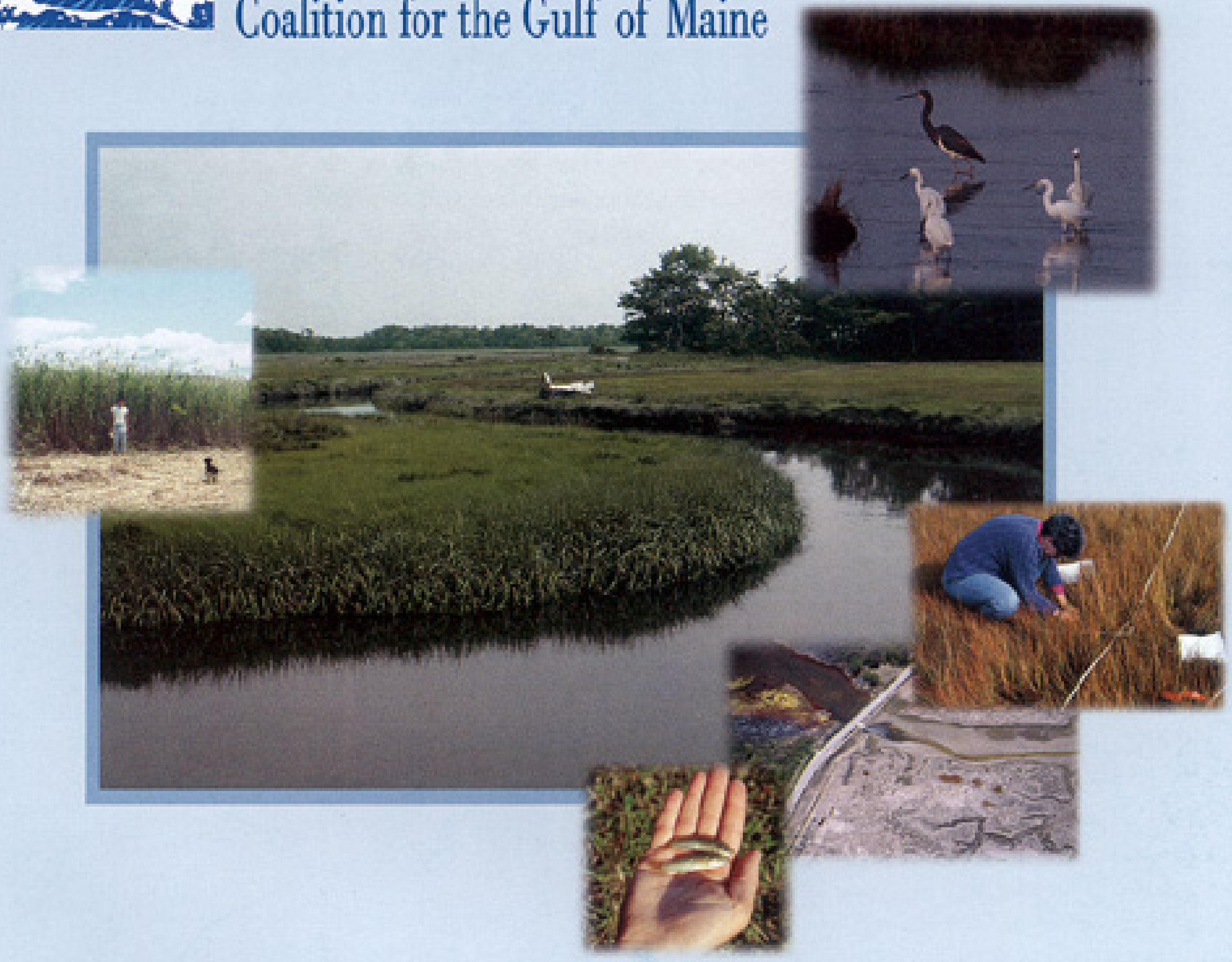
Global Programme of Action
Coalition for the Gulf of Maine



Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine

A GPAC WORKSHOP REPORT

Wells National Estuarine
Research Reserve
June 2-3, 1999

THIS REPORT WAS PRODUCED IN ASSOCIATION WITH:

CCE CCA CEC
Wells National Estuarine Research Reserve
National Estuarine Research Reserve System
NOAA
USGS science for a changing world

Published by the Wells National Estuarine Research Reserve

For more information about this report or to obtain additional copies contact:

The Wells National Estuarine Research Reserve
Research Department
342 Laudholm Farm Road
Wells, ME 04090
Tel: (207) 646-1555❖Fax: (207) 646-2930

E-mail: wellsnerr1@cybertours.com
Internet: http://www.wellsreserve.org

For information about this or other publications from the CEC, contact:

Commission for Environmental Cooperation
393, rue St-Jacques Ouest, bureau 200
Montreal (Quebec) Canada H2Y 1N9
Tel: (514) 350-4300❖Fax: (514) 350-4314

E-mail: info@ccemtl.org
Internet: http://www.cec.org

Cover Photo Collage

Background photo: mid-tide in an unaltered salt marsh (i.e., no tidal restrictions). Foreground photos clockwise from top right: wading birds foraging in a salt marsh panne; volunteer sampling vegetation on high marsh (orange color of grass indicates a fall rather than a summer sample date); road crossing with undersized culvert alters hydrology, functions and values of upstream marsh (photo taken at low tide in early spring); the mummichog *(Fundulus heteroclitus)* plays an important role in the marsh food web; *Phragmites australis* (commonly referred to as Phrag), a brackish marsh plant that can become invasive in salt marsh areas where elevations and/or hydrology have been altered. Credits: wading birds by B.A. King, aerial photo by J.List, others by M. Dionne.

Illustrations on pages 5 and 9 by Thomas R. Ouellette, 57 Hany Lane, Vernon, CT 06066 (860) 872-6180

Report Photo Credits: M. Dionne unless otherwise noted.

Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine

A GPAC Workshop
June 2-3, 1999

Report Edited By
Hilary Neckles, Workshop Co-Chair
US Geological Survey
Patuxent Wildlife Research Center
26 Ganneston Drive
Augusta, ME 04330
and
Michele Dionne, Workshop Co-Chair
Wells National Estuarine Research Reserve
342 Laudholm Farm Road
Wells, ME 04090

Table of Contents

Robert Shetterly

PREFACE

The Global Programme of Action Coalition for the Gulf of Maine (GPAC) was brought together by the commission for Environmental Cooperation (CEC), a North American organization which fosters environmental cooperation on transboundary issues between the United States, Canada, and Mexico. This binational effort is in response to the United Nations Environment Program's global action plan to reduce degradation of marine and coastal environments. It is internationally recognized that about eighty percent of marine pollution is caused by human activities on land. GPAC has been working for over two years to facilitate the implementation of the United Nations' global plan through the various communities, organizations, industries, and governments of the Gulf of Maine.

In 1998 GPAC engaged in a series of broad discussions via two regional workshops to identify the primary land-based threats to the Gulf of Maine marine environment and to develop actions for reducing or eliminating their impacts. These discussions highlighted the importance of tidal wetlands to the ecology, economy, and sustainability of coastal ecosystems and some critical gaps in their conservation, restoration, and management throughout Gulf of Maine jurisdictions. The workshop on "Regional Standards for Identifying and Evaluating Tidal Wetland Restoration in the Gulf of Maine" was supported by GPAC as an initial effort to address some of these gaps on a regional scale.

On behalf of GPAC, we would like to extend our sincere thanks to all who participated in the workshop and who contributed to its success. We particularly thank the Workshop Steering Committee for adding substance to GPAC's vision and the Wells National Estuarine Research Reserve for graciously hosting the workshop.

The results of the workshop presented in this volume provide the basis for developing some binational programs to enhance tidal wetland restoration across the Gulf of Maine. We are pleased to have been able to help in establishing an international network that has been greeted with enthusiasm on both sides of the US-Canada border, and we wish you continued success as these programs are implemented throughout the region.

