellaria	-	-	DF		
Rhynchocoela	-	-	DF		
Nemertea	Heteronemertea	-	DF/PR		
	Other				
Sipunculoidea	Peanut Worms		DF		
Oligochaeta	Haplotaxida	Naididae	DF		
		Tubificidae	DF		
		Other			
Polychaeta	Capitellida	Arenicolidae	PR		
		Capitellidae	DF		
		Maldanidae	DF		
	Cossurida	Cossuridae	DF		
	Ctenodrilida	Parergodrilidae	DF		
	Eunicida	Arabellidae	DF		
		Dorvilleidae	OM		
		Eunicidae	DF/OM		
		Lumbrineridae	DF/SF		
		Other			
	Opheliida	Opheliidae	DF		
		Scalibregmidae	DF		
	Orbiniida	Orbiniidae	DF		
	Phyllodocida	Glyceridae	DF/PR		
		Goniadidae	PR		
		Hesionidae	DF/G		
		Nereidae	OM		
		Nephtyidae	PR		
		Phyllodocidae	DF/OM		
		Pisionidae	PR		
		Sigalionidae	DF		
		Syllidae	OM		
	Sabellida	Sabellidae	SF		
		Spirorbidae	SF		

PHYLUM/CLASS	ORDER	FAMILY	FG	TALLY	TOTAL
	Spionida	Spionidae	DF		
	Cirratulida	Cirratulidae	DF		
		Paraonidae	DF		
	Terebellida	Ampharetidae	DF		
		Terebellidae	DF		
	Unknown				
Cephalopoda		Loliginidae	PR		
		Ommastrephidae	PR		
Polyplacophora	Ischnochitonida	Chitonidae	G		
Gastropoda	Archaeogastropoda	Acmaeidae	G		
	Neogastropoda	Buccinidae	PR/DF/SF		
		Columbellidae	G		
		Nassariidae	G		
	Mesogastropoda	Calyptraeidae	SF/SC		
		Cerithiidae	G		
		Hydrobiidae	G		
		Lacunidae	G		
		Littorinidae	G		
	Basommatophora	Melampodidae	G		
	Nudibranchia	Elysiidae	PR		
		Polyceridae	PR		
Pelecypoda	Veneroida	Mesodesmatidae	SF		
		Tellinidae	SF/DF		
		Veneridae	SF		
(Bivalvia)	Myoida	Myidae	SF		
	Myoida	Pandoridae	SF		
	Mytiloida	Mytilidae	SF		
	Nuculoida	Nuculanidae	SF		
	Ostreoida	Ostreidae	SF		
	Ostreoida	Pectinidae	SF		
Echinoidea			DF/G		
Stelleroidea	Sea Stars		PR/G		
Holothuroidea	Sea Cucumbers		DF		
Hemichordata	Acorn Worm		SF/DF		
Crustacea	Decapoda	Crangonidae	DF/SC/PR		
		Hippolytidae	DF		
		Palaemonidae	DF/SC/PR		
		Pandalidae	DF		
		Penaeidae	DF		
		Cancridae	OM		

PHYLUM/CLASS	ORDER	FAMILY	FG	TALLY	TOTAL
		Hippidae	OM		
		Majidae	OM		
		Paguridae	SC		
		Pinnotheridae	OM		
		Portunidae	OM		
		Xanthidae	G		
		Other			
	Cirripedia	Balanoidae	SF		
	Amphipoda	Ampeliscidae	DF/SF		
		Ampithoidae	DF		
		Aoridae	DF		
		Calliopiidae	DF/SF		
		Gammaridae	DF/G		
		Haustoriidae	DF		
		Hyalidae	DF		
		Ischyroceridae	DF		
		Talitridae	DF		
	Isopoda	Idoteidae	DF		
		Janiridae	DF/PR		
		Limnoriidae	DF		
		Oniscidae	DF		
		Other			
	Tanaidacea	Leptocheliidae	DF		
	Cumacea		DF		
Insecta	Collembola		DF		
	Diptera	Chironomidae	DF/SF/PR		
		Culicidae	SF/PR		
		Tabanidae	PR		
	Hemiptera		PR/G		
	Homoptera		G/PR		
	Odonata		PR		
Acachnida	Araneae	Clubionidae	PR		
		Micryphantidae	PR		
		Salticidae	PR		
	Acari (Acarina)	Mites	PR		
Others					
Total Taxonomic Groups:				Total Number of Individuals:	

FORM 4: INVERTEBRATE DATA FORM

Site Number: ______________________ Salt Marsh: ______________________

Date Sampled: ______________________ Name(s): ______________________

Date of Lab Work: ______________________ ______________________

TAXA	FG	D1	D2	D3	$\bar{D}$	%
NEMERTEA (N)						
Heteronemertea	DF/PR					
Other						
				Subtotal N		
CAPITELLIDA (C)						
Arenicolidae	PR					
Capitellidae	DF					
Others						
				Subtotal C		
COSSURIDA (CO)						
Cossuridae	DF					
Other						
				Subtotal CO		
CTENODRILLA (CT)						
Parergodrillidae	DF					
Others						
				Subtotal CT		
EUNICIDA (E)						
Arabellidae	DF					
Dorvilleidae	OM					
Lumbrineridae	DF/SF					
Onuphidae	PR					
Others						
				Subtotal E		
ORBINIIDA (O)						
Orbiniidae	DF					
Paraonidae	DF					
				Subtotal O		

TAXA	FG	D1	D2	D3	$\bar{D}$	%
SABELLIDA (S)						
Sabellidae	SF					
Other						
				Subtotal S		
SPIONIDA (SP)						
Spionidae	DF					
Other						
				Subtotal SP		
OPHELIIDA (OP)						
Opheliidae	DF					
				Subtotal OP		
PHYLLODOCIDA (P)						
Glyceridae	PR/DF					
Goniadidae	PR					
Hesionidae	DF/G					
Nereidae	OM					
Nephtyidae	PR					
Phyllodocidae	DF/OM					
Polynoidae	PR/SF					
Sigalionidae	DF					
Syllidae	OM					
Other						
				Subtotal P		
TEREBELLIDA (TE)						
Terebellidae	DF					
Ampharetidae	DF					
				Subtotal TE		

TAXA	FG	D1	D2	D3	$\bar{D}$	%
UNKNOWN POLYCHAETA (UP)						
Unknown						
				Subtotal UP		
AMPHIPODA (A)						
Ampithoidae	SF					
Caprellidae	SF					
Gammaridae	SF/G					
Hyalidae	SF					
Ingolfielidae	SF					
Ischyroceridae	SF					
Talitridae	SF					
Other						
				Subtotal A		
TANAIDACEA (T)						
Leptocheliidae	DF					
				Subtotal T		
GASTROPODA (G)						
Acteonidae						
Cerithiidae	G					
Columbellidae	G					
Hydrobiidae	DF					
Littorinidae	G					
Melampodidae	G					
Nassariidae	G					
Other						
				Subtotal G		
DECAPODA - Shrimps (DS)						
Crangonidae	DF/SC/PR					
Hippolytidae	DF					
Palaemonidae	DF/SC/C					
Pandalidae	DF					
Penaeidae	DF					
Other	DF					
				Subtotal DS		

TAXA	FG	D1	D2	D3	$\bar{D}$	%
DECAPODA - Crabs (DC)						
Cancridae	OM					
Majidae	OM					
Xanthidae	SF					
Other						
				Subtotal DC		
ISOPODA (I)						
Idoteidae	DF/C					
Janiridae	DF/SC					
Limnoriidae	DF					
Other						
				Subtotal I		
PELECYPODA (PE)						
Mesodesmatidae	SF					
Myidae	SF					
Mytilidae	SF					
Nuculanidae	SF					
Tellinidae	SF/DF					
Veneridae	SF					
Other						
				Subtotal PE		
OTHER GROUPS (OG)						
Cumacea	DF					
Echinodermata	DF					
Insecta	Mixed					
Acarina	PR					
Aranea	PR					
Merostomata	PR					
Nudibranchia	PR					
Oligochaeta	DF					
Polyplacophora	G					
Turbellaria	SF					
Urochordata	SF					
Other						
				Subtotal OG		

PERCENT COMPOSITION OF MAJOR GROUPS

SUBTOTALS	NUMBER	PERCENT
Subtotal N		
Subtotal C		
Subtotal CO		
Subtotal CT		
Subtotal E		
Subtotal O		
Subtotal S		
Subtotal SP		
Subtotal OP		
Subtotal P		
Subtotal TE		
Subtotal UP		
Subtotal A		
Subtotal T		
Subtotal G		
Subtotal DS		
Subtotal DC		
Subtotal I		
Subtotal PE		
Subtotal OG		
TOTAL		

PERCENT COMPOSITION OF MAJOR FEEDING GROUPS

FEEDING GROUP	PERCENT
Predator (PR)	
Deposit Feeder (DF)	
Grazer (G)	
Omnivore (OM)	
Scavenger (SC)	
Suspension Feeder (SF)	
Mixed	
TOTAL	

PERCENT INVASIVE SPECIES

SPECIES	PERCENT
Littorina littorea	
Palaemon macrodoctylus	
Hemigrapsus sanguineus	
Carcinus maenas	
TOTAL	

PERCENT INSECTS, SPIDERS, MITES

GROUP	PERCENT
Insects (Insecta)	
Spiders (Aranea)	
Mites (Acarina)	
TOTAL	

SUMMARY

Average Number of Organisms	
Taxonomic Richness	
% Contribution of Dominant Taxonomic Group	
% Contribution of Dominant Feeding Group	
% Insects, Spiders, and Mites	

FORM 5: HABITAT ASSESSMENT SCORE SHEET

Site Number:

Site Name:

Form Completed by: Phone:

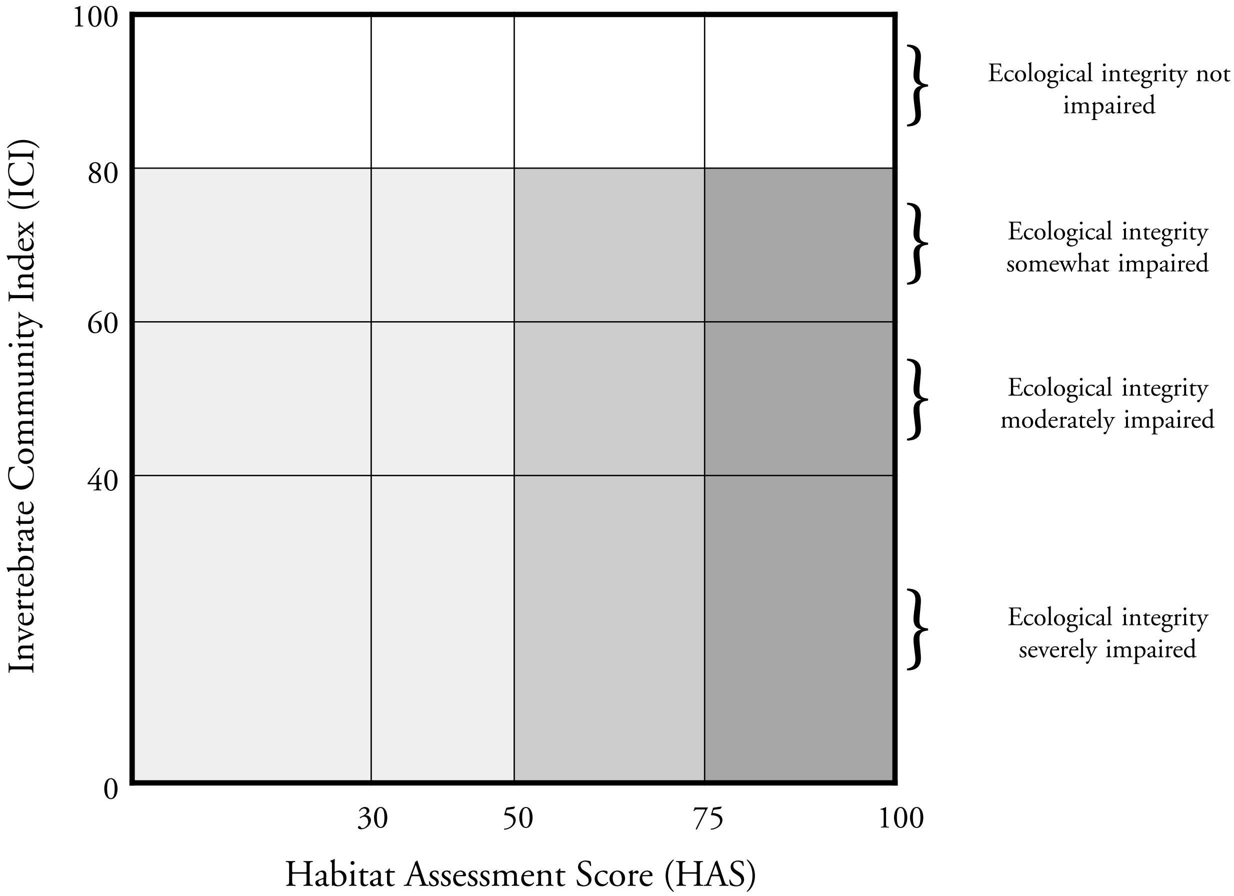
Use the range from 0-5 to score each condition. Half numbers (e.g. 3.5) are permissible).

INDICATOR	4 - 5	2 - 3	0 - 1	SCORE
Size of estuarine salt marsh	Larger than 20 acres (8 hectares)	Between 20 and 4 acres (8 -1.6 hectares)	Less than 4 acres (1.6 hectare)	
Tidal flushing	Natural tidal surges are unimpeded	Some modification to natural fluctuation	Salt marsh cut off from normal tidal fluctuation	
Outlet restriction	No outlet restriction	Outlet restriction between 30' and 5'	Outlet restriction < 5'	
Erosion of banks	Normal estuarine bank erosion with little slumping	Some evidence of accelerated bank erosion; slumping in progress	Severe bank erosion; slumping is common, stream widening occurring	
Vegetation cover	Even and complete vegetation cover of salt marsh	Some patches of exposed ground evident	Large areas of marsh are unvegetated	
100' vegetated wetland buffer	> 80%	80-40%	40%	
Nature of substrate within estuarine stream	Composed of a mixture of substrates: sand, silt, mud, and organic matter present	Mixture of two types of substrate	Predominantly one substrate type	
Evidence of freshwater intrusion	No evidence of fresh-water intrusion (Specific Conductivity > 5,000)	Some evidence of fresh-water intrusion (Specific Conductivity between 5,000 and 800)	Conductivity below 800, or little or no evidence of salt water	
Food sources for invertebrates*	Abundance of aquatic macrophytes, attached macro-algae, periphyton, CPOM and FPOM	Some attached algae and periphyton with CPOM and FPOM	No aquatic macrophytes, attached algae, or periphyton; only some CPOM and FPOM	
Degree of impact from human activities**	No human impact evident	Low to medium level with minimal impact	High level with marsh severely degraded	
			TOTAL SCORE	
			PERCENT SCORE [(TOTAL SCORE / 50) x 100]	

* CPOM = Coarse particulate organic matter, FPOM = Fine Particulate Organic Matter

** Disturbance from fishing, swimming, boating, trails, roads, vegetation removal, ditching, shoreline modification, solid waste dumping, etc.

Form 6: ICI and HAS Summary Graph



Legend	
(light shading)	Condition due primarily to poor habitat
(medium shading)	Condition due to poor habitat and other stressors
(dark shading)	Condition due to stressors other than poor habitat

chapter six

FISHES AND CRABS

Salt marshes support diverse and abundant **populations** of creatures that swim; these organisms are collectively called **nekton** and include fishes and many types of **invertebrates**. This chapter focuses on fishes and crabs that occupy estuarine **wetlands**. Salt marshes support most life stages of fishes 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. Mummichogs and fourspine sticklebacks are two species that reside in marshes throughout their lives and contribute to the environmental condition of near shore environments. 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 the Atlantic silverside, and commercial and sport species such as winter flounder and blue crab.

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 fishes 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 (Burdick et al. 1999).

Scientists do not fully understand the influence of marsh degradation on fishes 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.

This chapter provides volunteer monitors with the tools and instructions necessary to monitor the presence and relative abundance of fishes and crabs in submerged salt marsh habitats, and investigate differences between different sites. Submerged salt marsh habitats include tidal creeks, channels, near shore embayments, and salt ponds that are completely underwater during all tidal cycles (or during the majority of low tide). This chapter does not provide instructions for **monitoring** high marsh habitats, which requires different methods and equipment.

EQUIPMENT

There are a variety of equipment and methods used to collect salt marsh fishes and crabs, each suitable for different conditions, habitats, and target organisms. This chapter describes the equipment and methods required to use minnow traps and bag seines. Table 1 lists the equipment

TABLE 1. EQUIPMENT FOR NEKTON SAMPLING

ITEM	PURPOSE	DESCRIPTION
6 Minnow Traps	Collect creatures	Wire mesh traps
Two Seines Bag seine Stop Net	Bag seine catches fishes and crabs Stop net hinders fishes and crabs from escaping in front of seine	Bag seine: 4' (height) x 6' (width) Stop Net: 4'(height) x 4' (width)
Picking Nets (fine net)	Sub-sample and weigh fish	Standard aquarium net
Fish Measuring Board	Measure fish and crabs (length)	Metric ruler on board (millimeters)
Scale	Measure fish and crabs (weight)	Spring-loaded scale (grams)
3 five gallon buckets	Store and process samples	
Water quality instrument	Measure water quality parameters (temperature, salinity, and dissolved oxygen)	Example: YSI multi-parameter instrument (expensive; efficient) or chemical water test kits (inexpensive; time consuming)
Ethyl alcohol solution 70%	Preserve specimens	
Polypropylene bottle	Container for preserved creatures	Jar with water-tight lid
Chest waders and/or Neoprene boots	Walking through the marsh	
Clipboard, data sheets, pencil	Organize and collect field data	
Fish identification guides	Identify creatures in the field	Example: Peterson's Field Guide to Atlantic Coast Fishes

you will need for both methods and general equipment that you will need regardless of the method you use. The following section, "Sampling Methods," describes and compares different methodology for collecting fishes and crabs in estuarine wetlands.

SAMPLING METHODS

The goals and objectives of your study should dictate your sampling methods. Project leaders should examine a variety of methods that will effectively achieve monitoring objectives. One method will not characterize the entire fish and crab **community** or populations, rather a combination of methods are used to sample particular marsh habitats. Initially, 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 (Burdick et al. 1999). **Quantitative** estimates are possible as volunteers gain experience with salt marsh sampling. Innovative ideas for sampling fishes and crabs are encouraged because of the variety of organisms that are encountered and the variety of environmental conditions that exist within and between evaluation areas.

Table 2 lists the advantages and disadvantages of different types of equipment and methods. Equipment and sampling methods will influence the amount of area that can be sampled, the ease of taking multiple samples at different locations or dates, **catch efficiency** (the success of collecting species in an area), and **catch stability** (the success of collecting species at different locations or times). Rozas and Minello (1997) present a discussion of the relative merits of different sampling gear.

This manual recommends the use of minnow traps and haul seines. Minnow traps and haul seines are effective for collecting fishes and crabs and are widely used in marsh monitoring because they are easy to deploy and retrieve,

Caution!

Salt marshes can present a variety of challenges that affect seine efficiency. It is difficult to seine creeks that are deep or have a strong current, and can be dangerous for volunteers. In potentially dangerous situations, samples should be collected when conditions are less severe, or not at all.

TABLE 2. ADVANTAGES AND DISADVANTAGES OF DIFFERENT SAMPLING METHODS

GEAR TYPE	ADVANTAGE	DISADVANTAGE
Enclosures Throw Traps Lift Nets	Collect from known area Can yield quantitative data Can be used in a variety of habitats Will collect many species	Variable catch efficiency Awkward to throw Difficult sampling fishes in trap High initial construction time High maintenance
Passive Traps Minnow Traps Breder Traps	Will collect common marsh species Easy to deploy and retrieve Easy to collect multiple samples Only need two people Inexpensive	Collect from unknown area Only yields qualitative data Will not collect all species CPUE highly variable with minnow traps
Towed Nets Bag Seine Otter Trawl	Collect from known area Can yield quantitative data Will collect many species	Variable catch efficiency High initial cost High maintenance and labor intensive

sampling is repeatable, and start-up cost is relatively low. Minnow traps are easy to use, and catch efficiency can be stable if traps are placed in appropriate locations. Minnow traps will effectively catch killifishes (such as mummichogs) and lower numbers of other resident and transient species (such as sticklebacks and American eel). Catch stability is low with seines, but seines can capture a variety of fish and crab species in a sample area. Both techniques are easy to learn, and as volunteers become more familiar with the gear, catch efficiency and stability will increase.

Fishes and crabs can be sampled year-round, but this manual recommends June to September. Greater collection frequency improves the rigor of the data. Tidal stage and water level influence catch efficiency and species presence, so all sampling should occur at similar tidal stages or tidal cycles. Once you select **sample stations**, you should mark their locations with stakes or flagging, or record their position using high-accuracy **GPS** receivers (such as differential GPS). Use the same sample stations for the duration of the study to reduce variability in fish and crab communities caused by small-scale variability of habitat conditions. The following section describes the steps in collecting minnow trap samples and haul seine samples.

Collecting Minnow Trap Samples

1. You will need a total of six minnow traps for each sampling date — three for the study site and three for the reference site.
2. Place three minnow traps in the study and reference area (six total traps). The traps are equally spaced along the study and reference gradient; that is, for a 100 meter stretch, traps are located at 0m, 50m, and 100m.
3. Position the traps at the edge of the tidal creek, and be sure that they are completely submerged at low tide.
4. Place weight (rocks work well) in the traps so they will sink and remain on the bottom.
5. Deploy minnow traps for a specific tidal cycle (i.e., low tide to high tide or low tide to low tide). The soak time (hours in the water) corresponds to the tidal cycle and standardizes catches to time. Do not leave traps in the water if water subsides below trap at low tide.
6. Retrieve the traps and empty individual traps into individual buckets of water.
7. Process the sample (see below).
8. Take water quality readings at deployment and retrieval (see below).

Collecting Bag Seine Samples

1. You will collect six seine samples for each sampling date — three for the study site and three for the reference site.
2. Seine stations are equally spaced along the reference and study tidal creek. Identify the stretch of creek to survey and fix study and reference stations. Do not overlap stations.
3. Collect seine samples at the same tidal stage. Take samples during a moving tide (i.e., flood or ebb). This reduces the effects of tide on the composition and relative abundance of fishes and stabilizes seine efficiency.

4. Seining requires a minimum of three people. One person handles the stop net and two people handle the seine.
5. Make sure that sufficient weights are attached to the bottom of the seine so that the net drags along the bottom.
6. Place the stop net at the upstream end of your sample location.
7. Begin seining 10 meters downstream from the stop net and pull the seine upstream toward the stop net.
8. Haul the seine onto the marsh surface (out of the creek). Grab the bottom line to prevent creatures from escaping under the net as you pull the net out of the creek.
9. Place fishes and crabs from the bag seine into a bucket of water.
10. Process the sample (see below).
11. Take water quality readings prior to each seine (see below).