GPAC Co-chairs:

Joe Arbour
Environment Canada

Katie Ries
National Ocean Service, National Oceanographic and Atmospheric Administration

ACKNOWLEDGEMENTS

We thank the Commission for Environmental Cooperation, the Laudholm Trust, and the Wells National Estuarine Research Reserve for sponsoring the "Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine" workshop, held on June 2-3, 1999. This workshop and report represents the culmination of research planning efforts initiated at a 1996 New England Estuarine Research Society Symposium on the ecology of marsh-estuarine ecosystems in the Gulf of Maine, funded by planning grant BIR-95222314 from the National Science Foundatin to the Wells National Estuarine Research Reserve.

We also express our sincere appreciation to the Workshop Steering Committee for the months spent in organizing the workshop (see Appendix B for a complete listing). Special thanks go to committee members Arnold Banner, Robert Buchsbaum, David Burdick, Ted Diers, Eric Hutchins, and Charles Roman for leading work group breakout sessions and contributing their respective summaries to this report, and to Kim Hughes for focusing discussions on the concluding day of the workshop. Patrick Ewanchuck and Erno Bonebakker provided very helpful comments during final document review. In addition, we thank workshop speakers Katie Ries, of NOAA's National Ocean Service and GPAC, and Jeffrey Benoit, of NOAA's Office of Ocean and Coastal Resource Management, for their inspiring remarks.

We are extremely grateful to the Wells National Estuarine Research Reserve (WNERR) for hosting the workshop. Without the enthusiastic and professional support of Kent Kirkpatrick, Director of the WNERR, and Kathryn Davis, President of the Laudholm Trust, this workshop would not have been possible. Most importantly, we thank workshop coordinator Nancy Bayse for making the workshop and this report a reality. Her expert management and production skills, dedication, and unfailing good humor were the key ingredients to workshop success.

Finally, we thank the participants who generously devoted the time to attend the workshop. Their input forms the basis of this report.

Workshop Co-Chairs:
Hilary Neckles, US Geological Survey, Patuxent Wildlife Research Center
Michele Dionne, Wells National Estuarine Research Reserve

Citation Information

Neckles, H.A. and M.Dionne, Editors. 2000. Regional standards to identify and evaluate tidal wetland restoration in the Gulf of Maine. Wells National Estuarine Research Reserve Technical Report, Wells, ME. 21 p. plus appendices. Chapter authors are identified within the report. Individual chapters should be cited as, e.g. Burdick,D.M. 2000. Ecosystem indicator:hydrology. p 7-9 in H.A. Neckles and M.Dionne, Editors. Regional standards to identify and evaluate tidal wetland restoration in the Gulf of Maine. Wells National Estuarine Research Reserve Technical Report, Wells, ME.

Introduction

Restoration of tidal marshes in the Gulf of Maine has gained considerable momentum during the last ten to fifteen years. (Dionne et al. 1998) Following several centuries of human activities that have altered, degraded, or destroyed a large proportion of the tidal marshes in the region, the emphasis of many federal, state, provincial, and nongovernmental programs is now on restoring the natural hydrology and functional values of these systems. Restoration efforts include proactive projects that increase the amount and improve the quality of coastal habitats, and mitigation projects to compensate for permitted impacts to tidal wetlands. Despite this emphasis, however, the overall effectiveness of tidal marsh restoration in the Gulf of Maine is uncertain. Contributing to this uncertainty are a lack of comprehensive baseline information on sites available for restoration, widely varying degrees of restoration project monitoring, inconsistencies in monitoring data collection, and a paucity of scientifically defensible criteria for determining restoration success.

Undersized culverts significantly reduce tidal flow into marsh systems.

In 1999, the Global Programme of Action Coalition for the Gulf of Maine (GPAC) initiated a regionally coordinated project to address these needs. The goals of the projects are to develop a Gulf of Maine-wide inventory of potential salt marsh restoration sites and a regional monitoring network of restored and reference salt marshes. On June 2-3, 1999, a workshop was hosted by the Wells National Estuarine Research Reserve in Wells, Maine to develop the common protocols needed to establish these regional programs. Over the course of a day and a half, resource managers, scientists, and members of community organizations from the United States and Canada reached consensus on standard methods for inventorying restoration opportunities and for monitoring restoration efforts.

This report summarizes the resulting tidal marsh inventory model and monitoring protocols for the Gulf of Maine.

Dionne, M., D. Burdick, R. Cook, R. Buchsbaum, S. Fuller. 1998. Scoping Paper 5: Physical alterations to water flow and salt marshes. Commission for Environmental Cooperation. Montreal, Canada. 57p. and appendices.

Overview of the GPAC Initiative

The Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) was developed under the auspices of the United Nations Environment Programme to assist national and regional authorities in reaching the goal of "sustainable seas". The three North-American countries – Canada, Mexico, and the United States – were among the more than 100 signatories who agreed in 1995 to strengthen national, regional and global arrangements for addressing marine degradation from land-based pollution and activities.

The Commission for Environmental Cooperation (CEC) was established in 1994 by Canada, Mexico, and the United States under the North American Agreement for Environmental Cooperation to address transboundary environmental concerns, help prevent potential trade and environmental conflicts, and promote the effective enforcement of environmental law. The agreement complements the environmental provisions of the North American Free Trade Agreement (NAFTA).

In pursuing its mandate, the CEC is promoting two pilot projects in North America to help implement the GPA. The Gulf of Maine was selected as the focus of one of those projects. To carry out this binational effort, the CEC helped establish GPAC, a broad group of individuals from Canada and the United States with interest in the Gulf of Maine and the GPA. This group includes representatives of the federal governments of Canada and the United States, governments of the provinces (New Brunswick and Nova Scotia) and states (Maine, New Hampshire, and Massachusetts) bordering the Gulf of Maine, Native American tribes, First Nations of Canada, industry, community action groups, environmental advocacy groups, and research and academic institutions.

GPAC is intended to form the basis for continued regional cooperation and joint actions in marine and coastal areas of the Gulf of Maine. GPAC set a strategic course based on the principles of the GPA and is working toward the following vision for the future:

"A healthy marine and coastal environment in the Gulf of Maine where human use and biological diversity thrive in harmony."

To help implement the GPA in the Gulf of Maine, GPAC draws from and builds on the existing work of the Gulf of Maine Council on the Marine Environment, the Regional Association for Research in the Gulf of Maine, the CEC, and other organizations and individuals committed to the protection of this shared public resource of world-class cultural, economic and ecological value.

In 1998, GPAC sponsored two workshops to identify threats from land-based activities to marine and coastal habitats of the Gulf of Maine and determine strategies and measures to address these threats. Participants representing a broad range of disciplines, interests, and organizations developed a list of priority pollution and habitat issues requiring Gulf-wide action at the first workshop, which was held in Saint John, New Brunswick on April 27-28. These priority issues were combined into 5 broad categories, one of which focused on Physical Alterations to Water Flow and Salt Marshes. At the subsequent workshop in Portland, Maine on November 15-17, participants reviewed existing activities in the Gulf of Maine region related to these priority issues, identified gaps in current environmental protection and land-use programs, and proposed a series of actions to protect the coastal and marine environment from pollution and disturbance arising from land-based activities. Through this process, the need for a Gulf-wide inventory of potential tidal marsh restoration opportunities and regionally applicable standards for evaluating tidal marsh restoration projects emerged as high priorities. The workshop described in the following pages represents the next step toward addressing these needs on a regional basis.

Workshop Process

Workshop deliberations occurred within groups devoted to one of four topics: site inventory, monitoring marsh physical characteristics, monitoring plants and habitat mapping, and monitoring animals.