Sample Processing & Water Quality Measurements

Follow these steps for both the minnow trap samples and bag seine samples. However, if you collect large numbers (>40) of particular species you should also follow the sub-sampling procedure outlined below.

1. For each sample, identify all fishes and crabs to species and count the numbers of each species.
2. Measure length of each organism to the nearest millimeter. You should measure standard length (SL) of fish and carapace length of crabs (CL) (Figure 1).
3. Weigh each species to nearest gram. For example, if you have 10 blue crabs then you would weigh all 10 together to determine the **aggregate weight**.
4. Note any external abnormalities, such as **skin lesions** or **parasites**.
5. Return creatures to the water as soon as possible to limit mortality.

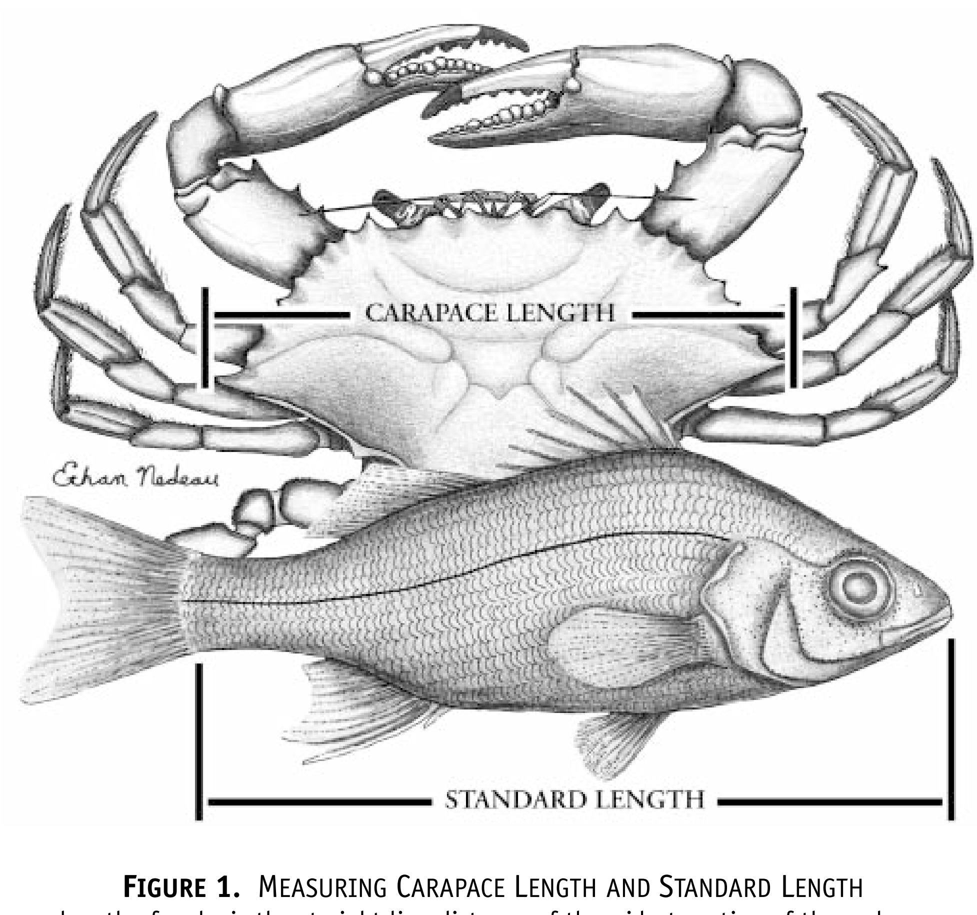


FIGURE 1. MEASURING CARAPACE LENGTH AND STANDARD LENGTH
Carapace length of crabs is the straight line distance of the widest portion of the crab carapace, as shown. Standard length of fish is the straight line distance from the tip of the snout to the posterior end of the vertebral column, as shown.

6. Collect water quality information (i.e., water temperature, salinity, and dissolved oxygen) at deployment and retrieval of traps and prior to seine samples.
7. If you have the equipment and resources, you may decide to collect additional water quality **parameters** such as pH and turbidity.

Sub-Sampling Procedure

Use this procedure if you collect greater than 40 individuals of any particular species. **Sub-samples** are a small but representative number of individuals randomly selected from a larger sample. It is important that the sub-sample is representative of the entire sample; that is, the length range of the species is represented in the sub-sample. Sub-sampling reduces processing time of large catches.

1. Separate the entire sample by species. Put species collected in large numbers in separate buckets.
2. Use the net to randomly capture 40 fish from the bucket containing the entire individual species catch.
3. You need to measure at least 40 individuals of any species that you sub-sample.
4. Weigh the entire sample of a particular species (not the sub-sample), and weigh the sub-sample. Note the sub-sample weight on the data sheet.
5. The proportion of sub-sample weight to total weight is used as an expansion factor. The expansion factor is the calculation derived from the sub-sample to the entire sample (i.e., a sub-sample of 40 fish weighs 10g; entire sample weighs 20 g; 10g to 20g is an expansion factor of 2; length measurements and relative abundance is doubled from the sub-sample).

Identification & Taxonomy

Excellent identification references include Bigelow and Schroeder 1953, Robins and Ray 1986, Weiss 1995, Murdy et al. 1997, and Pollock 1998. The volunteer coordinator should be familiar with common species to demonstrate distinguishing characteristics to volunteers. Table 3 lists fish and crab species commonly encountered in New England salt marshes, and provides information about habitat use and environmental preferences. Figure 2 shows important morphological characteristics that you will need to identify fish.

DATA ENTRY

Investigators should use a separate field data sheet for each sample. If groups use both minnow traps and bag seines, they will need 12 field data sheets per sample date (2 methods x 3 samples per method x 2 evaluation areas). The standard field data sheet is organized to clearly distinguish study sites, sampling stations, and individual samples. A blank

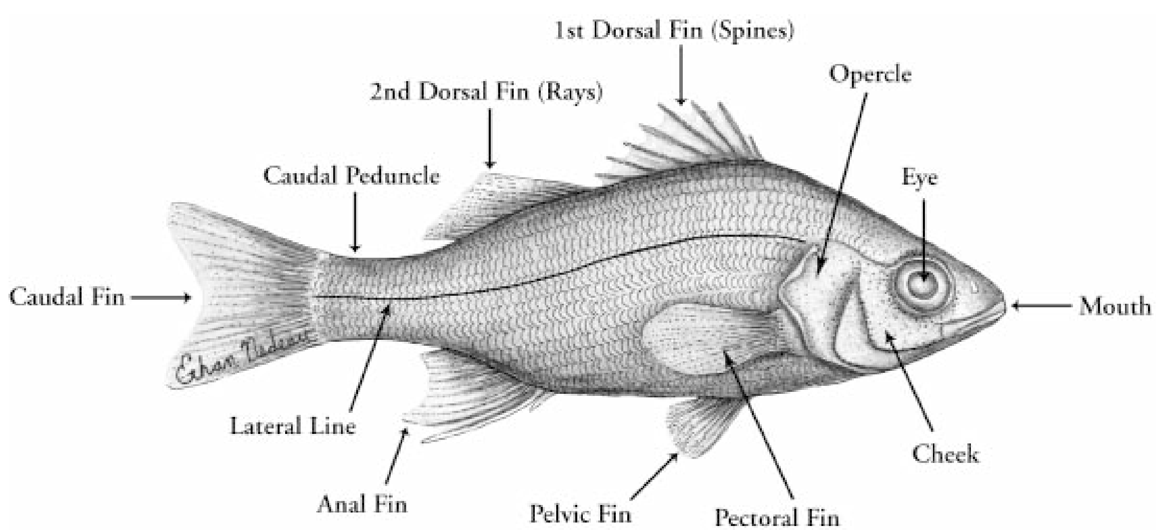


FIGURE 2. IMPORTANT MORPHOLOGICAL CHARACTERISTICS USED TO IDENTIFY FISH

TABLE 3. COMMON SALT MARSH FISHES AND CRABS AND IMPORTANT TRAITS
Abbreviations: RES = Resident, TRA = Transient, FRE = Freshwater, BRA = Brackish, MAR = Marine, ANA = Anadromous, CAT = Catadromous.

		Species Traits						
Common Name	**Scientific Name**	**RES**	**TRA**	**FRE**	**BRA**	**MAR**	**ANA**	**CAT**
Alewife	*Alosa pseudoharengus*		X	X	X	X	X	
American eel	*Anguilla rostrata*		X	X	X	X		X
American shad	*Alosa sapidisssima*		X	X	X	X	X	
Atlantic herring	*Clupea harengus*		X	X	X	X		
Atlantic silverside	*Menidia menidia*		X			X		
Atlantic tomcod	*Microgadus tomcod*		X	X	X	X		X
Blackspotted stickleback	*Gasterosteus wheatlandii*		X		X	X		
Blue crab	*Callinectes sapidus*		X		X	X		
Blueback herring	*Alosa aestivalis*		X	X	X	X	X	
Fourspine stickleback	*Apeltes quadracus*	X		X	X	X		
Green crab	*Carcinus maenas*	X			X	X		
Mummichog	*Fundulus heteroclitus*	X		X	X	X		
Ninespine stickleback	*Pungitius pungitius*		X		X	X		
Northern pipefish	*Syngnathus fuscus*		X		X	X		
Rainbow smelt	*Osmerus mordax*		X	X	X	X	X	
Rainwater killifish	*Luciana parva*	X		X	X			
Rock gunnel	*Pholis gunnelus*		X			X		
Sheepshead minnow	*Cyprinodon variegatus*	X		X	X	X		
Striped killifish	*Fundulus majalis*	X		X	X	X		
Sunfishes	*Lepomis spp.*		X	X				
Threespine stickleback	*Gasterosteus aculeatus*		X	X	X	X		
White mullet	*Mugil curema*		X	X	X			
White perch	*Morone americanus*		X	X	X		X	
Winter flounder	*Pseudopleuronectes americanus*		X		X	X		

standard field data sheet is provided in Appendix 1 of this chapter. Volunteers should follow the format provided in this manual, though project leaders can modify data sheets according to their specific needs.

On every field sheet it is extremely important to record exactly where, how, and when the samples were collected. The field sheet also contains all field measurements and site-specific environmental conditions. Investigators should neatly and thoroughly fill out field forms to ensure that no critical information is omitted. It is always frustrating to return to the office or laboratory after a long day in the field and realize that you forgot to record important information!

In the office, investigators should transfer information on field data sheets into a computer spreadsheet such as Microsoft Excel. An example of a typical spreadsheet is provided in Table 4. As with the field data sheets, you can customize the spreadsheet according to the specific requirements of your project.

TABLE 4. EXAMPLE DATA ENTRY SPREADSHEET

The top portion is for site data, physical data, and chemical data. The bottom portion is for biological data. This table only shows biological data for Station 0 at the reference site, and a complete spreadsheet would be longer to include both trap and seine samples from three stations at the study site and reference site.

Date	Site	Area	Station	Time	Tide	Temp (C)	Sal (ppt)	DO (mg/l)	pH	Depth (m)	Substrate
6-Jul-00	FH	Ref	0	1030	1	24	28	6.8	7.4	1.4	Soft Mud
6-Jul-00	FH	Ref	50	1040	1	24	27	6.8	7	1.1	Soft Mud
6-Jul-00	FH	Ref	100	1050	1	24	28	6.8	7.4	0.8	Soft Mud
6-Jul-00	FH	Study	0	1100	1	25	24	4.5	6.8	1.2	Soft Mud
6-Jul-00	FH	Study	50	1110	1	24	20	3.8	6.7	1	Soft Mud
6-Jul-00	FH	Study	100	1120	1	26	22	4.4	6.7	1.3	Soft Mud

							Species Traits						
Area	Station	Sample	Species	SL (mm)	Weight (g)	Abnormality	RES	TRA	FRE	BRA	MAR	ANA	CAT
Ref	0	Trap	Threespine Stickleback				0	1	1	1	1	0	0
Ref	0	Trap	Mummichog				1	0	1	1	1	0	0
Ref	0	Trap	Mummichog				1	0	1	1	1	0	0
Ref	0	Trap	Mummichog				1	0	1	1	1	0	0
Ref	0	Seine	Atlantic Silverside				0	1	0	0	1	0	0
Ref	0	Seine	Atlantic Silverside				0	1	0	0	1	0	0
Ref	0	Seine	Atlantic Silverside				0	1	0	0	1	0	0
Ref	0	Seine	Blueback Herring				0	1	1	1	1	1	0

Data Analysis and Comparison

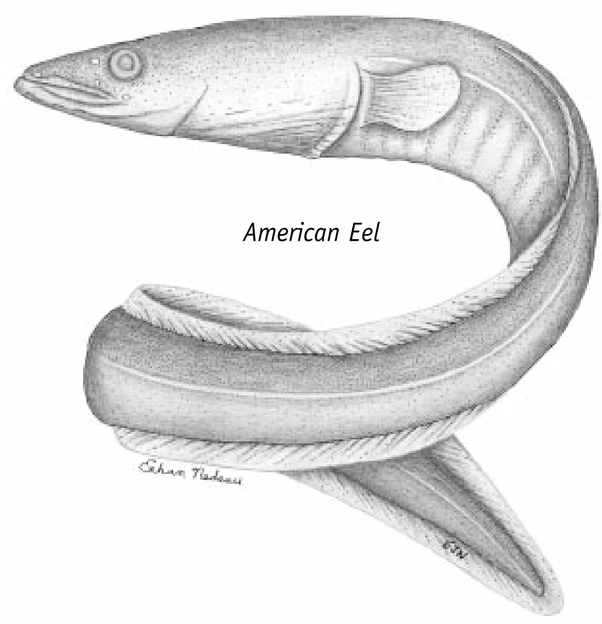
Relative abundance, biomass, species composition, species richness, life history characteristics, and fish condition are **variables** that describe the composition and quality of fish and crab communities. A short description of each variable along with instructions on how to compute these variables from your data is provided below. These variables can be important indicators of wetland condition, but generally only if the data is collected using a rigorous sample design that includes multiple samples taken over space (replicate samples within a marsh or across several marshes) and time (replicate samples at different seasons and years). This chapter provides the means to describe fish and crab communities, identify communities that are potentially impaired, and compare study sites and reference sites.

The methods described in this chapter will not allow investigators to estimate population size, or completely characterize a fish or crab community. This is because environmental conditions vary tremendously over time and space, and in order to completely quantify and characterize the biological community you would have to collect a large number of samples using several different methods during several consecutive years. Although the goal of most monitoring projects is to understand the effects of human influence on salt marshes, volunteers should understand that it is difficult — but not impossible — to collect rigorous and meaningful data on fish and crab communities. Pay attention to sampling details, such as trap location and tidal stage, and monitoring data will improve the description of the salt marsh community and provide the means to evaluate human impacts.

Relative Abundance

Relative abundance is used to compare **catch per unit effort** (CPUE) between sites. CPUE is a standardized catch (number or weight of organisms) for a sample. Since the number of organisms captured will depend on seine haul length or minnow trap soak time, volunteers must standardize catches so that different samples are comparable. One way to standardize samples is to define start/end points of seine samples and deployment/retrieval times of minnow traps.

- Bag Seine CPUE: # Organisms per 10-Meter Haul



American Eel

- Minnow trap CPUE: #Organisms per Trap (given equal soak time)

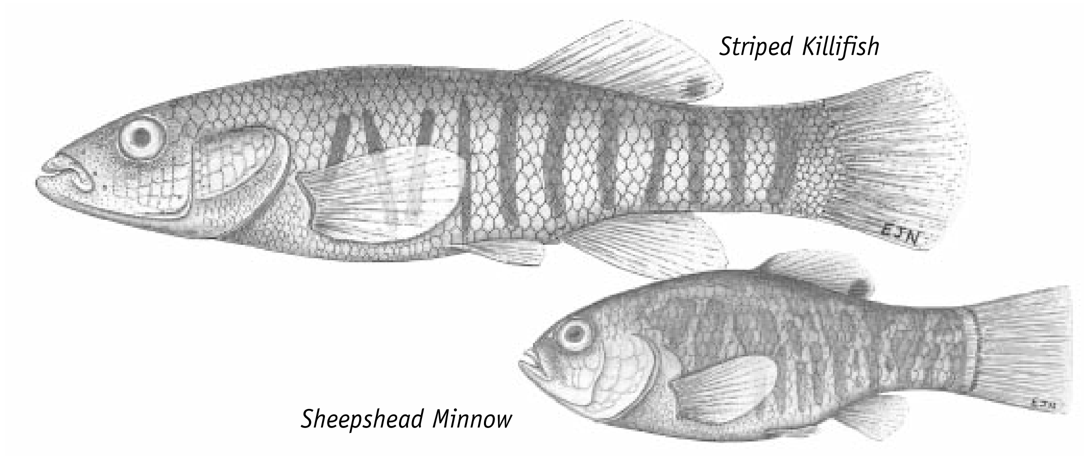
Relative abundance is the average CPUE in a sample area, which is either the study site or the reference site. The average (or mean) is the sum of all organisms in a sample divided by the sum of the number of samples. Volunteers can use relative abundance to make a variety of comparisons, including:

- Total number of fishes for study site and reference site samples.
- Total crabs for marsh, study, and reference samples.
- Species of interest for marsh, study, and reference samples.

In addition to computing average values, it may be useful to examine data variability within each site. For instance, in Table 5 the average relative abundance of

Table 5. Relative Abundance Example

	Study Site		Reference Site	
Station	**Seine**	**Trap**	**Seine**	**Trap**
0	34.0	12.0	256.0	11.0
50	68.0	3.0	61.0	17.0
100	41.0	34.0	44.0	23.0
Total	143.0	49.0	361.0	51.0
Average	47.7	16.3	120.3	17.0



organisms caught using bag seines is almost 2.5X higher in the reference site than the study site, yet the large number of organisms caught in Sample 1 accounts for virtually all of this difference. Sample 1 may contain a large number of schooling fish (e.g., blueback herring). The schooling fish may be collected in one sample or quickly move out of the sample area after the first sample. Volunteers should note the large difference between the study site and reference site and attempt to explain the difference. Overall, higher relative abundance usually indicates favorable conditions. Volunteers should also look at the relative abundance of **taxa** that are reliable indicators of environmental conditions, invasive species, or other taxa of interest.

Biomass

Biomass is the combined weight of all creatures or weight of a species in a sample. The justification, computation, and analysis for biomass are identical to that for relative abundance. The reason that scientists compute both relative abundance and biomass is because organisms and life history stages have vastly different biomass, and the number of individuals may not reflect the overall importance of a species in a community. Consider this example: you collect 1000 juvenile Atlantic silversides in a sample and the aggregate weight is eight grams. In the same sample, you collect 10 American eel with an aggregate weight of 80 grams. If you only computed relative abundance, you would conclude that Atlantic silverside are extremely important because they are 100X more abundant than American eel. However, the eel biomass is 10X greater than silverside biomass in the sample. Collectively, relative abundance and biomass provide a good overall indication of the size and composition of a community.

Species Richness

Species richness is the number of species collected in a sample area. Calculate species richness for the salt marsh, study, and reference area. Salt marsh quality may be related to species richness. High species richness may indicate a diversity of habitat features and valuable habitat quality.

Community Composition

It is important to know what species comprise a community because the environmental tolerance, life history traits, and ecology of different species provide clues about salt marsh condition. The list of common salt marsh fishes and crabs in Table 3 lists some important traits of each taxa that volunteers can use to determine community composition. Table 6 provides an example of how to display community composition data. The percent composition of different groups or species in a sample is computed using the following formula:

% Composition of Species A =
(# of Species A in Sample / # of Individuals in Entire Sample) x 100

Volunteer groups may be interested in determining the percent composition of several different species or species groups. Some useful species groups are defined by their environmental tolerance, such as freshwater species,

TABLE 6. COMMUNITY COMPOSITION EXAMPLE

Abbreviations for the column "Residency" are: RES = Resident and TRA = Transient. Abbreviations for the column "Tolerance" are: F = Freshwater, B = Brackish, M = Marine, C = Catadromous, A = Anadromous.

SPECIES	RESIDENCY	TOLERANCE	STUDY SITE NUMBER	STUDY SITE PERCENT	REFERENCE SITE NUMBER	REFERENCE SITE PERCENT
Mummichog	RES	F, B, M	170	88.5	224	54.4
Atlantic silverside	TRA	M	5	2.6	115	27.9
American eel	TRA	C	6	3.1	15	3.6
Threespine stickleback	RES	F, B, M	11	5.7	30	7.3
Blueback herring	TRA	A	0	0.0	28	6.8
		Total	192	100	412	100

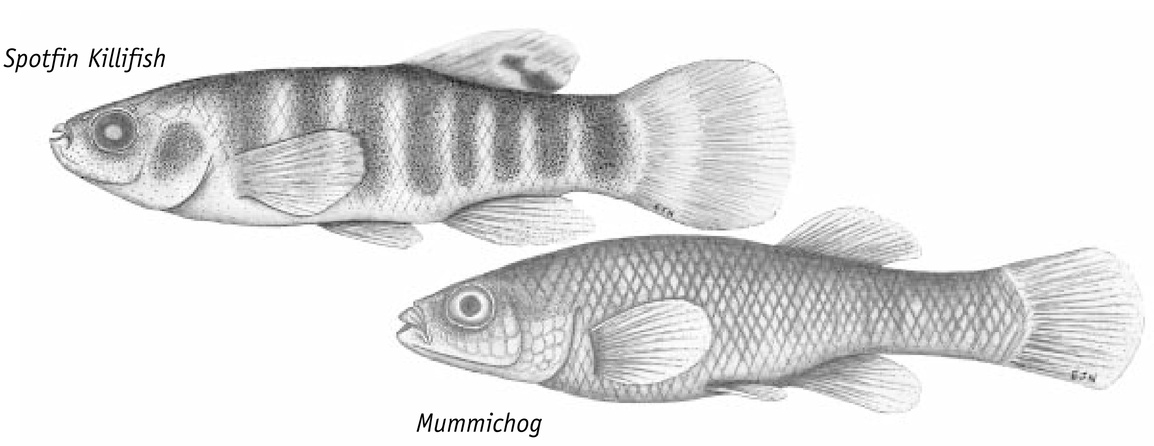
brackish species, or marine species. A change in the percent composition of these groups may provide clues about tidal restrictions, altered salinity regimes, or freshwater intrusion. Other species groups include marsh residents or transient species. In addition, project leaders may examine the percent composition of other species or groups according to the particular needs of their study.

Life History Characteristics

Fish and crab size (i.e., SL and CL) indicates how different life stages use salt marshes. Certain fish species inhabit marshes during juvenile, adult, or spawning stages. The presence of juvenile fishes, for example, indicates that a marsh is functioning as a nursery. A large size range of a particular species usually indicates that the species exists in the marsh for its entire life cycle, whereas a narrow size range usually indicates that the species only uses the marsh for a portion of its life cycle. Marshes that support the development of a species from egg to spawning adult are usually considered healthy and productive.

TABLE 7. LIFE STAGE (STANDARD LENGTH) EXAMPLE

SPECIES	SL AVERAGE (mm) STUDY	SL AVERAGE (mm) REF	SL RANGE (mm) STUDY	SL RANGE (mm) REF
Atlantic silverside	56.7	58.0	15 - 76	20 - 76
Striped killifish	44.2	45.2	13 - 55	15 - 62
Mummichog	39.2	45.6	25 - 47	9.0 - 65
American eel	85.5	95.8	70 - 96	68 - 110
Blue crab (CL)	59.8	75.8	13 - 125	65 - 80
Green crab (CL)	49.8	50.4	14 - 68	14 - 72



LENGTH CLASS (mm)	STUDY	REFERENCE
10 to 40	10	5
41 to 70	50	20
71 to 100	45	25
101 to 130	5	1

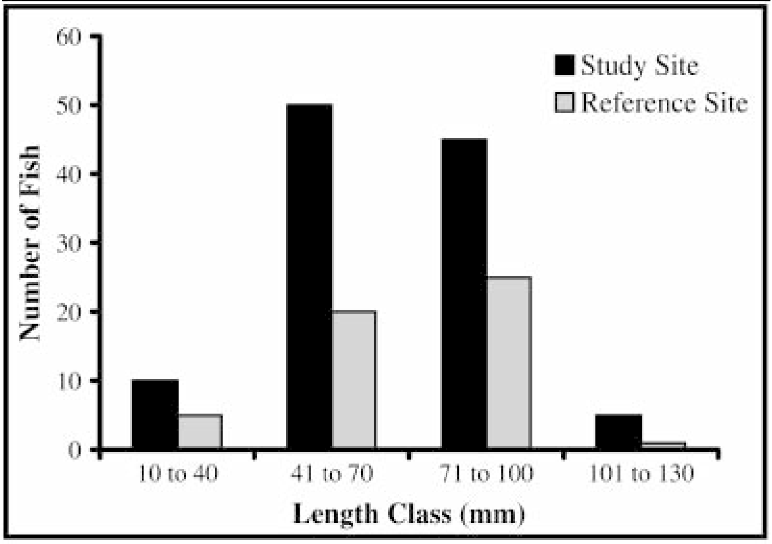


FIGURE 3. LENGTH FREQUENCY EXAMPLE

Volunteers should compute the average, range, and frequency distribution of SL (fish) and CL (crabs) to represent life history characteristics of the community. Volunteers should compute statistics for individual species (not the entire sample) and should first combine the data into two groups: the reference site and study site. Table 7 shows example data for SL averages and ranges, and Figure 3 shows a table and bar graph of frequency distribution.

Fish Condition

The presence of abnormalities, such as parasites, skin lesions, **fin rot**, and **mutation**, may indicate degraded environmental conditions. Volunteers should record the presence and type of abnormality on each species and include this information with their report. A simple table resembling Table 8 is suitable for this purpose.

TABLE 8. FISH CONDITION EXAMPLE

SPECIES	TYPE OF ABNORMALITY	% INDIVIDUALS WITH ABNORMALITY	% SPECIES WITH ABNORMALITY
Striped killifish	Fin Rot	6	6.5
	Lesions	13	14.0
Mummichog	Lesions	4	8.9
Sheepshead minnow	Lesions	7	29.2
Total Number of Fish with Abnormalities: 30			
Percent of Fish Community with Abnormalities: 7%			

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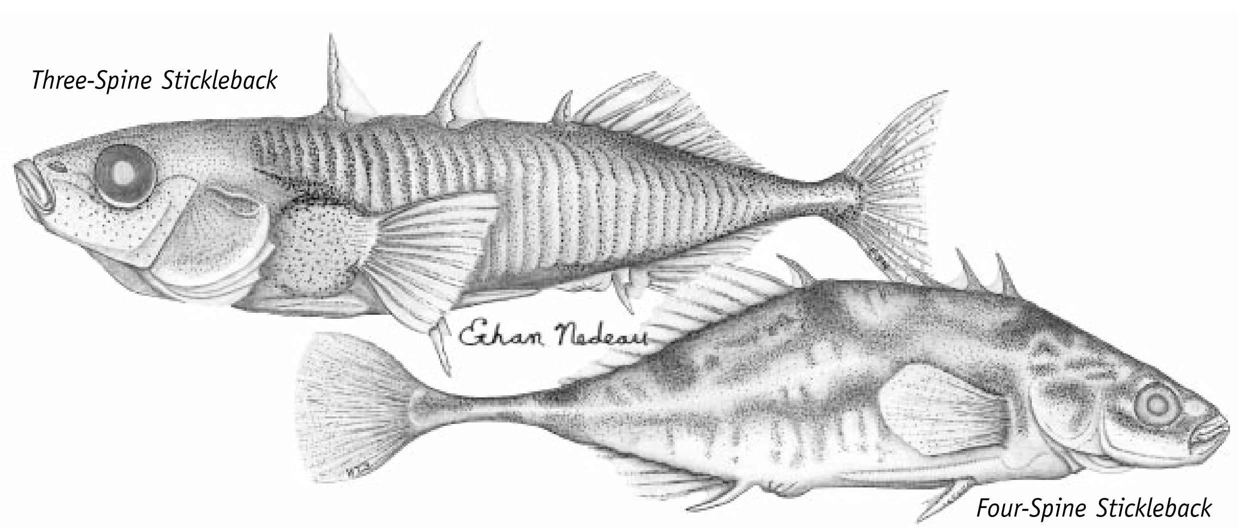
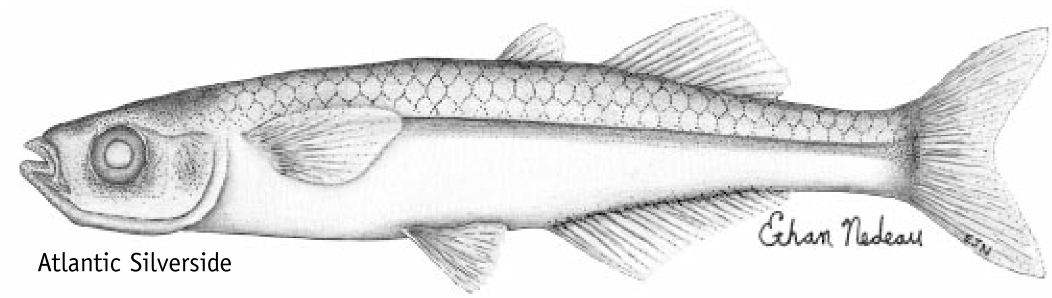


chapter six

APPENDICES

APPENDIX 1. NEKTON SURVEY FIELD SHEET



Atlantic Silverside

NOTES

NEKTON SURVEY FIELD SHEET

Project: ______________________________

Collectors: ______________________________

Date: ______________ Time: ______________

Sample ID#: ______________ Station: ______________

Method: ______________________________

Comments: ______________________________

Temperature: ______________ pH: ______________

Salinity: ______________ Tide: ______________

DO: ______________ Turbidity: ______________

Trap ID: ______________ Distance from Channel: ______________

Latitude: ______________ Haul Distance: ______________

Longitude: ______________ Depth: ______________

SPECIES	QUANTITY	WEIGHT (g)	LENGTH (mm)

SPECIES	QUANTITY	WEIGHT (g)	LENGTH (mm)

chapter seven

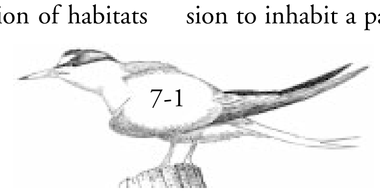
BIRDS

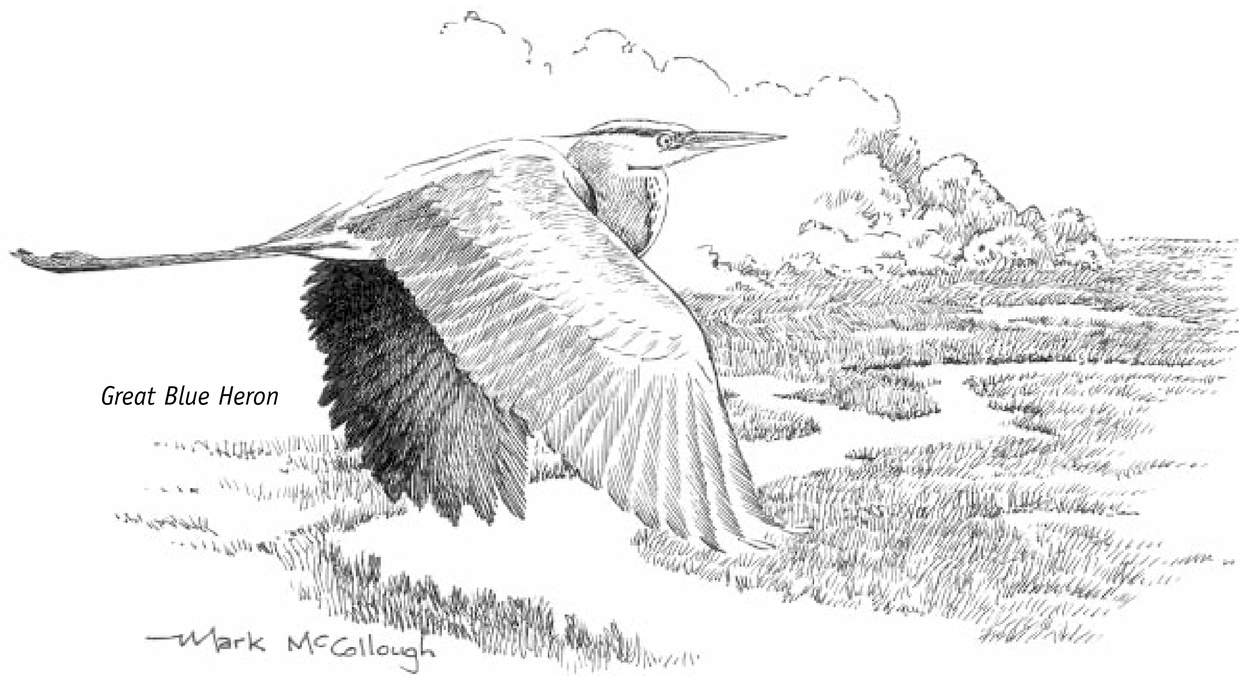
Birds are the most conspicuous animals inhabiting New England **salt marshes** because they fly around, sing, and attract attention. Birds have captured the imagination of artists and writers throughout time. For centuries, scientists and naturalists have studied avian life history, behavior, environmental requirements, and responses to environmental disturbance and pollution. The concept of using birds as **sensitive** environmental **indicators** has long been established. Historically, 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** project for salt marsh birds, and discusses how birds may be used as environmental indicators.

Wetland birds require certain types of **habitats** for different aspects of their lives such as nesting, feeding, perching, or migration. Salt marshes offer a variety of habitats such as mudflats, **pannes**, pools, various types of vegetation, and open water. 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, and therefore exploit shallow water habitats. 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 require suitable densities of *Spartina patens* (salt hay grass) and *Spartina alterniflora* (smooth cordgrass) for nesting and feeding, and 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 might reduce fish **populations** to the point where herons and egrets cannot get adequate nutrition. Birds that require specific habitats or conditions — called **specialists** — may avoid salt marshes that have been altered by disturbance or pollution, while birds that can tolerate a wide range of conditions — called **generalists** — 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 occupy unfavorable habitats if competition forces them to leave favorable areas. Human land use may affect a bird's decision to inhabit a particular salt marsh — some birds avoid





Great Blue Heron

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.

A complete list of pros and cons of using birds as indicators of wetland health is provided in Chapter Three. It is important to remember that 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, birds can yield insight that may be overlooked by studying only plants, invertebrates, or fish.

EQUIPMENT

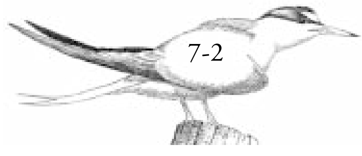
Of the **parameters** covered in this manual, birds are among the easiest and least costly to monitor. Volunteers only need five pieces of equipment to monitor birds: binoculars, field guides, recordings of birdcalls, pencil, and clipboard. Binoculars can be quite expensive, but most backyard birdwatchers and outdoor enthusiasts already have a pair. In addition to field guides, many people benefit from recordings of birdcalls. These are available on cassette or compact disc from a variety of sources. Both field guides and birdcall recordings are pieces of equipment that people should familiarize themselves with at home, not in the field. Field surveys require constant attention, and there is little time for looking at books (and especially not listening to recordings) during fieldwork.

SAMPLING METHODS

Scientists use two types of field protocols to monitor birds: area searches and point counts. Area searches require complete counts of all **species** and individuals at a site; this can be very time consuming and is therefore not recommend for volunteers. Point counts 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. The point count method is recommended because it is simple and volunteers can complete it quickly.

Procedure for Conducting Point Counts

1. Arrive between sunrise and eight o'clock when birds are most active. Bird calling and activity decreases during the day, and you can getter a better idea of bird communities by surveying during peak activity.
2. Locate a vantage point from which you can see a representative portion of a salt marsh, including the marsh border. You will want to use the same vantage point for all subsequent visits to the marsh.



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 high 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 general area, it is quite 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 good notes and try to figure it out later.

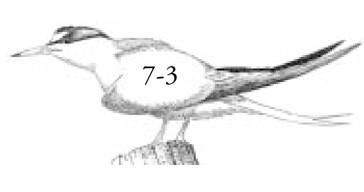
3. Record all species and individuals seen or heard for a fixed amount of time (ideally 20 minutes). You should count birds located in the wetland and a 50-100 foot wetland buffer.
4. Record the activity or habitat of each bird that you observe.
5. Completely fill out field data forms.

When comparing different sites it is important to conduct counts as close together in time as possible. Ideally, for sites that are being compared to each other, surveys should be conducted on the same morning to minimize the effects of different environmental conditions (especially weather and tides) on bird richness and abundance. The same observer(s) should monitor the sites to ensure a consistent level of expertise.

It is important to conduct surveys at different times of the year under different environmental conditions. This gives a better understanding of the importance of a wetland to breeding, migratory, and non-breeding birds. At a minimum, four surveys per site are recommended during the breeding and migration season (May to September). You may also consider monitoring wetlands during other times of the year to document use by non-breeding birds. Surveys should be conducted during different tidal conditions, since exposed mudflats at low tides provide important resources for some species, and high tides may force secretive species out of the vegetation where you can see them. In addition, survey 50-100 feet of the wetland buffer because many species use the buffer zone for nesting or perching (since the salt marsh itself provides few opportunities for this), yet depend on the wetland for other aspects of their lives such as feeding. The quality of the buffer zone also affects the quality of the salt marsh, and important indicator species will depend on both.

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 difficulty arises 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. 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.



Semipalmated Sandpiper

As stated previously, actual field 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 should not conduct actual field surveys until they are proficient with identifying birds by sight.

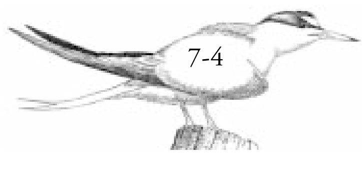
The first step for visual observation is to determine what general type of bird you are looking at. You should know key characteristics for a few basic groups of birds, based largely on shape and posture. Familiarize yourself with the main groups of birds, many of which you probably already know to some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

- Is it duck-like? [Ducks, geese, swans]
- Is it gull-like? [Gulls, terns]
- 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 most 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?). Pay attention to the bird's behavior, including feeding, resting, and 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.

Appendix 1 to this chapter provides a list of birds that are likely to occur in or near wetlands in northeastern North America. This list is based on the biology of each species and what volunteer groups have observed over several years of monitoring. The list should aid volunteers in bird identification by narrowing the search and serving as a reference



list. If you are not sure that you have identified a bird properly and it is not on the list, then it is likely that you have misidentified the bird. See if you can get another look at it. The list includes greater than 95% of the species you should expect to see in coastal salt marshes, though keep in mind that birds appear in unexpected places and there is always a chance of encountering unusual species.

DATA ENTRY

In The Field

A separate field data sheet should be used for each site and survey date. A blank sheet is provided in Appendix 2 of this chapter. You can modify field data sheets to suit the objectives of your study, but all data sheets should have the following types of information: observer(s), site location, a rough sketch of the study area with the vantage point location, survey date, weather, and tidal conditions. A good field data sheet will also include a sketch or photographs of the study area.

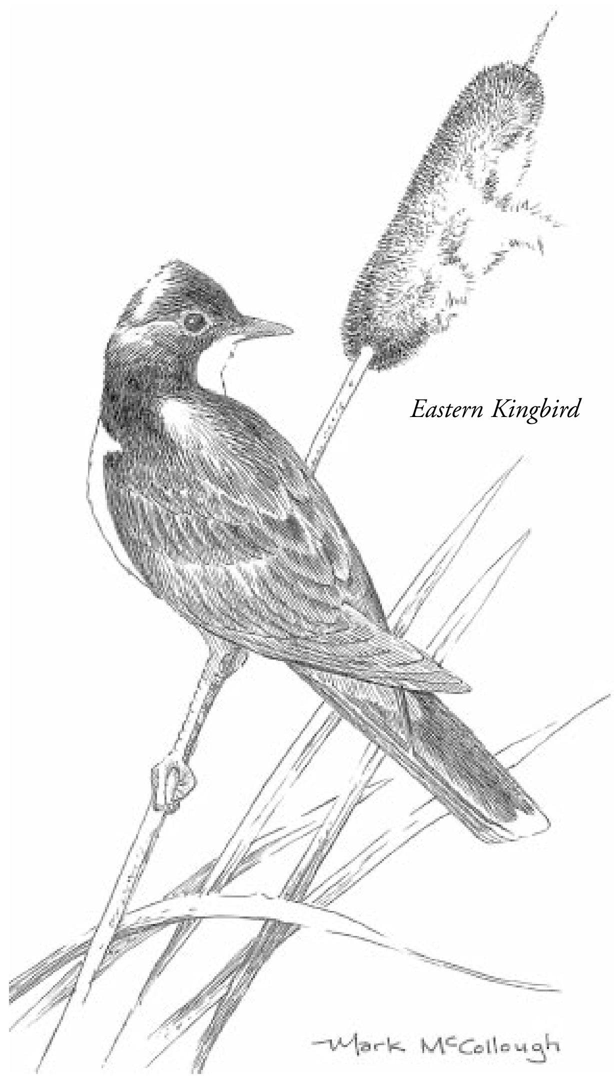
One person should perform all of the data entry so that entries are consistent. If two people are working together, one can observe while the other person records information. Data should be entered neatly and thoroughly so that there is not any missing, incomplete, or incorrect information. When the 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, since the data are often entered in haste when there is a flurry of bird activity.

In the Office

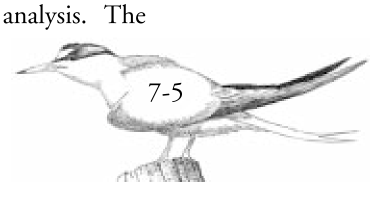
The field data should be entered into a spreadsheet such as Microsoft Excel or a database such as Microsoft Access. A database is useful for storing large amounts of information and creating lists, queries, and reports from the data. Digital photographs and sketches can be stored in Microsoft Access. You can use a spreadsheet to store data, but a spreadsheet is better suited for performing computations and summarizing data.

For each sample site, create a spreadsheet with columns for date, site code, species name, number of individuals, and species traits. Table 1A and Table 1B (pages 7-7 and 7-8) are examples of spreadsheet design and include real data to illustrate key concepts of data entry and analysis. The main objective is to enter raw data into the spreadsheet and then use functions and tools available to compute percentages of species, species groups, or particular traits.

Volunteers interested in entering data and computing important **metrics** about the salt marsh **community** should follow all six steps in the following section, and then continue in the "Data Analysis and Comparison" section. If volunteers are only responsible for entering data, then they should perform steps 1-3 in the following section and then give the spreadsheet to the project leader for further analysis.



Eastern Kingbird



Steps in Data Entry

1. Enter site name, date, species, and number of individuals per species into the first four columns of the spreadsheet. Once you enter this information, it is useful to sort the species column alphabetically. Select all of the data you entered (not including column headings), go to Data → Sort, select the column "Species," and select "Sort Ascending." Alphabetizing the list makes it easier to locate each species on Appendix 1 and fill in species traits.

2. Table 1A and 1B have two columns for Location: WET (seen in wetland) and BUF (seen in buffer zone). The tables also have two columns for Behavior: SIT (seen sitting) and FLY (seen flying). Place the value 0 or 1 for each species depending on where you saw the species and what it was doing at the time. For example, in Table 1A the American Crow was seen sitting in the buffer zone, so you would enter the following values: WET = 0, BUF = 1, SIT = 1, FLY = 0. Complete these columns for all species. It is important to enter a value (0 or 1) for all cells in these columns.

3. Table 1A and 1B have columns for six important species traits that are used to compute metrics (names and abbreviations are listed in the table heading). For each species, place the value 0 or 1 into each of these columns depending on its individual traits — all of this information is provided in Appendix 1. Some species will have more than one of the six traits. For example, in Table 1A the American Crow is Resident (RES) and **Tolerant** (TOL), and therefore "1" is entered in these columns and "0" is entered in the other four columns. Do this for all species; it is important to enter a value (0 or 1) for all cells in these columns.

4. In the row "Total," count the number of species and enter this value in the column "Species." For example, Table 1A shows that 16 species were encountered at the study site. Sum the remaining columns using the SUM function in the spreadsheet program. The total for the column "#" represents the total number of birds (individuals) encountered during the survey, and the total for the remaining columns represent the total number of species. For example, the sum total of the column "NMIG" in Table 1A is 5, which means that 5 neotropical migrant species were encountered during the survey.

5. In the row "Percent Species," divide the number of species in the row "Total" by the total number of species encountered during the survey. For example, in Table 1A there were 10 tolerant species (TOL) encountered. To determine what percent of all species this represents, divide 10 by 16 (total number of species) and multiply by 100 to get a value of 62.5%. This number means that 62.5% of the species you saw at the site were tolerant species.

6. In the row "Percent Individuals," multiply the value (0 or 1) for each species in the columns "WET" through "RARE" by the number of individuals of each species (column "#") and sum these values for all species. This will allow you to calculate a percent abundance based on individual birds rather than species. For example, to compute the percentage of birds that were seen in the wetland (column LOCATION → WET), you would use the following formula:

   =(0 x 2) + (0 x 1) + (1 x 1) + (1 x 4) + (1 x 4) + (0 x 5) + (0 x 3) + (1 x 1) + (1 x 2) + (0 x 1) + (0 x 2) + (0 x 1) + (0 x 8) + (1 x 1) + (1 x 3) + (0 x 1) = 16.

   Divide this sum by the total number of individuals encountered during the survey and multiply by 100 to compute a percentage.=(16/40) x 100 = 40%.

   This number means that 40% of all individuals were seen in the wetland. If you are proficient with spreadsheets, you will only need to enter this long formula once, copy it to all other columns in the row, and have it calculate these percentages automatically.

You have now finished the most tedious portion of data entry and in the process you have computed some important metrics of the bird community. The following section talks about 10 important metrics and discusses how to compute them using the same example data we used in the Data Entry section.

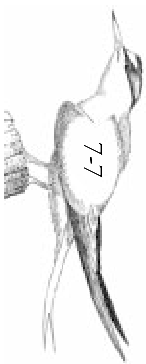


TABLE 1A. EXAMPLE DATA ENTRY SPREADSHEET FOR A STUDY MARSH

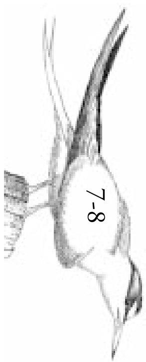
Column Abbreviations: # = Number observed, WET = Wetland, BUF = Buffer, SIT = Sitting, FLY = Flying, NMIG = Neotropical migrant, RES = Resident, TOL = Tolerant, AFOR = Aerial Foraging Species, R = Rare.

				LOCATION		BEHAVIOR		SPECIES TRAITS					
SITE	DATE	SPECIES	#	WET	BUF	SIT	FLY	NMIG	WET	RES	TOL	AFOR	RARE
Study	7/10/01	American Crow	2	0	1	1	0	0	0	1	1	0	0
Study	7/10/01	Black-Capped Chickadee	1	0	1	1	0	0	0	1	1	0	0
Study	7/10/01	Chimney Swift	1	1	0	0	1	1	0	0	1	1	0
Study	7/10/01	Common Grackle	4	1	0	0	1	0	0	0	0	0	0
Study	7/10/01	Double-Crested Cormorant	4	1	0	1	0	0	1	0	0	0	0
Study	7/10/01	European Starling	5	0	1	1	0	0	0	1	1	0	0
Study	7/10/01	House Sparrow	3	0	1	1	0	0	0	1	1	0	0
Study	7/10/01	Least Sandpiper	1	1	0	1	0	1	1	0	0	0	0
Study	7/10/01	Lesser Yellowlegs	2	1	0	1	0	1	1	0	0	0	0
Study	7/10/01	Northern Mockingbird	1	0	1	1	0	0	0	0	1	0	0
Study	7/10/01	Mourning Dove	2	0	1	1	0	0	0	1	1	0	0
Study	7/10/01	Northern Cardinal	1	0	1	1	0	0	0	1	1	0	0
Study	7/10/01	Rock Dove (Pigeon)	8	0	1	1	0	0	0	1	1	0	0
Study	7/10/01	Short-Billed Dowitcher	1	1	0	1	0	1	1	0	0	0	0
Study	7/10/01	Snowy Egret	3	1	0	1	0	1	1	0	0	0	0
Study	7/10/01	Song Sparrow	1	0	1	1	0	0	0	1	1	0	0
TOTAL		16	40	7	9	14	2	5	5	8	10	1	0
PERCENT SPECIES				43.8	56.3	87.5	12.5	31.3	31.3	50.0	62.5	6.3	0.0
PERCENT INDIVIDUALS				40.0	60.0	87.5	12.5	20.0	27.5	57.5	62.5	2.5	0.0

TABLE 1B. EXAMPLE DATA ENTRY SPREADSHEET FOR A REFERENCE MARSH

Column Abbreviations: # = Number observed, WET = Wetland, BUF = Buffer, SIT = Sitting, FLY = Flying, NMIG = Neotropical migrant, RES = Resident, TOL = Tolerant, AFOR = Aerial Foraging Species, R = Rare.

				LOCATION		BEHAVIOR		SPECIES TRAITS					
SITE	DATE	SPECIES	#	WET	BUF	SIT	FLY	NMIG	WET	RES	TOL	AFOR	RARE
Ref	7/10/01	American Crow	1	0	1	0	1	0	0	1	1	0	0
Ref	7/10/01	American Goldfinch	2	0	1	1	0	0	0	1	0	0	0
Ref	7/10/01	American Robin	1	0	1	1	0	0	0	0	1	0	0
Ref	7/10/01	Canada Goose	1	1	0	1	0	0	1	1	1	0	0
Ref	7/10/01	Chimney Swift	1	1	0	0	1	1	0	0	1	1	0
Ref	7/10/01	Common Grackle	1	1	0	1	0	0	0	0	0	0	0
Ref	7/10/01	Common Tern	1	1	0	0	1	1	1	0	0	0	0
Ref	7/10/01	Double Crested Cormorant	1	1	0	0	1	0	1	0	0	0	0
Ref	7/10/01	Gray Catbird	1	0	1	1	0	1	0	0	0	0	0
Ref	7/10/01	Great Black-Backed Gull	1	1	0	1	0	0	1	1	1	0	0
Ref	7/10/01	House Finch	1	0	1	1	0	0	0	1	1	0	0
Ref	7/10/01	House Sparrow	3	0	1	1	0	0	0	1	1	0	0
Ref	7/10/01	Least Sandpiper	7	1	0	1	0	1	1	0	0	0	0
Ref	7/10/01	Mallard	3	1	0	1	0	0	1	1	1	0	0
Ref	7/10/01	Northern Mockingbird	1	0	1	1	0	0	0	0	1	0	0
Ref	7/10/01	Mourning Dove	3	0	1	1	0	0	0	1	1	0	0
Ref	7/10/01	Northern Cardinal	1	0	1	1	0	0	0	1	1	0	0
Ref	7/10/01	Northern Rough-Winged Swallow	1	1	0	0	1	1	1	0	0	1	0
Ref	7/10/01	Song Sparrow	2	0	1	1	0	0	0	1	1	0	0
TOTAL		19	33	9	10	14	5	5	7	10	12	2	0
PERCENT SPECIES				47.4	52.6	73.7	26.3	26.3	36.8	52.6	63.2	10.5	0.0
PERCENT INDIVIDUALS				51.5	48.5	84.8	15.2	33.3	45.5	54.5	57.6	6.1	0.0



Data Analysis And Comparison

Now that you have entered and compiled all of the field data, you can begin to explore what it means. This chapter uses 10 metrics to indicate the health of salt marsh bird communities. A complete analysis should include all of these metrics, and perhaps other metrics or indices developed to meet specifically project goals. The 10 metrics described in this chapter are still being tested for their ability to discriminate between different bird communities and wetlands, and though none of them works perfectly all of the time, collectively they provide a good summary of the bird communities in salt marsh environments. Table 2 lists each metric and provides a brief explanation of why it is used and its expected response to stressors.

Species Richness

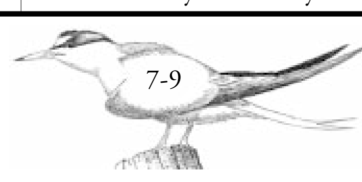
Description: Species richness is the total number of species observed during the study.

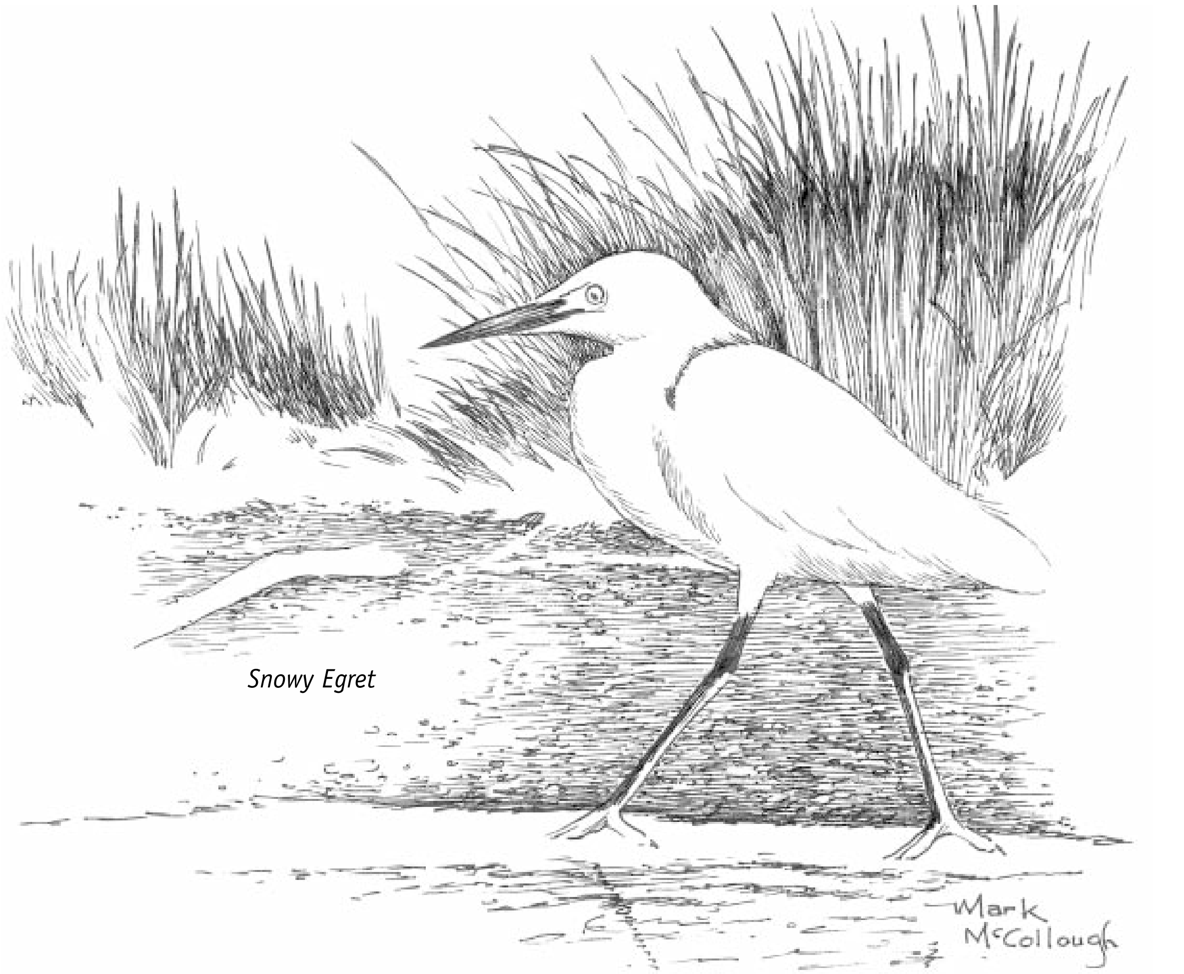
Calculation: Simply count the number of species observed at each site. From the example data in Table 1A and 1B, the species richness is 16 at the study site and 19 at the **reference site**. You can compute a ratio of species richness by dividing the number of species at the study site by the number of species at the reference site and multiplying by 100. For our example data, this ratio would be 84.2% (=(16/19) x 100). This means that the study site has 15.5% fewer species that the reference site.

Interpretation: Species richness is an important variable because in general pristine salt marshes will support more species than disturbed salt marshes. Usually, severe pollution or habitat degradation will eliminate sensitive species, thereby reducing species richness. This metric does not always reflect pollution or degradation, especially when there are natural habitat differences between two sites that are unrelated to stressors of interest.

Table 2. Summary of Bird Community Metrics

Metric	Rationale	Response to Stressors
Species Richness	Species richness is expected to be highest in sites where habitat quality and food supply are most optimal.	Decline
% Neotropical Migrants	Neotropical migrants are habitat specialists and sensitive to habitat quality.	Decline
% Wetland Dependent Species	Wetland-dependent species require habitat that ties them exclusively to healthy, aquatic sites.	Decline
% Resident Species	Resident species are less sensitive to habitat quality and tend to be habitat generalists.	Increase
% Tolerant Species	Tolerant species are generalists that adapt to human-altered habitats and landscapes.	Increase
% Starlings and Blackbirds	Starlings and blackbirds are tolerant species whose numbers are expected to increase in habitats that are degraded.	Increase
% Insectivorous Aerial Foragers	Flying, insect-feeding species depend on a healthy invertebrate population for food.	Decline
Number of Regionally Rare Species	Regionally rare species are expected to be found only in the best available habitat.	Decline
% Abundance of 3 Most Abundant Species	Overall species diversity will decrease under impacted conditions, allowing a few species to dominate.	Increase
Community Similarity Ratio	The percent similarity between reference sites and other similarly structured sites should be the same if they are healthy.	Decline





Snowy Egret

Percent Neotropical Migrants

Description: Neotropical migrants are species that migrate toward the southern hemisphere for the northern winter, and include species such as warblers and flycatchers. This metric is the proportional abundance of these species and individuals.

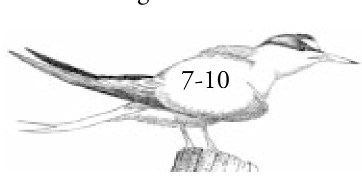
Calculation: Appendix 1 lists all of the neotropical migrants, and this information was transferred onto your spreadsheet during data entry. This metric can be computed for either species or individuals. From the example data in Table 1A and 1B, neotropical migrants comprise 31.3% and 26.3% of all species in the study site and reference site, respectively. When this is weighted by abundance, they comprise 20.0% and 33.3% of all individuals in the study site and reference site, respectively.

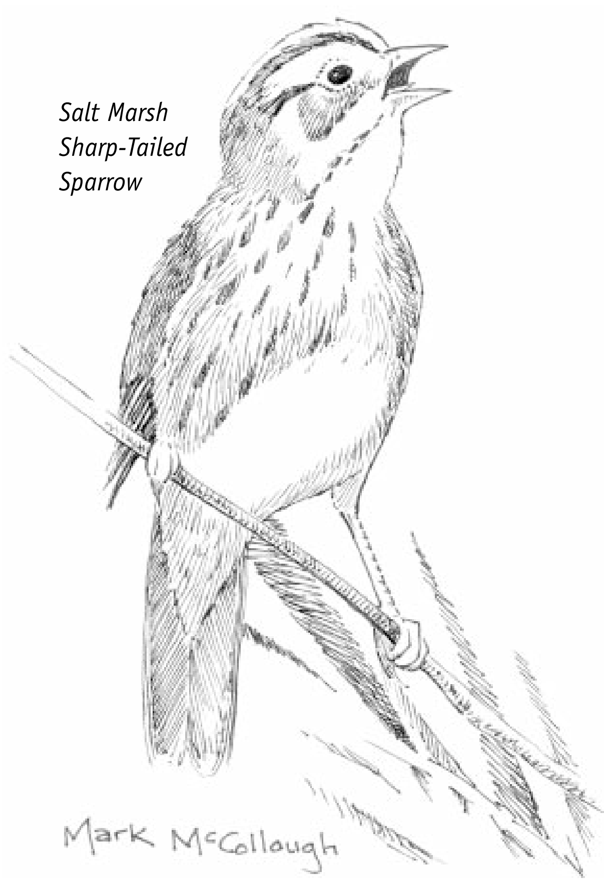
Interpretation: Most neotropical migrants are very sensitive species with specific habitat requirements. Higher quality wetlands are expected to support greater numbers of neotropical migrants. Time of year is an important consideration when using this metric, however, since migratory species are usually only encountered during the warmer months.

Percent Wetland-Dependent Species

Description: Wetland-dependent species are those species that rely on wetlands for some portion of their life cycle such as nesting or feeding, and include species such as Red-Winged Blackbirds, various shorebirds, ducks, and herons. This metric is the proportional abundance of these species and individuals.

Calculation: Appendix 1 lists all of the wetland-dependent species, and this information was transferred onto your spreadsheet during data entry. This metric can be computed for either species or individuals. From the example data in Table 1A and 1B, wetland dependent species





comprise 31.3% and 36.8% of all species in the study site and reference site, respectively. When this is weighted by abundance, they comprise 27.5% and 45.5% of all individuals in the study site and reference site, respectively.

Interpretation: Wetland-dependent species are more sensitive to habitat conditions and feeding opportunities in wetlands because they are strictly reliant on the wetland during critical phases of their life cycle. Polluted and degraded marshes can continue to support non-wetland species because they can forage in upland areas also. Thus, the proportional abundance of wetland-dependent species is expected to be higher in pristine marshes, and lower in polluted or degraded marshes.

Percent Resident Species

Description: Resident species — such as American Crows, House Sparrows, and Northern Cardinals — do not migrate, are generalists, and can shift their diets in response to seasonal or resource changes. This metric is the proportional abundance of these species and individuals.

Calculation: Appendix 1 lists all of the resident species, and this information was transferred onto your spreadsheet during data entry. This metric can be computed for either species or individuals. From the example data in Table 1A and 1B, resident species comprise 50.0% and 52.6% of all species in the study site and reference site, respectively. When this is weighted by abundance, they comprise 57.5% and 54.5% of all individuals in the study site and reference site, respectively.

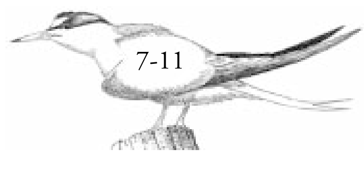
Interpretation: Since resident species have the ability to use different resources and adapt to scarce resources, they are better able to cope with alterations to food quality/quantity or habitat conditions that result from pollution or degradation. Therefore, resident species are expected to comprise a higher proportional abundance of the bird community in polluted or degraded marshes.

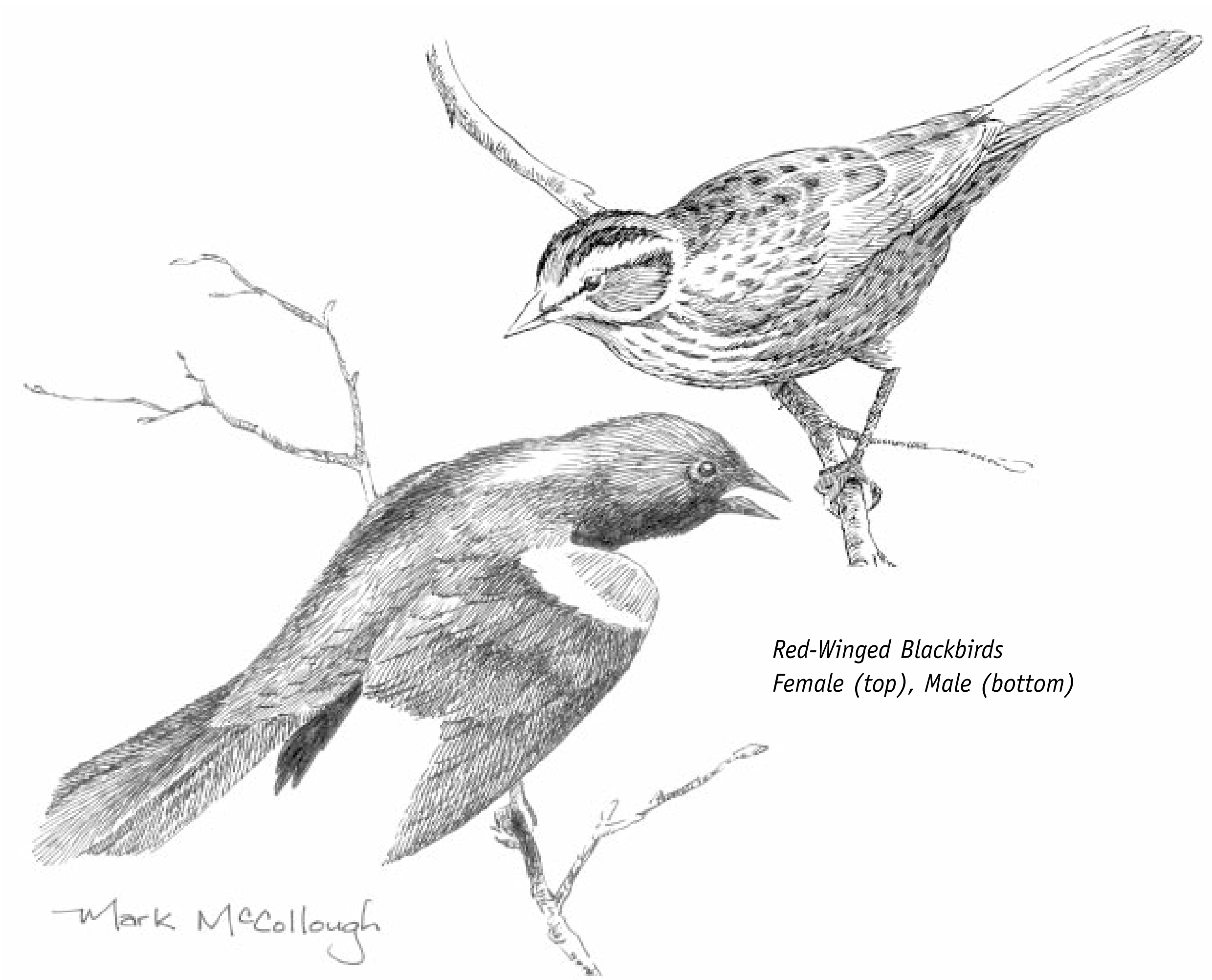
Percent Tolerant Species

Description: Tolerant species are generalists that are adapted to living close to man and his activities, but unlike resident species may be migratory or partially migratory. Examples include American Robins, Cedar Waxwings, Blue Jays, and American Crows. This metric is the proportional abundance of these species and individuals.

Calculation: Appendix 1 lists all of the tolerant species, and this information was transferred onto your spreadsheet during data entry. This metric can be computed for either species or individuals. From the example data in Table 1A and 1B, tolerant species comprise 62.5% and 63.2% of all species in the study site and reference site, respectively. When this is weighted by abundance, they comprise 62.5% and 57.6% of all individuals in the study site and reference site, respectively.

Interpretation: Similar to resident species, tolerant species have the ability to use different resources and adapt to scarce resources, and are better able to cope with alterations to food quality/quantity or habitat conditions that result from pollution or degradation. Sites that are suffering from environmental impacts should have more species that can tolerate such conditions.





Red-Winged Blackbirds
Female (top), Male (bottom)

Percent Starlings and Blackbirds

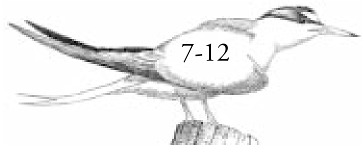
Description: Blackbirds and starlings are **opportunistic** feeders that often occur in large flocks, and are generally tolerant of **human disturbance**. In our area, these include European Starlings, Red-Winged Blackbirds, Brown-Headed Cowbirds, and Common Grackles. This metric is the proportional abundance of these species and individuals.

Calculation: You should look through the species list for each sampling date and record the presence and numbers of each the four species that comprise this metric. Divide the number of species by the total number of species recorded at each site, and divide the number of individuals of these species by the total number of individuals recorded at each site. Table 3 shows data for this metric extracted from the example data in Tables 1A and 1B.

Interpretation: Similar to resident and tolerant species, a high proportional abundance of blackbirds and starlings can be a signal of poor habitat quality, since these species, when in large post-breeding feeding flocks, are generalists, tolerant of man, and thrive in poorer quality habitats.

TABLE 3. PERCENT STARLINGS AND BLACKBIRDS
Data taken from Tables 1A and 1B

	PERCENT ABUNDANCE	
SITE	INDIVIDUALS	SPECIES
Study Site	22.5	12.5
Reference Site	3.0	5.3



Percent Insectivorous Aerial Foragers

Description: Warblers, swallows, and flycatchers are among the many species that feed by flying around and catching insects, and are dependent on healthy invertebrate communities. This metric is the proportional abundance of these species and individuals.

Calculation: Appendix 1 lists all of the aerial foraging species, and this information was transferred onto your spreadsheet during data entry. This metric can be computed for either species or individuals. From the example data in Table 1A and 1B, aerial foragers comprise 6.3% and 10.5% of all species in the study site and reference site, respectively. When this is weighted by abundance, they comprise 2.5% and 6.1% of all individuals in the study site and reference site, respectively.

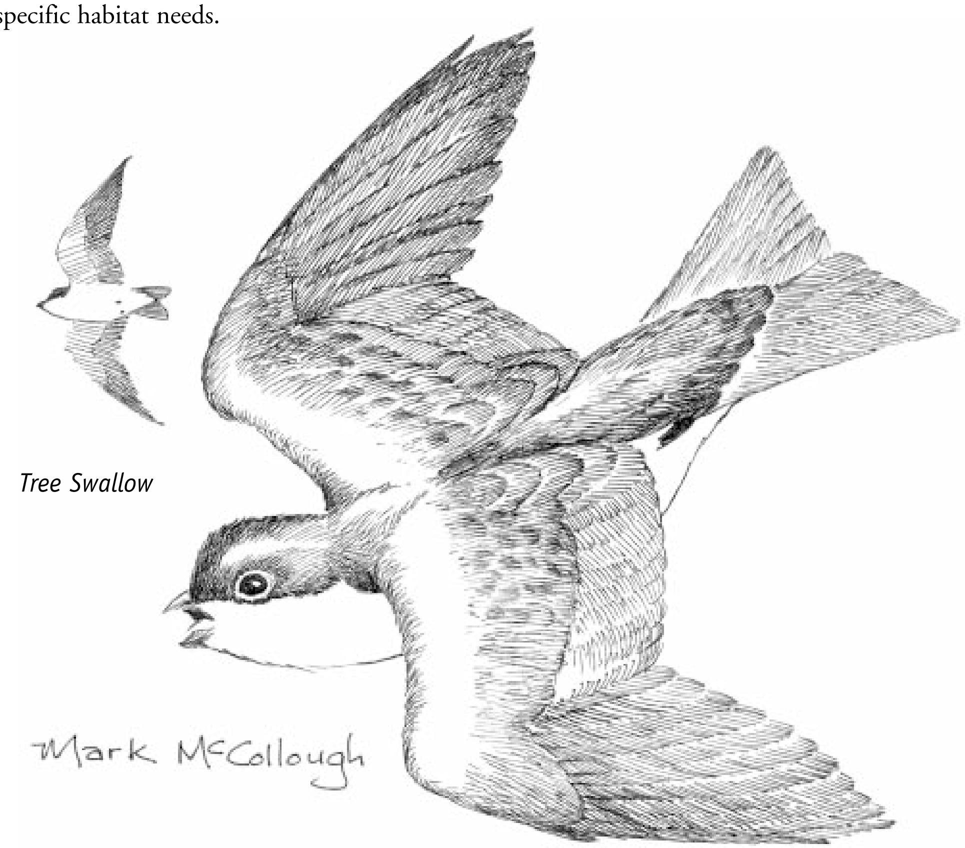
Interpretation: Marsh pollution or habitat degradation that affects invertebrate communities is also expected to decrease the proportional abundance of birds that prey on invertebrates. A high proportional abundance of aerial foragers is a good indication that environmental conditions are suitable for a healthy invertebrate community. In addition, many of the insectivorous aerial foragers are also neotropical migrants with specific habitat needs.

Number of Regionally Rare Species

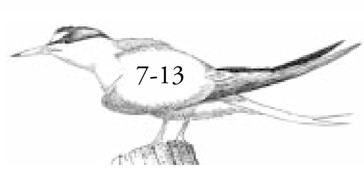
Description: Rare species are those with a restricted geographical distribution, or unusually specific habitat needs that only enable them to exist at extremely low population densities and a small number of locations. Examples include the Salt Marsh Sharp-Tailed Sparrow, Cliff Swallow, Least Tern, and Clapper Rail. This metric is simply the number of rare species and individuals.

Calculation: Appendix 1 lists all of the rare species, and this information was transferred onto your spreadsheet during data entry. From the example data in Table 1A and 1B, no rare species were encountered at the study site or reference site. The reason that this is not computed as a percentage or proportional abundance of the total community is because they occur very infrequently and in extremely low numbers.

Interpretation: The presence of rare species can sometimes be a good indicator of relatively pristine and healthy conditions, although you should exercise caution when interpreting this value because rare species are often found at unexpected times and unexpected locations and your observation may be largely due to chance.



Tree Swallow



Percent Abundance of Three Most Common Species

Description: This metric is a measure of dominance, and reflects the degree to which a community is dominated by a small number of species. In other words, it is a measure of how evenly distributed the species are in a community.

Calculation: To compute this metric, you need to compute the percent abundance of all species encountered at a site and then find the sum of the three highest values. The easiest way to do this is to copy the columns "Species" and "#" from Table 1 to a new spreadsheet, determine the percent abundance of each species by dividing the number of individuals of each by the total number of individuals and multiplying by 100, and then sort the data by these percentages. Table 4 shows what this looks like using data from Table 1A and Table 1B. For the study site, add Rock Dove (20%), European Starling (12.5%), and Common Grackle (10%) to compute a value of 42.5%. For the reference site, add Least Sandpiper (21.2%), House Sparrow (9.1%), and Mallard (9.1%) to compute a value of 39.4%.

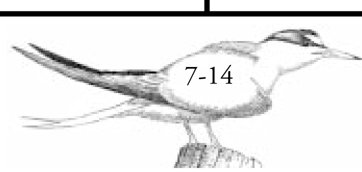
Interpretation: Marshes that are polluted or degraded often provide few feeding opportunities, and the bird community is usually dominated by a small number of tolerant species that can adapt to existing resources. Pristine and healthy marshes provide many opportunities for nesting or foraging, which allow many different species to coexist, and leads to a more equitable distribution of species. Therefore, this metric is expected to be higher in polluted or degraded marshes and lower in pristine marshes.

Community Similarity Ratio

Description: Community similarity refers to the types of species that occur in a community, and in particular the similarity or difference between two communities. Metrics for species richness and relative abundance were already calculated, yet two sites can have identical species richness and relative abundance and have entirely different species. Since different species have different environmental requirements, the types of species in a community provide clues about salt marsh condition.

TABLE 4. PERCENT ABUNDANCE OF THREE MOST COMMON SPECIES

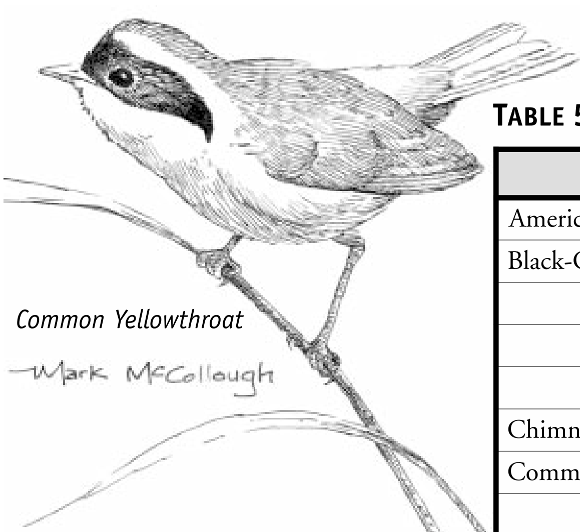
STUDY SITE	%	REFERENCE SITE	%
Rock Dove (Pigeon)	20.0	Least Sandpiper	21.2
European Starling	12.5	House Sparrow	9.1
Common Grackle	10.0	Mallard	9.1
Double-Crested Cormorant	10.0	Mourning Dove	9.1
House Sparrow	7.5	American Goldfinch	6.1
Snowy Egret	7.5	Song Sparrow	6.1
American Crow	5.0	American Crow	3.0
Lesser Yellowlegs	5.0	American Robin	3.0
Mourning Dove	5.0	Canada Goose	3.0
Black-Capped Chickadee	2.5	Chimney Swift	3.0
Chimney Swift	2.5	Common Grackle	3.0
Least Sandpiper	2.5	Common Tern	3.0
Mockingbird	2.5	Double-Crested Cormorant	3.0
Northern Cardinal	2.5	Gray Catbird	3.0
Short-Billed Dowitcher	2.5	Great Black-Backed Gull	3.0
Song Sparrow	2.5	House Finch	3.0
Three Most Common Species	42.5	Mockingbird	3.0
		Northern Cardinal	3.0
		Northern Rough-Winged Swallow	3.0
		Three Most Common Species	39.4



Calculation: One way to examine community similarity is to compare species lists from two or more sites and see how many unique species exist at each site. Copy the species lists from the data entry spreadsheet onto a new spreadsheet, place them side-by-side, and compare the species lists. Table 5 shows data taken from Table 1A and Table 1B. The study site has six unique species, the reference site has nine unique species, and the two sites share 10 species. You can calculate a community similarity ratio by dividing the number of species that the two sites share (10) by the number of species at the reference site (19) and multiplying by 100. From Table 5, the ratio is:

$$=(10/19) \times 100 = 52.6\%.$$

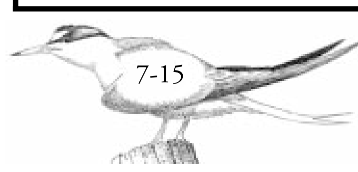
Interpretation: When interpreting community composition data, it is important to understand the ecology and environmental tolerance of the birds. The community similarity ratio is a quick way to judge the similarity of two sites, but the interpretation of this ratio is somewhat subjective. More importantly, you should look at the unique species from each site and consider what traits unite these species and why they are present at one site and not the other. Perhaps one site has a large number of sensitive neotropical migrants that are not found at another site, or a large number of resident or tolerant species that may indicate poor wetland conditions.



Common Yellowthroat

TABLE 5. COMMUNITY SIMILARITY EXAMPLE

STUDY SITE	REFERENCE SITE
American Crow	American Crow
Black-Capped Chickadee	
	American Goldfinch
	American Robin
	Canada Goose
Chimney Swift	Chimney Swift
Common Grackle	Common Grackle
	Common Tern
Double-Crested Cormorant	Double-Crested Cormorant
European Starling	
	Gray Catbird
	Great Black-Backed Gull
	House Finch
House Sparrow	House Sparrow
Least Sandpiper	Least Sandpiper
Lesser Yellowlegs	
	Mallard
Northern Mockingbird	Northern Mockingbird
Mourning Dove	Mourning Dove
Northern Cardinal	Northern Cardinal
Rock Dove (Pigeon)	
Short-Billed Dowitcher	
Snowy Egret	
	Northern Rough-Winged Swallow
Song Sparrow	Song Sparrow

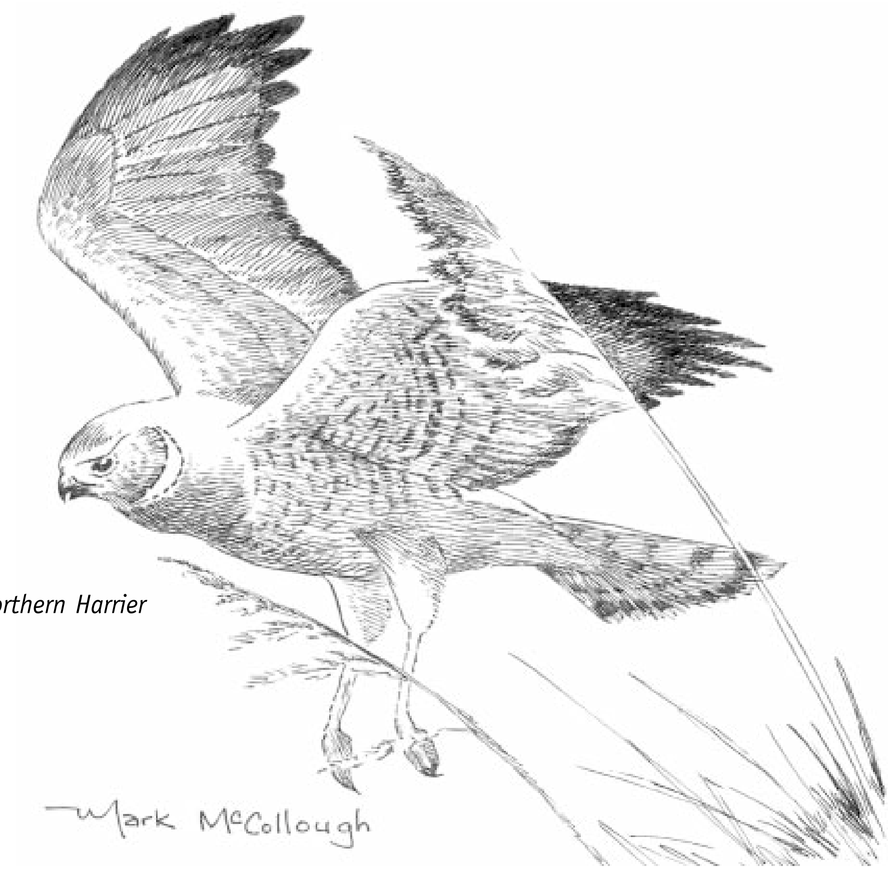


Summary

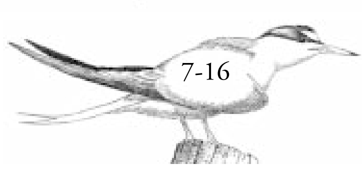
Once you have calculated each of the 10 metrics, it is useful to put all of the data into a summary table. Table 6 provides a summary of all metrics calculated using the example data in Table 1A and Table 2A. You should calculate metrics separately for each sampling day and then average these over the entire sampling period, except for species richness, which should be calculated by combining the data from all of the sampling days for one calculation.

TABLE 6. SUMMARY OF BIRD METRICS CALCULATED FROM EXAMPLE DATA

	STUDY SITE		REFERENCE SITE	
METRIC	INDIVIDUALS	SPECIES	INDIVIDUALS	SPECIES
Species Richness	-	16	-	19
% Neotropical Migrants	20	31.3	33.3	26.3
% Wetland Dependent Species	27.5	31.3	45.5	36.8
% Resident Species	57.5	50	54.5	52.6
% Tolerant Species	62.5	62.5	57.6	63.2
% Starlings and Blackbirds	22.5	12.5	3	5.3
% Insectivorous Aerial Foragers	2.5	6.3	6.1	10.5
Number of Regionally Rare Species	0	0	0	0
% Abundance of 3 Most Abundant Species	-	42.5	-	39.4
Community Similarity Ratio	62.5%			



Northern Harrier



REFERENCES AND OTHER SUGGESTED READING

These are just a sampling, and many other good field guides, audio recordings, and general bird biology books are also available.

Identification Guides

Kaufman, K. 2000. *Birds of North America*. Houghton Mifflin Company. [$20.00]

National Geographic Society. 1999. *Field Guide to the Birds of North America, 3rd Edition*. National Geographic Society. [$21.95]

Peterson, R.T. 1980. *Field Guide to Birds East of the Rockies*. Houghton Mifflin Company. [$18.00]

Sibley, D.A. 2000. *National Audubon Society Sibley Guide to Birds.* Alfred A. Knopf, Inc. [$35.00]

Behavior and General Biology

Attenborough, D. 1998. *The Life of Birds.* Princeton University Press. [$29.95]

Kaufman, K. 1996. *Lives of North American Birds.* Houghton Mifflin Company. [$35.00]

Sibley, D.A. 2001. *The Sibley Guide to Bird Life and Behavior*. Alfred A. Knopf, Inc. [$45.00]

Stokes, D. and L. Stokes. 1996. *Stokes Field Guide to Birds: Eastern Region*. Little Brown and Company. [$16.95]

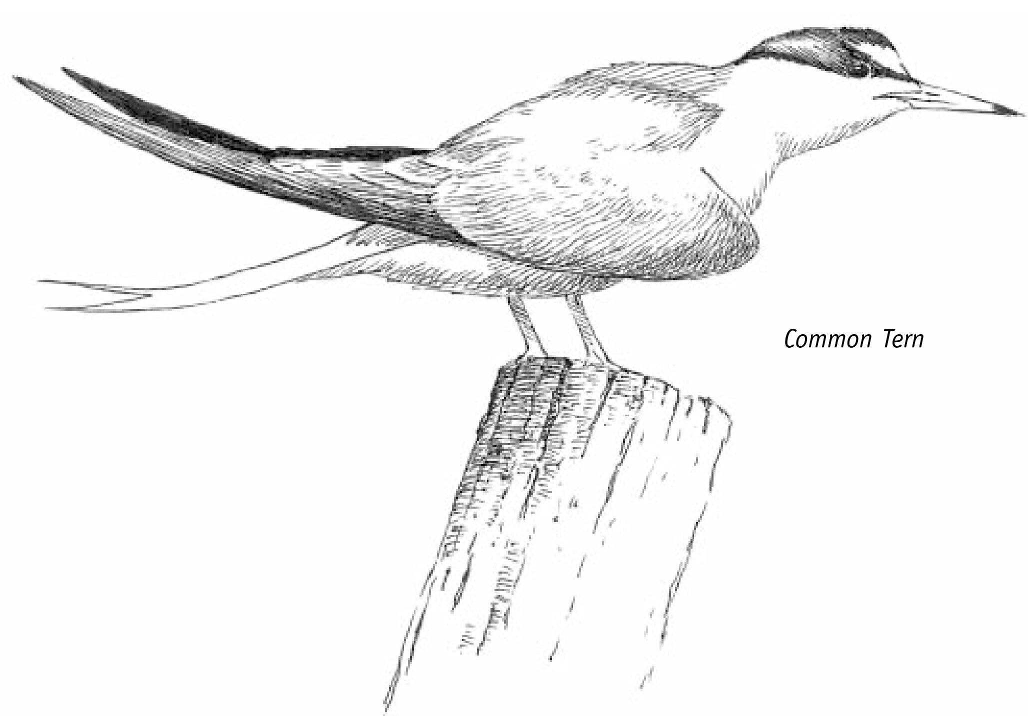
Sound Recordings

National Geographic Society. 1986. *Guide to Bird Songs*. National Geographic Society and the Cornell University Library of Natural Sounds. [1 CD, $ 24.95]

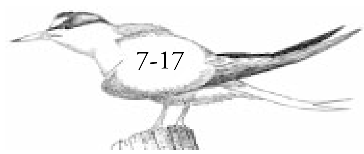
Peterson, R.T. 1999. *Field Guide to Bird Songs - Eastern/Central North America*. Cornell University Library of Natural Sounds. [2 cassettes or 1 CD, $ 29.95]

Walton, R.K. and R.W. Lawson. 1999. *Peterson Field Guides: Eastern/Central Birding by Ear.* Cornell University Library of Natural Sounds. [3 cassettes or 3 CDs, $25.00]

Walton, R.K. and R.W. Lawson. 1994. *Peterson Field Guides: Eastern and Central More Birding By Ear*. Cornell University Library of Natural Sounds. [3 cassettes or 3 CDs, $ 35.00]



Common Tern



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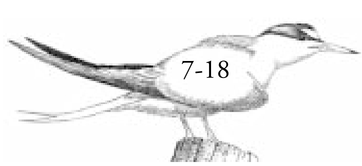


chapter seven

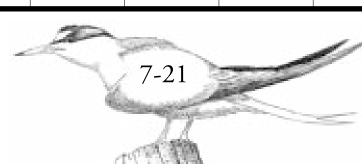
APPENDICES

Appendix 1. Birds Likely to Be Seen Near Salt Marshes

This list has been compiled from years of surveys near New England salt marshes and from knowledge about the ecology of each species. Though rare species may be encountered, this list should contain 95% of what you will find. Abbreviations: COM = Common, PRE = Present, RARE = Rare, WET = Wetland-dependent, AFOR = Aerial forager, NMIG = Neotropical migrant, RES = Resident, TOL = Tolerant

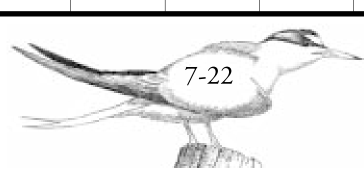
	Species Traits							
Species	**COM**	**PRE**	**RARE**	**WET**	**AFOR**	**NMIG**	**RES**	**TOL**
Double-Crested Cormorant	x			x				
Great Blue Heron		x		x				
Great Egret	x			x		x		
Snowy Egret	x			x		x		
Little Blue Heron			x	x		x		
Green (or Green-Backed) Heron		x		x		x		
Black-Crowned Night Heron		x		x				
Yellow-Crowned Night Heron			x	x		x		
Glossy Ibis		x		x		x		
Mute Swan		x		x			x	x
Canada Goose	x			x			x	x
Mallard	x			x			x	x
Black Duck	x			x			x	
Wood Duck		x		x				
Gadwall		x		x			x	
Northern Harrier		x		x				
Sharp-Shinned Hawk		x						
Cooper's Hawk		x						
Broad-Winged Hawk		x			x	x		
Red-Tailed Hawk		x			x		x	
Osprey		x		x		x		
Kestrel		x						
Merlin		x						
Pheasant		x					x	
Clapper Rail			x	x		x		
Virginia Rail		x		x		x		
Black-Bellied Plover	x			x		x		
Semipalmated Plover	x			x		x		
Killdeer	x			x		x		
Willet		x		x		x		
Greater Yellowlegs	x			x		x		
Lesser Yellowlegs	x			x		x		
Spotted Sandpiper		x		x		x		

PAGE 1 OF 4



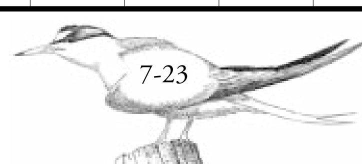
APPENDIX 1. Continued

SPECIES	SPECIES TRAITS							
	COM	PRE	RARE	WET	AFOR	NMIG	RES	TOL
Whimbrel		x		x		x		
Ruddy Turnstone		x		x		x		
Dunlin		x		x		x		
Sanderling		x		x		x		
Semipalmated Sandpiper	x			x		x		
Least Sandpiper	x			x		x		
Short-Billed Dowitcher		x		x		x		
Wilson's Phalarope			x	x		x		
Laughing Gull		x		x		x		
Bonaparte's Gull		x		x				
Ring-Billed Gull		x		x			x	x
Herring Gull	x			x			x	x
Great Black-Backed Gull	x			x			x	x
Common Tern		x		x		x		
Least Tern			x	x		x		
Rock Dove (Common Pigeon)		x					x	x
Mourning Dove	x						x	x
Yellow-Billed Cuckoo			x			x		
Black-Billed Cuckoo			x			x		
Chimney Swift	x				x	x		x
Belted Kingfisher		x		x				
Northern Flicker	x							
Downy Woodpecker		x					x	x
Hairy Woodpecker		x						
Eastern Kingbird	x			x	x	x		
Great Crested Flycatcher					x	x		
Eastern Wood-Pewee		x			x	x		
Eastern Phoebe		x			x	x		
Willow Flycatcher		x		x	x	x		
Tree Swallow	x				x	x		
Purple Martin		x			x	x		
Bank Swallow		x			x	x		
Northern Rough-Winged Swallow		x		x	x	x		
Cliff Swallow			x	x	x	x		
Barn Swallow	x				x	x		
Blue Jay	x						x	x



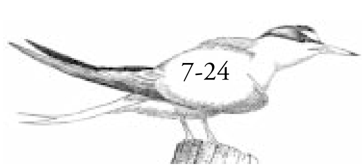
APPENDIX 1. Continued

SPECIES	SPECIES TRAITS							
	COM	PRE	RARE	WET	AFOR	NMIG	RES	TOL
American Crow	x						x	x
Black-Capped Chickadee	x						x	x
Tufted Titmouse							x	x
White-Crested Nuthatch							x	
Red-Breasted Nuthatch		x						
House Wren		x						x
Marsh Wren		x		x				
Carolina Wren		x					x	
Golden-Crowned Kinglet		x						
Eastern Bluebird		x						
Wood Thrush		x				x		
American Robin	x							x
Water Pipit		x		x		x		
Gray Catbird	x					x		
Northern Mockingbird	x						x	x
Cedar Waxwing	x				x			
European Starling	x						x	x
Warbling Vireo		x		x	x	x		
Red-Eyed Vireo					x	x		
Nashville Warbler					x	x		
Black and White Warbler						x		
Chesnut-Sided Warbler					x	x		
Prairie Warbler					x	x		
Yellow Warbler	x			x	x	x		
Wilson's Warbler		x			x	x		
Yellow-Rumped Warbler		x			x	x		
Ovenbird						x		
Common Yellowthroat	x			x		x		
American Redstart		x			x	x		
Rose-Breasted Grosbeak						x		
Northern Cardinal	x						x	x
Scarlet Tanager						x		
Indigo Bunting						x		
Eastern Towhee	x							
Salt-Marsh Sharp-Tailed Sparrow			x	x				
Seaside Sparrow			x	x				



APPENDIX 1. Continued

SPECIES	SPECIES TRAITS							
	COM	PRE	RARE	WET	AFOR	NMIG	RES	TOL
Song Sparrow	x						x	x
Savannah Sparrow	x							
Field Sparrow								
Chipping Sparrow		x						
Swamp Sparrow	x			x				
Bobolink		x				x		
Eastern Meadowlark								
Red-Winged Blackbird	x			x				
Brown-Headed Cowbird		x						
Common Grackle	x							
Baltimore Oriole	x					x		
Orchard Oriole	x					x		
American Goldfinch	x						x	
Purple Finch		x						
House Finch	x						x	x
House Sparrow	x						x	x



AVIFAUNA SURVEY FIELD FORM

Investigators: ______________________ Date: ______________________

____

____

____

Wetland Area: ______________________ Study or Reference (Circle)

Begin Time: __________ End Time: __________ Tide: Ebb Low Flow High (Circle)

Conditions: ______________________

COMMON NAME	#	LOCATION	ACTIVITY	NOTES
		Wetland / Buffer	Sitting / Flying	
		Wetland / Buffer	Sitting / Flying	
		Wetland / Buffer	Sitting / Flying	
		Wetland / Buffer	Sitting / Flying	
		Wetland / Buffer	Sitting / Flying	
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		Wetland / Buffer	Sitting / Flying	

COMMON NAME	#	LOCATION	ACTIVITY	NOTES
		Wetland / Buffer	Sitting / Flying	
		Wetland / Buffer	Sitting / Flying	
		Wetland / Buffer	Sitting / Flying	
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		Wetland / Buffer	Sitting / Flying	

ADDITIONAL NOTES AND COMMENTS

chapter eight

SALINITY

There are many 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 aquatic **invertebrate** and fish **monitoring** methods described in this handbook, and the parameters of interest include salinity, dissolved oxygen, pH, and temperature. Researchers usually collect measurements for a range of parameters with an automated water chemistry multimeter, which can be cumbersome to calibrate and prohibitively expensive for most volunteer monitoring groups. This chapter describes methods for a more specific investigation of one parameter — salinity — that is considered the most important chemical parameter in salt marshes and does not require the purchase of an expensive multimeter.

Tidal inundation controls **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. Perhaps the most recognizable consequence of salinity regimes in salt marshes is the vegetation **zonation** patterns (see Chapter Two). Some dominant salt marsh plants are **specialists** that require specific salinity ranges and cannot tolerate fresh water (i.e. *Spartina alterniflora* [smooth cordgrass]), whereas other plants can tolerate high salinity levels, but do not necessarily require it (i.e. *Spartina patens* [salt hay grass]). Some plant species are **generalists** because they can exist in a wide range of salinities. *Phragmites australis* (common reed) is an invasive species that is widespread in New England because it can tolerate saline, brackish, and freshwater conditions. Alterations to natural salinity regimes often result in the loss of specialist species and the spread of generalist or invasive species, which in turn affects plant and animal communities and the overall structure and function of salt marsh ecosystems.

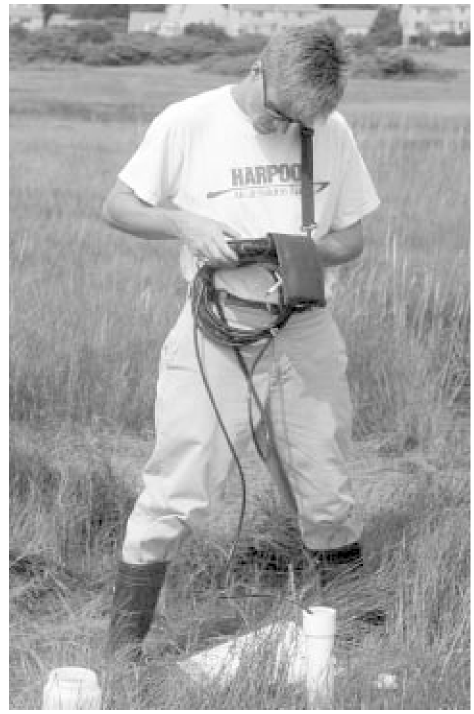
Measurements of salinity can help to explain the **diversity**, distribution, and **abundance** of plants and animals in a salt marsh. Salinity is also a critical parameter to measure when investigating any type of tide restriction or tide restoration project. Salinity measurements often provide a clear understanding of the effect of a tidal restriction, and careful measurements before and after the removal of a tide restriction can provide an excellent indication of the success of restoration efforts. The primary goals of programs that seek to restore tidal flow are the reestablishment of natural salinity regimes and restoration of biological communities.

EQUIPMENT

Table 1 lists the equipment needed for a salinity monitoring project. Water salinity is a relatively inexpensive parameter to incorporate into a monitoring program. A group that needs to buy all new equipment can expect to spend roughly $450. However, many of the more expensive pieces of equipment are also required for other parameters listed in this manual. For example, volunteers will need a measuring tape for vegetation, fish, macroinvertebrate, and tidal influence monitoring and will need an auger to collect invertebrates. It can be time consuming to assemble **groundwater** wells. Two people that are adept with power tools can build wells in an afternoon.

TABLE 1. EQUIPMENT FOR SALINITY MONITORING

EQUIPMENT
8 groundwater wells, constructed from the following materials:
3" plastic PVC pipe
PVC caps for pipe
Power drill to drill holes in PVC pipe
3/16, 1/4, or 3/8-inch drill bit
Permeable black garden mulching fabric
Duct tape
Water pump: Beckson Model #9A
Bailer: Forestry Suppliers, Inc., dimensions: 1.66"O.D., 36"L
Refractometer: VISTA Series Instruments Portable Refractometer (Model Number A366ATC (0-10% Sal.))
Measuring tape
Auger
Disposable paper cups
Plastic pipette
Dipper with long-handled stick
Tap water (in large container)
Deionized water
Field data sheets
Pencils



Measuring salinity with a digital multimeter.
Photo: Vivian Kooken

Volunteers can construct groundwater wells from materials that are available at hardware or garden supply stores. Investigators have developed a variety of groundwater well designs to suit specific conditions and data needs. For instance, some researchers install wells at different soil depths to obtain precise information about the vertical gradient of salinity in the **pore water**. This manual provides instructions for wells that integrate approximately 16 inches of subsurface soil, which represents the rooting zone for most salt marsh plants. Assembly and installation instructions are as follows:

Well Assembly (all measurements given are approximate and serve as guidance only!) (see Figure 1)

1. Cut a 3-foot section of 3-inch PVC pipe.
2. Drill 3/16 to 3/8-inch holes into the lower third of the pipe at a frequency of one hole per square inch.
3. Wrap the lower end of the pipe, including the opening and all of the drill holes, with garden mulching fabric and secure the fabric with duct tape.
4. Drill one 3/16 to 3/8-inch vent hole four inches from the top of the pipe.
5. Fit a screw top or cap (male and female adapters can be purchased to fit the pipe) over the top opening of the pipe, being careful not to cover the vent hole.

Well Installation

1. Using an auger, extract a 1-2 foot core of marsh sediment.
2. Gently push the lower end of the pipe (the end covered with fabric) into the hole, and make sure that the perforated section of the pipe is completely submerged into the ground.
3. To secure the well, pack the sediment extracted with the auger around the edge of the pipe.

SAMPLING METHODS

Deciding where to locate salinity **sample stations** can be subjective and should be done by an individual with some background knowledge in salt marsh vegetation. However, once the wells are in place, salinity sampling becomes a simple and straightforward exercise. As in all fieldwork, safety is the top priority. Work in teams and avoid entering the salt marsh alone.

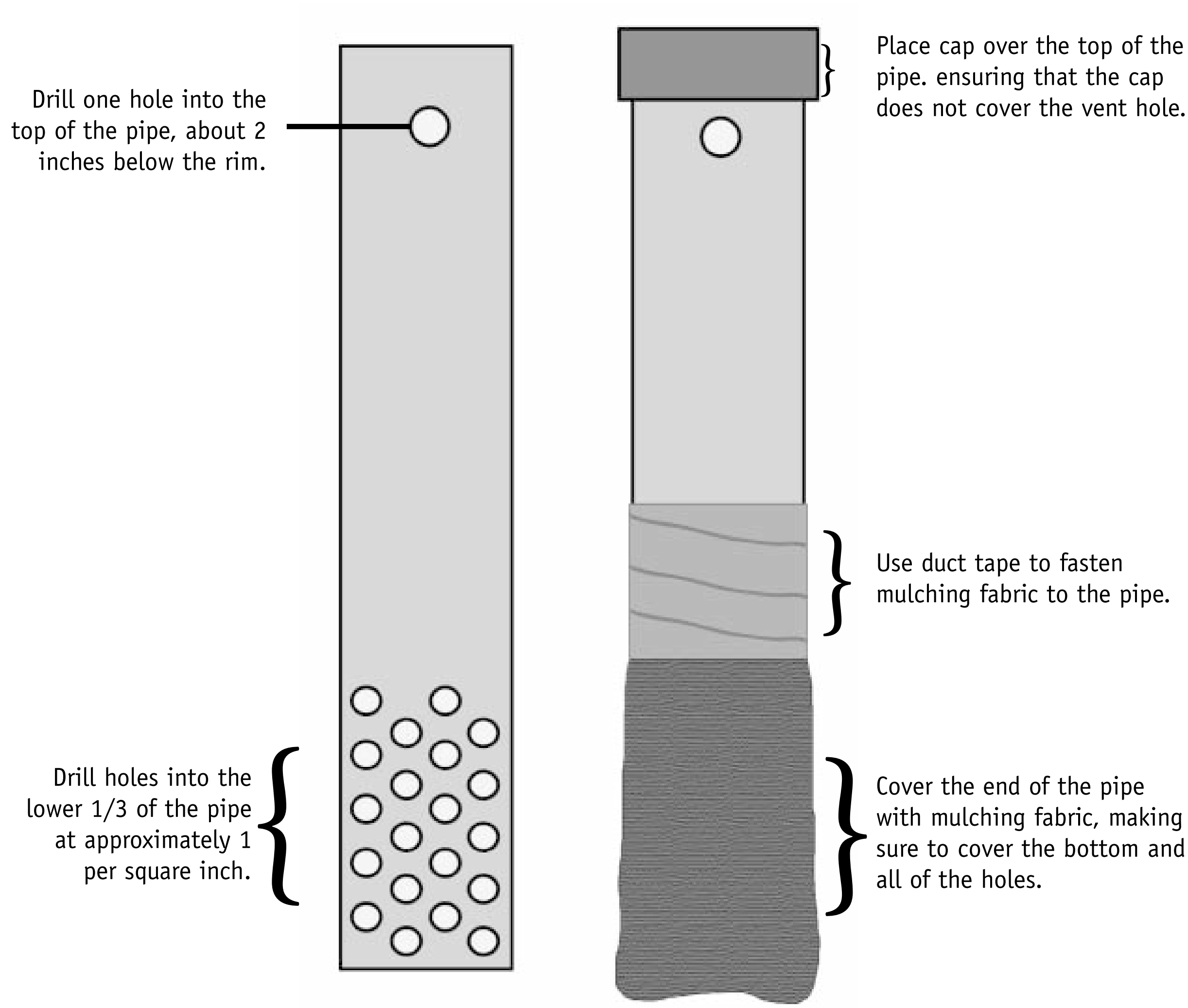


FIGURE 1. GROUNDWATER WELL ASSEMBLY See text for details.

Sampling Location

The number of sampling stations depends on the specific objectives of the study design. Obviously, increasing the number of sampling stations will increase your understanding of salinity regimes, but also requires more time, effort, and equipment. Investigators need to find a balance between data quantity and available resources (time and money). The protocols in this manual call for a minimum of six sampling stations per site, which includes three sampling stations located along two **transects** that bisect the **wetland evaluation area**. The textbox on the following page provides an example of the types of questions investigators should consider when establishing sampling locations.

Specific Guidelines for Transect & Sampling Locations

1. At each site, establish two transects perpendicular to the tidal creek or shoreline from the bank to the upland edge of the salt marsh. Transects should originate 150 feet and 300 feet from the tide restriction along the salt marsh creek (Figure 2). If you are studying a marsh that borders open water (not a tide restriction study), then establish two transects at opposite ends of the wetland evaluation area.
2. Install two groundwater wells along each transect, one closer to the bank (Well A) and the second near the upland edge of the salt marsh (Well B).
3. Collect surface water samples where each transect meets the creek channel, ditch, bay, or pond.

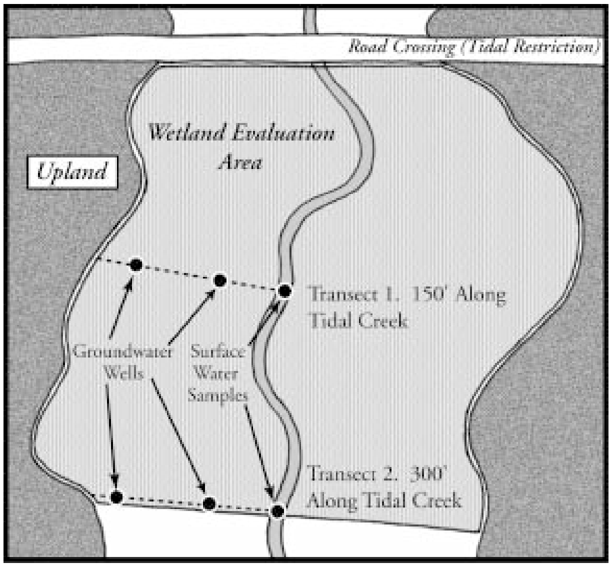


FIGURE 2. SAMPLE LOCATIONS
This figure shows transects and sample locations for one side of a tide restriction study. See text for details.

Data Collection

A **refractometer** is used to measure salinity. There are several different types of refractometers and users should be familiar with the specific instructions for their instrument. It is important that the refractometer have internal temperature compensation, otherwise the readings will have to be adjusted. Users must calibrate the refractometer before each sampling run, and rinse and dry the sensor (prism) with deionized water between readings.

At the minimum, collect samples monthly from July through September. Volunteer groups may want to collect samples more frequently, but as stated previously, investigators need to find a balance between data quantity and available resources. Volunteers should collect salinity measurements at low, late ebbing, or early flowing tides, as long as there is no surface water on the marsh near the wells. If there is surface water on the marsh, you should return later when the tide is low.

Specific Procedures for Collecting Samples

1. Use a hand-held pump to remove standing water from the groundwater well and wait for a few minutes until the well refills with pore water. This ensures that the water sample consists of pore water and not rain or surface water.
2. To be time efficient, pump out all wells within the marsh first, and then revisit them to obtain salinity readings.
3. Once a sufficient amount of water has recharged the well, extract a water sample using a **bailer**. Rinse the bailer with tap water before collecting water samples.
4. Pour the water sample from the bailer into a clean, dry Dixie® cup.
5. Use a plastic pipette (rinsed with deionized water between samples) to transfer sample water from the Dixie® cup to the sensor on the refractometer.
6. Read water salinity according to specific instructions for your refractometer.
7. Record the salinity measurement on the field data sheet.

To collect water from the creek channel, ditch, bay, or pond, use a Dixie® cup, bailer, or a cup on a pole depending on how easy it is to reach the water. If using either the bailer or a pole, be sure to rinse those pieces of equipment with tap water prior to use.

PLACEMENT OF GROUNDWATER WELLS

Where on your transect do you place Well A and Well B? Well A is installed closer to the salt marsh creek than Well B, which is located near the upland edge of the marsh. Vegetation patterns within the marsh may influence your decision on where to place the wells. Here is an example of this thought process:

You are standing on a transect in a marsh study site and just placed Well A in a *high marsh* community dominated by *Spartina patens* and *Distichlis spicata*. While determining where to install Well B, you notice a stand of *Scirpus robustus* (Salt marsh bulrush) near the upland edge of the salt marsh you are studying. Your research indicates that this plant species enjoys more brackish conditions. Is there a fresh groundwater seep in your salt marsh? Does this area of marsh receive an abundance of freshwater runoff? You decide to place Well B within that stand of *Scirpus robustus* to better understand the salinity patterns at work there.

Volunteers being trained to monitor salinity. **Photo: Vivian Kooken**

DATA ENTRY

Volunteers should use one field data sheet for both the study site and **reference sites**. A blank standard field data sheet is provided in Appendix 1 of this chapter. Project leaders can modify field data sheets according to specific objectives of the study. For example, studies that examine additional study and reference sites, transects, or groundwater wells will need to adjust field data sheets accordingly.

Data entry occurs both in the field and in the office. Users should carefully record all of the information requested on the field data sheet, and make sure that site-specific information is recorded in the proper location. The standard field data sheet is organized to clearly distinguish study sites, transects, and sampling stations. Investigators should fill out field forms neatly and thoroughly to ensure that no critical information is omitted. It is frustrating to return to the office or laboratory after a long day in the field and realize that you forgot to record important information!

In the office, investigators should transfer data into a computer spreadsheet such as Microsoft Excel. On the computer spreadsheet, create clearly-marked columns for site name, date, transect number, station, time of high tide, time sampling began, and salinity. Tables 2 and 3 show example data for a study site and reference marsh in Gloucester, Massachusetts; only data for transect #1 is shown and it is intended for illustrative purposes only. Table 2 has row (1-13) and column (A-G) identifiers that are used to identify individual cells, similar to how a computer spreadsheet is organized.

Looking through a refractometer. **Photo: Vivian Kooken**

TABLE 2. EXAMPLE DATA ENTRY SPREADSHEET

	A	B	C	D	E	F	G
1	**SITE**	**DATE**	**TRANSECT**	**STATION**	**TIME OF HIGH TIDE**	**TIME BEGIN SAMPLING**	**SALINITY (PPT)**
2	Gloucester-Study	7/13/00	1	Channel	10:31	16:00	25.0
3	Gloucester-Study	7/13/00	1	Well A	10:31	16:00	18.0
4	Gloucester-Study	7/13/00	1	Well B	10:31	16:00	11.0
5	Gloucester-Ref	7/13/00	1	Channel	10:31	16:00	26.0
6	Gloucester-Ref	7/13/00	1	Well A	10:31	16:00	20.0
7	Gloucester-Ref	7/13/00	1	Well B	10:31	16:00	15.0
8	Gloucester-Study	8/2/00	1	Channel	23:09	11:30	7.0
9	Gloucester-Study	8/2/00	1	Well A	23:09	11:30	8.0
10	Gloucester-Study	8/2/00	1	Well B	23:09	11:30	5.0
11	Gloucester-Ref	8/2/00	1	Channel	23:09	11:30	12.0
12	Gloucester-Ref	8/2/00	1	Well A	23:09	11:30	20.0
13	Gloucester-Ref	8/2/00	1	Well B	23:09	11:30	7.0

TABLE 3. EXAMPLE AVERAGE SALINITY DATA

SITE	**TRANSECT**	**STATION**	**SALINITY (PPT)**	**FORMULA** (from Table 2)
Gloucester - Study	1	Channel	16.0	=average(G2,G8)
Gloucester - Study	1	Well A	13.0	=average(G3,G9)
Gloucester - Study	1	Well B	8.0	=average(G4,G10)
Gloucester - Study	1	Combined	12.3	=average(G2:G4,G8:G10)
Gloucester - Reference	1	Channel	19.0	=average(G5,G11)
Gloucester - Reference	1	Well A	20.0	=average(G6,G12)
Gloucester - Reference	1	Well B	11.0	=average(G7,G13)
Gloucester - Reference	1	Combined	16.7	=average(G5:G7,G11:G13)

Once you have entered all of your data (2 sites x 2 transects per site x 3 stations per transect x 3 sample dates = 36 salinity measurements), create a second table to compute average values for different combinations of sample date, site location, transect, and station location; specific combinations will depend on the scope of your salinity study. You may customize the spreadsheet to calculate average salinity for each station using formulas shown in Table 3.

DATA ANALYSIS AND COMPARISON

Once investigators complete data entry and compute average salinity, they can graph average salinity to provide a visual representation of salinity differences between the study site and reference site (Figure 3).

Volunteers can review data sets in the field after completing salinity sampling to get a sense of the salinity regimes within the salt marsh. However, one day's worth of salinity measurements gives only a snapshot of the salinity levels within a marsh. Volunteers can get a much better understanding of salinity regimes by taking multiple measurements over time, averaging these measurements, and comparing averages between wells, transects, or sites.

Two common comparisons are:

- Compare salinities at different sampling stations within a marsh. This may provide insight on the spatial extent of seawater inundation and influence within a marsh, and can help explain distribution patterns of plants and animals.

- Compare salinities at different marshes, such as the study site and reference site. This may provide insight about the effect of a tidal restriction on salinity regimes, and/or help explain why the plant and animal communities differ between two marshes.

	Salinity (ppt)	
Station	**Study Site**	**Reference Site**
Channel	27.5	30.7
Well A	28.9	31.3
Well B	27.5	28.7
Combined	28.0	30.2

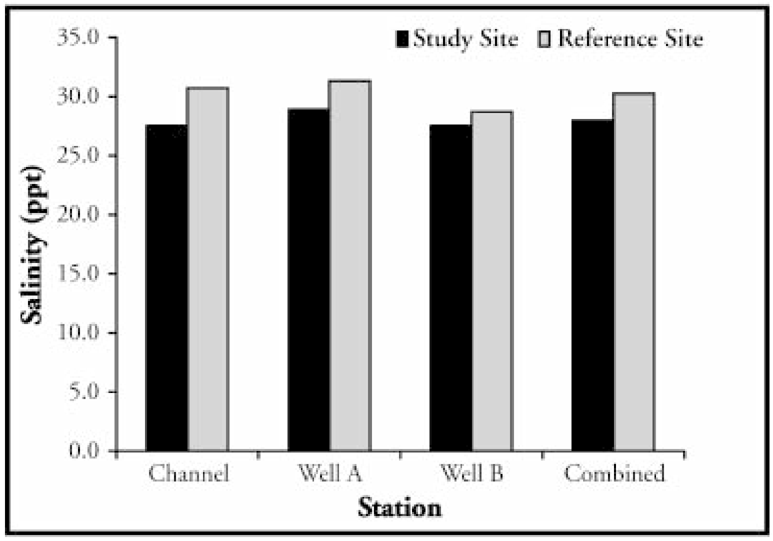


FIGURE 3. DISPLAYING AVERAGE SALINITY

Comparing average salinity data is subjective. It is important to note the error of the refractometer used to measure salinity, which may be as much as 1.0 ppt. Only salinity differences that exceed the error of the refractometer are considered significant. At what point is the difference in salinity between two marshes large enough to warrant closer examination? This is a difficult question to answer, and is usually left to the project leader. If volunteers detect a large difference in the salinity regime of two marshes, they should carefully examine all potential causes and the consequences for the marsh **community**. In many instances, salinity regimes differ because of natural phenomena, and investigators should not necessarily presume that humans are responsible.

References and Other Suggested Reading

Brown, M.T., K. Brandt, and P. Adamus. 1990. Indicator fact sheets for wetlands. In: *Ecological Indicators for the Environmental Monitoring and Assessment Program* (Hunsaker and Carpenter, eds.). US EPA, Office of Research and Development. EPA 600/3-90/060.

Carlisle, B.K., A.L. Hicks, J.P. Smith, S.R. Garcia, and B.G. Largay. 1998. *Wetland Ecological Integrity: An Assessment Approach: The Coastal Wetlands Ecosystem Protection Project.* MCZM, Boston, MA.

Hemmond, H.F. and J. Benoit. 1988. Cumulative impacts on water quality functions of wetlands. *Environmental Management* 12(5):6639-6653.

Leibowitz, N.C. and M.T. Brown. 1990. Indicator strategy for wetlands. In: *Ecological Indicators for the Environmental Monitoring and Assessment Program*. Hunsaker and Carpenter (Eds.) US EPA, Office of Research and Development. EPA 600/3-90/060.

NOTES

chapter eight

APPENDICES

APPENDIX 1. SALINITY FIELD DATA SHEET

Salinity Field Data Sheet

Names of Volunteers: ______________________________

____

Site Name: ____________________ Date: ____________________

Time of Low Tide: ____________________ Time of High Tide: ____________________

Approximate Tide at Time of Sampling:

LOW HIGH OUTGOING INCOMING

STUDY SITE (UPSTREAM OF TIDAL RESTRICTION)

TRANSECT 1	SALINITY (PPT)
CHANNEL WATER	
WELL A	
WELL B	

TRANSECT 2	SALINITY (PPT)
CHANNEL WATER	
WELL A	
WELL B	

REFERENCE SITE (DOWNSTREAM OF TIDAL RESTRICTION)

TRANSECT 1	SALINITY (PPT)
CHANNEL WATER	
WELL A	
WELL B	

TRANSECT 2	SALINITY (PPT)
CHANNEL WATER	
WELL A	
WELL B	

ADDITIONAL OBSERVATIONS: (incl. weather) ______________________________

____

chapter nine

TIDAL HYDROLOGY

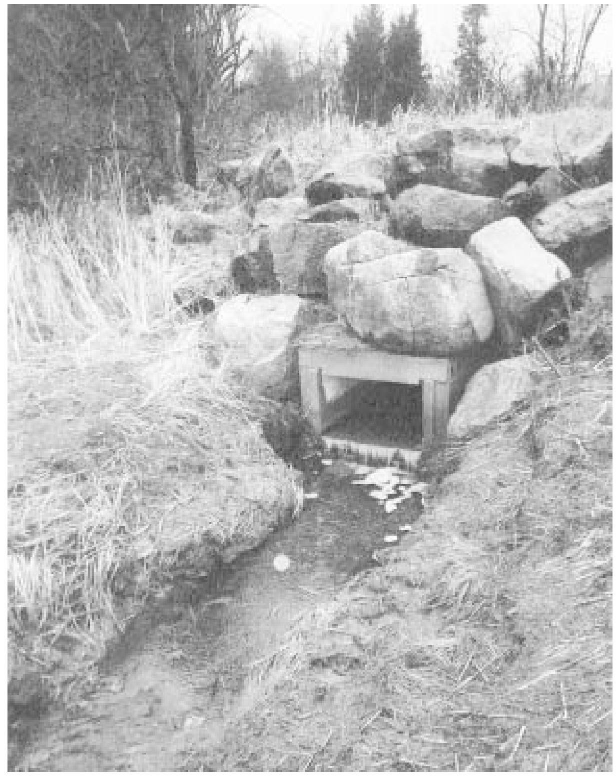
The presence, type, and potential effects of **tide restrictions** are critical information for salt marsh **monitoring** and assessment. Tidal influence is an important **parameter** to measure, and along with salinity can provide a very good understanding of the effect of tide restrictions on the physical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

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 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 possibly wetness, 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 "onion-shaped pools," which form on either side and directly next to the culvert.

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 parts per thousand (ppt), the invasion of opportunistic brackish plants such as *Phragmites australis* (common reed) becomes a problem. Tide restrictions may also block the passage of estuarine invertebrates and fish into the upper estuary, and reduce 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.

A culvert placed too high in relation to the tidal creek. **Photo: Vivian Kooken**



An undersized culvert. **Photo: Vivian Kooken**

EQUIPMENT

Volunteers need some basic equipment to monitor tidal hydrology (Table 1), though this parameter is less expensive and easier to measure than most of the other parameters in this manual. Biodegradable paint or a waterproof marker and a weighted tape measure are required for the reference mark technique. Ideally, the measuring tape should be an open reel fiberglass variety, although other types may be more appropriate for your specific conditions. You should attach a lead weight or small stone to the end of the tape measure using duct tape. The added weight helps keep wind or water currents from moving the tape measure. Be sure that by adding weight you are not also adding extra length to the tape measure because this could affect your measurements.

The staff gauge technique requires the construction or purchase of two staff gauges (one each for the study site and reference site). Staff gauges are essentially large rulers staked in a fixed position, and are used to measure water levels. You can construct staff gauges from a variety of materials, and the only requirement is that they be durable and appropriate for the site location, budget, and needs of the investigators. Rustproof materials that can withstand wind and water currents work best. It is common to use PVC pipe to construct gauges, with units marked with paint or permanent marker. Another option is to use metal pre-marked gauges attached to garden stakes or fence posts. Our advice is to use cheap, readily available materials and your imagination!

The reference mark technique and staff gauge techniques both require field data sheets, pencils, a clock or watch, stopwatch, and clipboard. Extra copies of field data sheets and pencils are a good idea. As always, safety is your first priority. It may be desirable to have volunteers work in pairs, especially if the sampling site is in a remote location.

SAMPLING METHODS

Two different sampling methods — reference mark technique and staff gauge technique — can be used to collect tidal hydrology data at a tidal restriction. Since both of these sampling methods are easy and inexpensive, volunteer groups should employ both methods in their study. It is prudent to collect two independent data sets at the same time so that if an unforeseen problem arises with one method, you will still have one good set of data.

TABLE 1. EQUIPMENT FOR MEASURING TIDAL INFLUENCE

REFERENCE MARK TECHNIQUE
Waterproof marking material (biodegradable paint or permanent marker)
Tape Measure
Lead Weight or Small Stone
Watch or Clock
Clipboard
Field Data Sheets
Pencils
STAFF GAUGE TECHNIQUE
Staff Gauge
Hammer or Mallet
Watch or Clock
Clipboard
Field Data Sheets
Pencils

Reference Mark Technique

The idea behind the reference mark technique is that you can determine differences in tidal hydrology between a study site and a reference site by carefully measuring water levels at regular intervals over an entire tidal cycle. A reference mark is simply a fixed location, and the distance between a reference mark and the water's surface is used to measure tidal height. You can compute tidal range from this data, and differences in tidal range between a study site and a reference site indicates the overall effect of a tide restriction.

Step One: Fix a permanent or semi-permanent mark on both the study and reference sides of the tidal crossing from which to measure vertical distance to the water's surface. Here are some considerations for this important step:

- Place the mark on the head wall, bank, or bridge, depending on what is available.
- Reference points can be marked with either a small spot of paint or permanent marker and are best located near the center of the channel or where water is most likely to remain at low tide.
- You should visit the site at high and low tides prior to sampling to make sure that the mark is not covered during high tide and at low tide water does not recede beyond the vertical reach of the mark.

If your reference mark cannot be located above the high tide mark, it is possible to measure from the reference mark up to the surface of the water (Figure 1a). The easiest way to do this is to place a meter stick or staff gauge exactly perpendicular to the reference mark and record the distance between the mark and the water's surface. Be certain that the implement you choose uses the same units as your measuring tape. Alternatively, you can simply mark the distance from your reference mark to the water's surface with an unmarked pole and use the measuring tape to measure the length. Any measurements from the reference mark up to the water's surface must be recorded as negative numbers on the data sheet, and you should include notes to explain the change in sampling protocol. If high tide will cover your reference mark, make sure it is painted with a waterproof material!

You can use a couple different techniques if low water recedes beyond the vertical reach of the reference mark. The best solution is to use a leveled staff (such as a carpenter's level) to extend the reference mark horizontally far enough to reach the water (Figure 1b). You must be certain that the staff is level and at the same elevation as the reference mark;

Measuring tidal height using the reference mark method.

Photo: Vivian Kooken

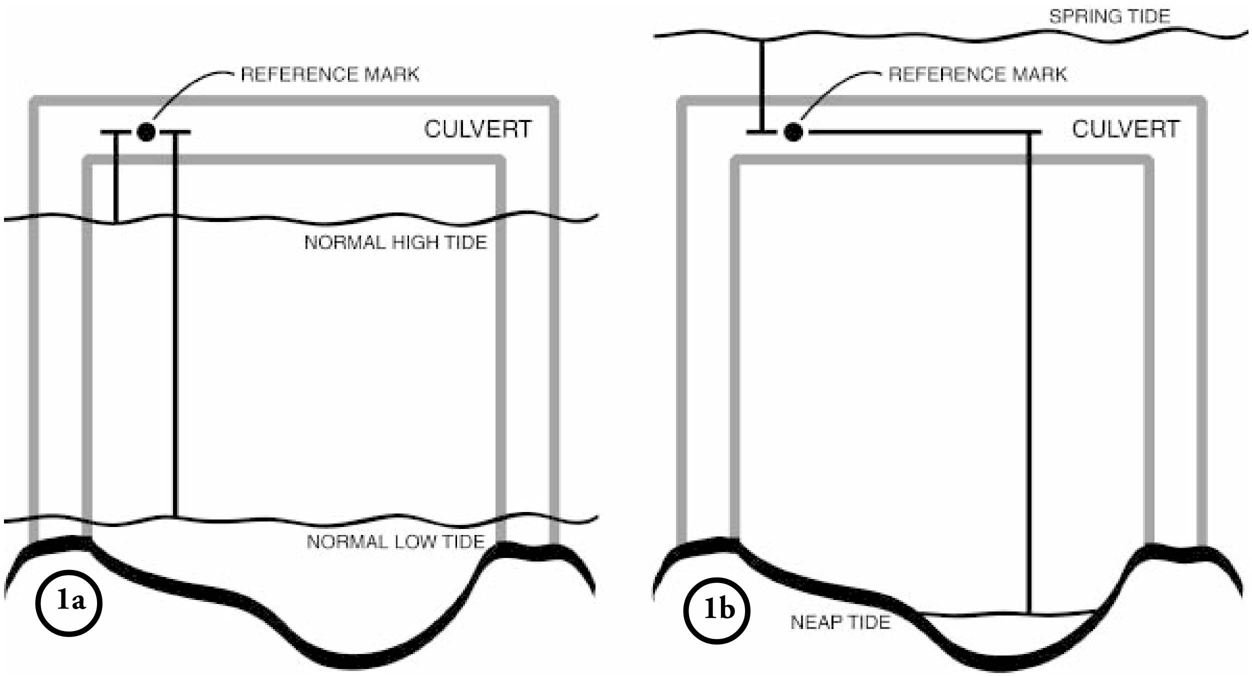


FIGURE 1. MEASURING TIDAL HEIGHT
Figure 1a shows how to measure tidal height from the reference mark when the reference mark is directly above the high water mark and low water mark. Figure 1b shows how to measure tidal height from the reference mark when the reference mark is below the high tide mark, or when water has receded below the vertical plane of the reference mark.

this is best accomplished with two people. You can still produce meaningful results by measuring from the reference mark to bare substrate as long as you record on the data sheet that there is no water. Finally, you can have more than one reference point for different stages of the tide as long as the relative vertical distance (elevation) between the marks are clearly marked on the data sheet.

Step Two: Gather necessary materials for data collection. The previous section lists and explains the equipment you will need.

Step Three: Collect the data. Using the tape measure, you should record distance from the reference mark to the water's surface every 15 minutes at both the study site and reference site. Fill out any other information required on the field data sheet.

Staff Gauge Technique

The staff gauge technique is similar to the reference mark technique and provides the same type of information. Staff gauges are commonly used to measure flood levels in rivers, and can often be seen bolted to bridge abutments. Staff gauges are graduated, meaning that units (feet or meters) are clearly written on the staff so that water levels can be recorded by simply looking at the gauge. The Equipment section describes how to construct or acquire staff gauges.

Step One: Find a suitable location for the staff gauges. You should investigate potential locations at different tidal stages to foresee possible difficulties with installation or sampling. You should try to install the gauge in an area of the creek that retains water at low tide, such as the center of the channel. However, be mindful of strong currents that may accompany incoming and outgoing tides, and if necessary place the staff closer to the bank. Strong currents can cause water to swirl around the base of the staff and make it difficult to take accurate readings, and currents can be dangerous for volunteers if they have to wade out to the staff.

Step Two: Install the staff gauges. Gauges should be installed a day or two before the sampling date to ensure they are in a suitable location. You should install staff gauges no further than 50 feet from the tidal restriction in both the study site and reference site. Two people may be necessary to install the gauge — one to hold the gauge while the other pounds it into the substrate with a hammer or mallet. Be sure to position the staff gauge so that the tick marks are readily visible by the observer.

A staff gauge installed on a culvert. **Photo: CZM Staff Photo**

Step Three: Gather necessary materials for data collection. The Equipment section lists and explains the equipment you will need for data collection.

Step Four: Collect the data. Record water levels (tidal height) on the staff gauges in the study site and reference site every 15 minutes, noting the time of day for each measurement on the field data sheet. Fill out any other information required on the field data sheet, such as names of investigators, date of sampling, and time of high tide.

Considerations for Both Methods

The field day should coincide with a particularly high tide, such as a "spring tide." On sampling day, record tidal measurements over a six-hour period, capturing both high and low tides. The six-hour period can be broken into shifts to shorten the amount of time that volunteers have to spend on the marsh. If using shifts, there should be a half-hour overlap between teams to be sure that the new team has a complete understanding of the sampling protocol. You may want to bring something to pass the time between readings. Good books and crossword puzzles can help ward off boredom! An egg timer might help to ensure you do not miss scheduled readings.

DATA ENTRY

Investigators should use a separate field data sheet for the study site and reference site. Also, use separate data sheets for the reference mark technique and staff gauge technique if you are planning to use both methods. A blank standard field data sheet is provided in Appendix 1 of this chapter. Basic information, such as the name of the observer(s), date, site name, site number, and the time of high tide at a specific station are included near the top of the field data sheet. Project leaders can modify field data sheets according to their specific objectives.

While in the field, it is extremely important to accurately record water height and time. It is essential not to confuse field data sheets, either between reference sites and study sites, or between staff gauge and reference mark techniques. If you are careful and thorough when filling out a field data sheet, there should be no confusion about where or how the data were collected and what the data represent. Confusion usually results from poor organization, such as mixing field data sheets from different sites or techniques and failure to completely fill out necessary information. One way to reduce confusion is to keep reference site and study site data sheets in their own clipboards and leave the clipboards on their respective sides of the tidal restriction.

In the office, investigators should transfer information on field data sheets into a spreadsheet program such as Microsoft Excel. Make any necessary unit conversions (such as feet to inches) when transferring the data from the field data sheet to the computer spreadsheet. The spreadsheet should have clearly marked rows and columns similar to Table 2. Table 2 is set up similar to a spreadsheet with column and row identifiers (letters for columns and numbers for rows), so that any cell in the figure can be identified. For example, cell D5 is located in column D and row 5.

TABLE 2. EXAMPLE DATA ENTRY SPREADSHEET

The following data table represents data collected using the reference mark technique, and is for illustration purposes only. See text for a complete explanation of this table and how to compute variables.

	A	B	C	D	E	F	G
1				**TIDAL HEIGHT (in)**		**CHANGE IN TIDAL HEIGHT (in)**	
2	**SITE**	**DATE**	**TIME**	**STUDY**	**REFERENCE**	**STUDY**	**REFERENCE**
3	Marsh X	8/15/01	0900	-29.61	-50.94	24.72	53.24
4	Marsh X	8/15/01	0915	-32.13	-25.86	27.24	28.16
5	Marsh X	8/15/01	0930	-26.61	-10.86	21.72	13.16
6	Marsh X	8/15/01	0945	-16.17	2.58	11.28	-0.29
7	Marsh X	8/15/01	1000	3.87	14.10	-8.76	-11.81
8	Marsh X	8/15/01	1015	14.79	22.14	-19.68	-19.85
9	Marsh X	8/15/01	1030	21.39	34.14	-26.28	-31.85
10	Marsh X	8/15/01	1045	25.35	33.06	-30.24	-30.77
11	**Average Tidal Height**			-4.89	2.30		
12	**Tidal Range**			57.48	85.08		
13	**Tidal Range Ratio**			67.56			
14	**Difference in Tidal Range**			27.60			

Steps in Data Entry

1. Enter site, date, and time intervals into the first three columns of the spreadsheet. Enter Tidal Height of the study site and reference site into columns D and E, respectively (Table 2). Raw data collected using the reference mark method can be entered directly into the spreadsheet for computation. Raw data collected using the staff gauge method must have reversed signs when entered into the spreadsheet. For example, enter any positive (+) numbers recorded on the field data sheet as negative (-) numbers in the spreadsheet, and visa versa.

2. Compute Average Tidal Height for the study site and reference site by averaging tidal height values over the entire time period. For example, in Table 2 enter the formula "=average(D3:D10)" into cell D11 to compute the average tidal height of the study site.

3. For each time interval, add the negative (-) tidal height at that time and station to the Average Tidal Height to compute Change in Tidal Height. For example, Change in Tidal Height for the first time interval at the study site is computed by typing the formula "=(-D3)+D11" into cell F3 of Table 2.

4. Compute Tidal Range by subtracting the minimum tidal height from the maximum tidal height over the entire time period. In Table 2, Tidal Range of the study site is computed by entering the formula "=max(D3:D10)-min(D3:D10)" into cell D12.

5. Compute Tidal Range Ratio by dividing the study site Tidal Range by the reference site Tidal Range. On Table 2, divide cell D12 (value = 57.48) by cell E12 (value = 85.08) and multiply by 100 to compute a Tidal Range Ratio of 67.56% (formula: "=(+D12/E12)*100").

6. Compute Difference in Tidal Range by subtracting the study site Tidal Range from the reference site Tidal Range. On Table 2, subtract cell D12 (value = 57.48) from cell E12 (value = 85.08) to compute a Difference in Tidal Range of 27.60 (formula: "=E12-D12").

DATA ANALYSIS AND COMPARISON

Data from the unadjusted reference marks and tidal gauges cannot be compared in raw form. Instead, data are analyzed as total change in the average tidal range on either side of a tidal restriction. The authors of this manual recommend that volunteer groups acquire the publication *Tidal Crossing Handbook: A Volunteer Guide to Assessing Tidal Restrictions* (Purinton and Mountain, 1998) before entering, analyzing, and comparing data [the publication is produced by the Parker River Clean Water Association (PRCWA), and their website is www.parker-river.org]. You should follow the steps outlined below to analyze and compare your data. This procedure is more completely outlined in Purinton and Mountain (1998).

Plot the Data

From Table 2, create a double line graph with columns F and G on the Y-axis and column C on the X-axis. The Y-axis represents the departure from mean tidal range, and the X-axis represents recorded time. Figure 2A-C (next page) provides three examples of what these graphs look like and how they are used to interpret data.

Difference in Tidal Range and Tidal Range Ratio

The difference in tidal range is computed by subtracting the study site tidal range from the reference site tidal range. This difference is the actual measurement of the amount of tidal restriction present on the day you measured — keep in mind that the height of tides varies from day to day according to factors like moon phase and wind speed and direction. This value should be a positive number because it assumes that the reference site has a greater tidal range than the study site. If the opposite is true and a negative number results, you may want to review the data collected to be sure the correct protocol was followed or revisit the overall study design. While the actual measurement of tidal range difference is important, the severity of the restriction is best understood by examining the Tidal Range Ratio.

The Tidal Range Ratio is computed by dividing the tidal range of the study site by the tidal range of the reference site. Multiply this ratio by 100 to express as a percentage. A tidal range ratio of 68% indicates that the study site receives only 68% of the tidal range experienced at the reference site. With free, unrestricted flow of the tides, the study site would have the same tidal range as the reference site (the tidal range ratio would be 1.0 and the percentage tidal range would be 100%). As the severity of the tidal restriction increases, so will the difference in tidal range between the two sites. Each **wetland** must be studied individually, however, to determine the effect of a tidal restriction on its ecology.

Using the data collected as part of a tidal influence study, as well as specific calculations such as the tidal range and tidal range ratio, provides valuable insight into the degree of tidal flushing at a specific salt marsh. Investigators can use this data to determine the presence, absence, or severity of a tidal restriction. When tidal influence data are coupled with biological monitoring, it can provide a better understanding of the effect of a tidal restriction on wetland ecology.

REFERENCES AND OTHER SUGGESTED READING

Mitsch, W.J. and J.G. Gosselink. 1993. *Wetlands.* Van Nostrand Reinhold Inc., New York, NY.

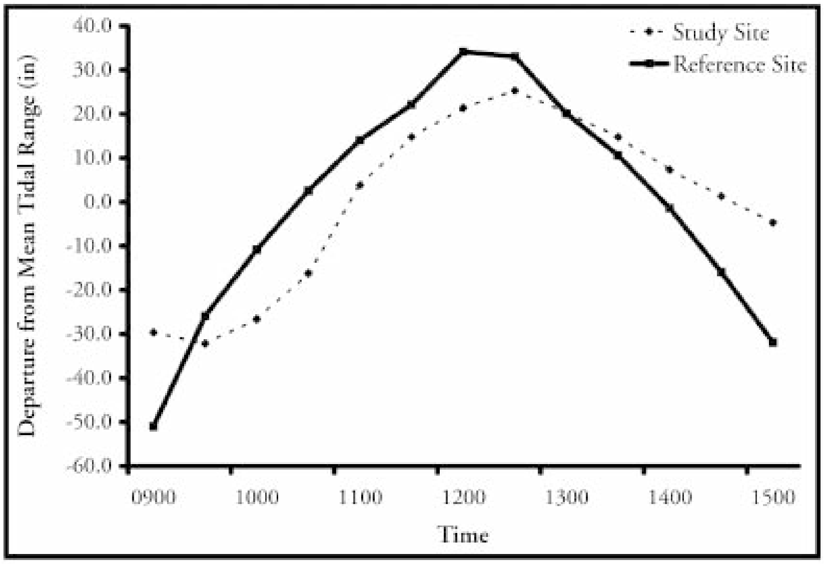
Purinton, T.A. and D.C. Mountain. 1998. *Tidal Crossing Handbook: A Volunteer Guide to Assessing Tidal Restrictions.* Parker River Clean Water Association, Byfield, MA.

Rozas, L.P. 1995. Hydroperiod and Its Influence on Nekton Use of the Salt Marsh: A Pulsing Ecosystem. *Estuaries* 18(4):579-590.

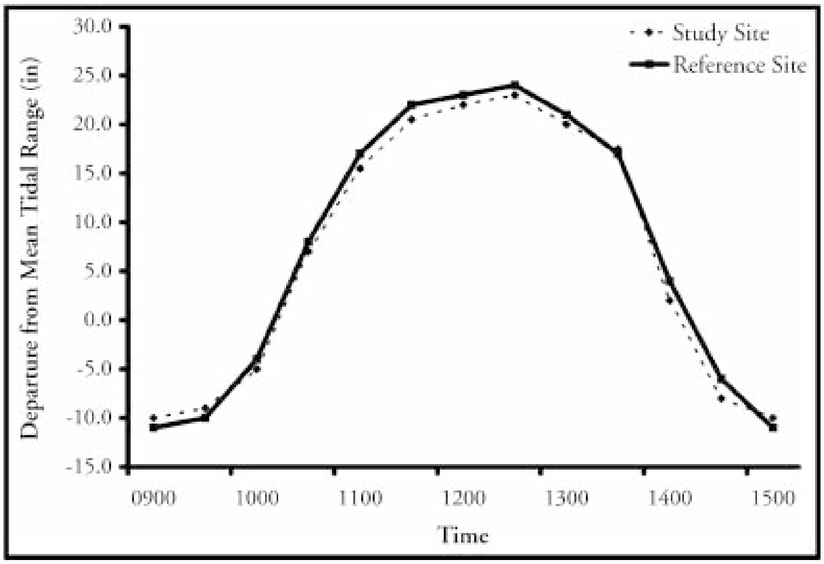
Sinicrope, T.L., G. Hine, R.S. Warren, and W.A. Niering. 1990. Restoration of an impounded salt marsh in New England. *Estuaries* 13(1):25-30.

FIGURE 2. TIDE RESTRICTION GRAPHS

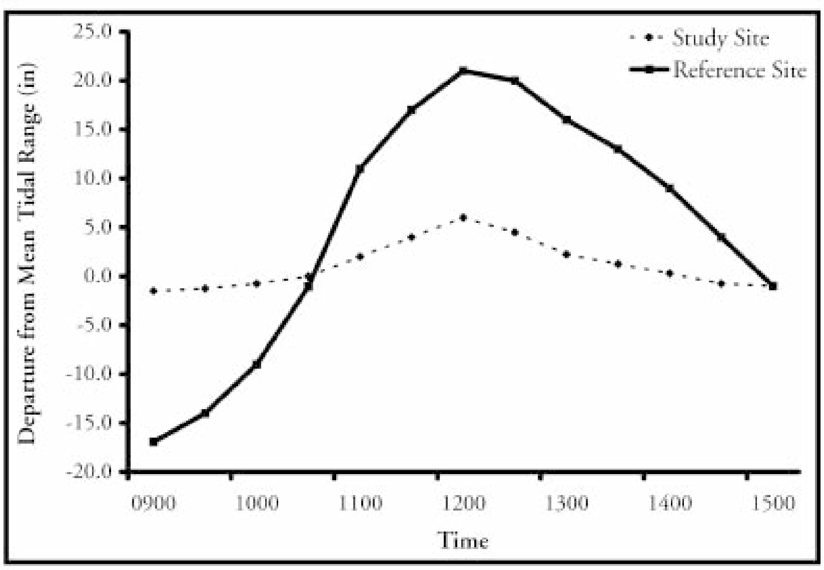
A. Tidal graph of a study site that has a culvert placed too high in relation to the creek bed, causing a tide restriction. The graph shows a delayed reaction to tidal changes, caused by the fact that the water level must rise at the reference site before it passes through the elevated culvert to the study site. The tidal peak at the study site occurs later than the reference site, and the study site begins draining after the reference site. The water level at the study site may not reach the low seen at the reference site because water gets trapped at the study site after the water level drops below the culvert.



B. Tidal graph of an unrestricted study site and reference site. The two lines are nearly identical, indicating little or no difference in tidal range between the two sites.



C. Tidal graph showing a severe tidal restriction caused by an insufficiently sized or collapsed culvert. The tidal peak occurs at the same time in the study site and reference site, but the change in tidal height is significantly less at the study site, indicating that water is prevented from flowing freely from one side of the marsh to the other.



chapter nine

APPENDICES

APPENDIX 1. TIDAL INFLUENCE FIELD SHEET

NOTES

TIDAL INFLUENCE FIELD SHEET

Site: ______________________________

Date: ______________________________

Investigators: ______________________________

____

High Tide: ______________________________ (Boston Harbor)

Circle One: **REFERENCE SITE** **STUDY SITE**

[If in doubt regarding study and reference sites, just select one side to be Site 'A' and the other Site 'B', keep these consistent throughout the sampling and describe each site.]

	TIDAL HEIGHT (METERS)	
TIME (EVERY 15 MINUTES)	STAFF GAUGE METHOD	REFERENCE MARK METHOD

appendix a

SALT MARSH RESOURCES AND CONTACTS

TECHNICAL RESOURCES EPA BIOMONITORING GUIDELINES

The U.S. Environmental Protection Agency has supervised the assembly of a series of guidelines on evaluating wetland condition. Teams of expert scientists formed the Biological Assessment of Wetlands Workshop Group (BAWWG) to pool their resources to compile these guidelines. Most of the guidelines deal specifically with freshwater wetlands, but many of the principles are applicable to evaluating salt marshes. The table below lists the series of guidelines that are available on the following EPA websites:

http://www.epa.gov/owow/wetlands/monitor/#meth
http://www.epa.gov/ost/standards
http://www.epa.gov/owow/wetlands/bawwg

"METHODS FOR EVALUATING WETLAND CONDITION" MODULES

MODULE #	MODULE TITLE
1	Introduction to Wetland Biological Assessment
2	Introduction to Wetland Nutrient Assessment
3	The State of Wetland Science
4	Study Design for Monitoring Wetlands
5	Administrative Framework for the Implementation of a Wetland Bioassessment Program
6	Developing Metrics and IBIs
7	Wetlands Classification
8	Volunteers and Wetland Biomonitoring
9	Wetland Biological Assessment with Invertebrate Indexes of Biotic Integrity
10	Using Vegetation to Assess Environmental Conditions in Wetlands
11	Using Algae to Assess Environmental Conditions in Wetlands
12	Bioassessment Methods for Amphibians
13	Biological Assessment for Birds
14	Wetland Bioassessment Case Studies
15	Bioassessment for Fish
16	Vegetation-Based Indicators of Wetland Nutrient Enrichment
17	Land-Use Characterization for Nutrient and Sediment Risk Assessment
18	Biogeochemical Indicators
19	Nutrient Load Estimation
20	Sustainable Nutrient Load

FEDERAL GOVERNMENT CONTACTS

National Park Service
Northeast Region
U.S. Custom House
200 Chestnut Street, 5th Floor
Philadelphia, PA 1906
(215) 597-7013
www.nationalparks.org

New England Biological Assessment of Wetlands Workshop Group (NEBAWWG)
U.S. Environmental Protection Agency
Region 1 (New England)
John F. Kennedy Building
Boston, MA 02203
(617) 918-1628
www.epa.gov/region1

New England Interstate Water Pollution Control Commission
Boott Mills South
100 Foot of John St.
Lowell, MA 01852-1124
(978) 323-7929
www.neiwpcc.org

NOAA Office of Ocean and Coastal Resources Management
1305 EW, Hwy, SSMC #4,
Room 10414
Silver Spring, MD 20910
(301) 713-3155
http://cdmo.baruch.sc.edu/

NOAA Office of Ocean and Coastal Resources Management
Sanctuaries and Reserves Division
1305 East-West Highway
Silver Spring, MD 20910
(301) 713-3478
http://cdmo.baruch.sc.edu/

U.S. Environmental Protection Agency
Wetlands Division
1200 Pennsylvania Ave. N.W. (4502F)
Washington, DC 2060
(202) 260-7717
http://www.epa.gov/owow/wetlands/bawwg

U.S. Fish and Wildlife Service
Region 5 - Northeast Regional Office
300 Westgate Center Drive
Hadley, MA 01035
http://northeast.fws.gov

STATE GOVERNMENT CONTACTS

Connecticut

Connecticut's Coastal Management Program
Office of Long Island Sound Programs
Department of Environmental Protection
79 Elm Street
Hartford, CT 06106-5127
(860) 424-3034
http://www.ocrm.nos.noaa.gov/czm/czmconnecticut.html

Connecticut Department of Environmental Protection
79 Elm Street
Hartford, CT 06106-5127
(860) 424-3034
www.dep.state.ct.us

Maine

Maine Coastal Program
Maine State Planning Office
38 State House Station
Augusta, ME 04333
(207) 287-3261
http://www.state.me.us/mcp/

Massachusetts

Massachusetts Bays Program
Executive Office of Environmental Affairs
251 Causeway Street, Suite 900
Boston, MA 02114
www.state.ma.us/czm/mbp.htm

Massachusetts Office of Coastal Zone Management
Executive Office of Environmental Affairs
251 Causeway Street, Suite 900
Boston, MA 02114
www.state.ma.us/czm/CZM.htm

Massachusetts Division of Marine Fisheries
Dept. of Fisheries, Wildlife and Environment
Law Enforcement
251 Causeway Street
Boston, MA 02114
(617) 72-3193
www.state.ma.us/dfwele/dmf/dmf_toc.htm

Massachusetts Wetlands Restoration Program
Executive Office of Environmental Affairs
251 Causeway Street
Boston, MA 02114
(617) 727-9800 x 213
www.state.ma.us/envir/mwrp

Riverways Program
Dept. of Fisheries, Wildlife and Environment
Law Enforcement
251 Causeway Street
Boston, MA 02114
(617) 727-1614 x 360
www.state.ma.us/dfwele/River/riv_toc.htm

New Hampshire

New Hampshire Coastal Program
2 1/2 Beacon Street
Concord, NH 03301
(603) 271-2155
www.state.nh.us/coastal

New Hampshire Division of Environmental Services
P.O. Box 95
Concord, NH 03302
(617) 271 4065
www.des.state.nh.us

New Hampshire Estuaries Program
2 1/2 Beacon Street
Concord, NH 03301
(603) 433-7187
www.epa.gov/owow/estuaries/nhe.htm

Rhode Island

Coastal Resources Center
Narragansett Bay Campus
University of Rhode Island
Narragansett, RI 02882
(401) 874-6224
http://www.crc.uri.edu/

Rhode Island Department of Environmental Management
235 Promenade Street
Providence, RI 02908-5767
(401) 277-6605
www.state.ri.us/dem

Save the Bay
434 Smith Street
Providence, RI 02908
(401) 272-3540
http://www.savebay.org/explorethebay/

OTHER ORGANIZATION CONTACTS

Audubon Society of New Hampshire
3 Silk Farm Road
P.O. Box 528-B
Concord, NH 03302-0516
(603) 224-9909
www.nhaudubon.org

Buzzards Bay Project
2870 Cranberry Highway
East Wareham, MA 02538
(508) 291-3625
www.buzzardsbay.org

Casco Bay Estuary Program
University of Southern Maine
49 Exeter Street
Portland, ME 04104
(207) 780-4820
www.cascobay.usm.maine.edu

Eight Towns and the Bay
160 Main Street
Haverhill, MA 01830
(978) 374-0519
www.thecompass.org/8TB

Great Bay Estuary Program
152 Court Street
Portsmouth, NH 03801
(603) 433-7187
www.inlet.geolsc.edu/GRB/related-sites.html

Great Bay National Estuarine Research Reserve
Sandy Point Discovery Center
Depot Road
Stratham, NH 03885
(603) 778-0015
www.greatbay.org

Long Island Sound Study
64 Stamford Government Center
888 Washington Boulevard
Stamford, CT 06904
(203) 977-1541
www.epa.gov/region01/eco/lis

Massachusetts Audubon Society: North Shore Conservation Advocacy
346 Grapevine Road
Wenham, MA 01984
(978) 927-1122
www.massaudubon.org/Birds_&_Beyond/IBA/sites/iba_nshore.html

Massachusetts Water Watch Partnership
Blaisdell House
University of Massachusetts
Amherst, MA 01002
(413) 545-2842
www.umass.edu/tei/mwwp

Narragansett Bay Estuary Program
235 Promenade Street
Providence, RI 02908
(401) 222-2165 x 7271
www.nbep.org

Narragansett Bay National Estuarine Research Reserve
55 South Reserve Drive
Providence Island, RI 02872
(401) 683-6780
http://www.ocrm.nos.noaa.gov/nerr/reserves/nerrnarragansett.html

Natural Heritage Endangered Species Program
Massachusetts Division of Fisheries and Wildlife
Route 135
Westboro, MA 01581
(508) 792-7270
http://www.state.ma.us/dfwele/dfw/nhesp/heritage.htm

Salem Sound 2000
201 Washington Street, Suite 9
Salem, MA 01970
(978) 741-7900
www.salemsound.org

Save the Sound, Inc.
185 Magee Ave.
Stamford, CT 06902
(203) 327-9786
www.savethesound.org

Waquoit Bay National Estuarine Research Reserve
P.O. Box 3092
Waquoit, MA 02536
(508) 457-0495
www.waquoitbayreserve.org

Wells National Estuarine Research Reserve
342 Laudholm Farm Road
Wells, ME 04090
(207) 646-1555
www.wellsreserve.org

Woods Hole Oceanographic Institute
Information Office, Co-op Building, MS #16
Woods Hole, MA 02543
(508) 548-1400
www.whoi.edu

Salt Marsh Monitoring Workshop Contacts

Massachusetts Bays Program
Executive Office of Environmental Affairs
251 Causeway Street, Suite 900
Boston, MA 02114
Attention: Jan Smith (617) 626-1231
www.state.ma.us/czm/mbp.htm

Salem Sound 2000
201 Washington Street, Suite 9
Salem, MA 01970
(978) 741-7900
www.salemsound.org

U.S. Environmental Protection Agency
Region 1 (New England)
John F. Kennedy Building
Boston, MA 02203
(617) 918-1628
www.epa.gov/region1

ADDITIONAL CONTACTS:

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.

Aggregate Weight: Total biomass of group of individual species.

Alga (Plural: 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.

Alga Mats: Floating clumps of algae.

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.

Archival Action: Stored away for future reference or further research.

Auger Sample: A field sample taken within the bottom substrate of a marsh using an auger.

Bailer: A device used to gather water from a groundwater well. A bailer is lowered into the well, a sample of groundwater is forced into the container, and the bailer is removed from the well with the sample.

Barrier Beach: Narrow, low-lying strips of shifting beach and dunes that are roughly parallel to the coastline, and are separated from the mainland by a body of water or wetland.

Bioassay: A sample of plant or animal tissue is analyzed for the concentration of a particular chemical or toxic substance.

Biological Community: See Community.

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.

Biomagnification: The process by which chemicals accumulate in the body tissue of organisms and increase in concentration as the chemical passes through successive trophic levels.

Catch Efficiency: The success of collecting species in an area.

Catch Per Unit Effort (CPUE): Standardized catch (number or weight of creatures) for a sample.

Catch Stability: The success of collecting species at different locations or times.

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

Composite Sample: A series of samples taken over a given period of time and integrated or combined by sample station or other variable (e.g. flow rate).

Debris: Unwanted material (either organic such as vegetation and peat, or mineral such as mud and sand) collected in a sample.

Deposit Feeder: Organism that scavenges food from materials at rest on substrate surfaces.

Detritivore: Organism that ingests either coarse or fine detritus pieces.

Detritus: Dead and decomposing plant and animal material.

Diversity: Variety or heterogeneity in taxonomic groups.

D-Net Sample: A field sample taken within the water column and substrate surface using a D-Net (a sampling net having an opening in the shape of a "D").

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.

Evaluation Tool: Any evaluation method (water quality analysis, biomonitoring method, remote sensing, etc.) used to evaluate the condition of a salt marsh.

Family: See Taxonomic Group.

Feeding Group: A related group of organisms that acquire food by the same means.

Filter Feeders: Aquatic organisms that obtain food by removing solid (particulate) matter from water.

Fin Rot: Abnormal area and/or injury to fleshy, spine, and/or ray appendage of bony fishes.

Food Web: The linkage of organisms based on their feeding relationships sources, or trophic interaction.

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

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

Grazer: An animal that eats living plant matter.

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.

Habitat Assessment: A method for evaluating the quality of the habitat of a particular group of organisms, e.g. invertebrates.

Habitat Assessment Score: A numerical score, expressed as a percentage, of overall habitat condition for a particular group of organisms.

Herbivores: An animal that eats living plant matter.

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.

Index (Plural: Indices): A value combining several metrics (or scores) into a single measure, integrating the information from the original measurements.

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

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 outcompeting native species.

Invertebrate: 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.

Invertebrate Community Index: A summary of all the metrics and indices that have been selected to evaluate the overall condition of the invertebrate community.

Land Use Analysis: An examination of landscape characteristics and indicators with an emphasis on human development patterns.

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.

Metric: Particular attribute of a biological community or taxonomic group that is expected to change in response environmental stressors and human disturbance.

Microtox: The means by which the toxicity of a chemical or other material is determined in microorganisms.

Mitigation: An action taken to moderate or alleviate environmental damage or degradation by improving, restoring, or replacing the affected natural resource (Adverb: Mitigative).

Mixed Feeding Group: Taxonomic groups that have more than one feeding group (e.g. deposit feeders and suspension feeders).

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.

Multiple Metric Index: A means to analyze the health of an ecosystem by combining several measured traits (usually of biological communities or habitat characteristics) into a single comprehensive score that can be compared to other locations or times.

Mutation: Change in the genotype of an organism occurring at the gene, chromosome, or genome level; frequently demonstrating evidence of change in phenotype (outer appearance).

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.

Opportunistic: A species (genus, family) that is able to compete advantageously during periods of stress, both natural and human-induced, by colonizing new areas or expanding existing habitat.

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).

Parasite: An organism that derives benefit from another organism (host) without providing benefit to the host.

Phytoplankton: Minute, free-floating aquatic photosynthetic plankton (mainly unicellular algae).

Plot Sample: A field sample technique that gathers information from an area enclosed within the dimensions set by a frame of a standard size.

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.

Predator: An organism that hunts and consumes other animals.

Preservative: A chemical solution that preserves the condition of dead organisms.

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 wetland evaluation area of a salt marsh site selected to conduct field sampling.

Sensitive: Organisms that have a low tolerance of pollution and disturbance, whose numbers tend to decrease with impact.

Skin Lesions: Abnormal area on outer layer of body; normally present due to injury or disease.

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.

Species: See Taxonomic Group.

Stressor: See Environmental Stressor.

Sub-Sample: A small but representative portion of a sample, usually taken when a very large number of organisms are in the sample and it is not practical to identify and count each individual.

Substrate: 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.

Suspension Feeders: Organism that filters fine organic particles from the water column for food.

Taxon (Plural: Taxa): The organisms comprising a particular classification group, e.g. a particular phylum, class, order, family, genus, or species.

Taxonomic Group: Phylum, class, order, family, genus, species, and related sub-divisions of these groups.

Taxonomist: An expert in the skills of systematic classification of organisms.

Taxonomy: The study of the relationships and classification of organisms.

Tide 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.

Toxicity Test: The means by which the toxicity of a chemical or other test material is determined.

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

Variable: See Parameter.

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.

Wetland Evaluation Area: See Evaluation Area.

Woody Debris: Dead logs, limbs, sticks, etc.

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.