Workgroup discussions were guided strongly by existing information. For example, various tidal marsh inventory models are in use within specific jurisdictions of the Gulf of Maine region, each including certain site characteristics to be evaluated with varying degrees of overlap (Appendix C). Similarly, a number of protocols also exist for monitoring restored tidal marshes in the region, some of which emerged from previous workshops on the same subject (Appendix C). This information provided a critical springboard for work group discussions.

Inventory work group participants used existing databases to propose data fields for inclusion in the regional site inventory database model. To be selected as a field for the regional database structure, the required information was determined to be regionally applicable, reasonably available, and relevant to making decisions on costs and benefits of potential and completed restoration actions.

Existing protocols for monitoring restoration projects were distilled into a list of potential variables for consideration by the monitoring work groups. Work group participants evaluated potential variables in terms of critical information gained, feasibility, cost (in U.S. dollars), the skill level required for measurement, and spatial and temporal sampling frequency. In recognition that application of a lengthy, complex monitoring protocol on a large scale would be cost prohibitive, participants were asked to reach consensus on a minimum number of core variables to include in a standardized, regional protocol. Participants also recommended the "best" protocol by identifying additional variables, techniques, sampling periods, etc. to be included in a monitoring project as resources allow.

Product Design

The protocols developed at the workshop are intended to serve as springboards for assessments of Gulf of Maine salt marshes that are either likely candidates for restoration or that are being restored. To be most successful, these assessments will involve the combined efforts of practicing environmental professionals and members of volunteer, community based organizations. The products of this workshop are intended for use by professionals to plan inventory and monitoring projects, and for professionals and volunteers working in partnership to actually undertake projects. Consequently, the level of detail presented here assumes professional involvement. As presented, these methods will assure the consistency of data collection efforts required for implementation on a regional scale. We expect that in most cases, more detailed procedures of field techniques will be compiled to guide on-the-ground data collection.

Database Model for Restoration and Reference Site Inventory

Work Group Participants

Summary by: Eric Hutchins-NMFS, Arnold Banner-USFWS, John Catena-NMFS, Lou Chiarella-NMFS, Pascal Giasson-NB DNRE, Jennifer Graham-Ecology Action Center, Kim Hughes-NB Dept. of the Env., Chuck Katuska-MA Wetlands & Banking Program, Tim Purinton-Northeast Wetlands Restoration,Vic Pyle- Restore America's Estuaries, Aviva Rahmani-Ghost Nets, Bob Rutherford- NS Dept. of Fisheries & Oceans.

Rationale

The work group agreed on the following database structure to inventory existing and potential tidal marsh restoration sites. Data fields were selected based on regional applicability, availability of information, and relevance for making decisions on costs and benefits of completed and potential restoration actions. A Regional Inventory Data Sheet and list of regional inventory coordinators are included in Appendix D.

Aerial View of Webhannet Marsh, within Wells NERR and Rachel Carson NWR, Wells, ME

Core Variables

- **Site I.D.:** two letter state/province ID followed by consecutive numerals, max. of five characters, e.g. MA1, MA2, MA3,….MA99
- **Project Name:** subjective name, maximum of forty characters, e.g. Conomo Point
- **Town/City:** town, city, maximum of forty characters, e.g. Manchester-By-The-Sea
- **Waterbody:** closest waterbody identified from a 1:24,000, 7.5 minute quadrangle map produced by the US Geological Survey or a 1:50,000 map produced by Energy, Mines, and Resources, Canada, maximum of forty characters, e.g. Saratoga Creek
- **Latitude/Longitude:** a point near center of restoration site, including degrees, minutes and seconds, e.g. 40° 18' 23" N, 70° 34' 45" W
- **Owner:** public and/or private, and/or Non-Profit Organization; enter owner acronym or abbreviation if known, otherwise use PUB/PRV/NPO, maximum of 15 characters, e.g. USFWS/PRV/NPO
- **Historic Condition:** pre-impact National Wetlands Inventory Classification (US) or Canadian Wetlands Atlas Classification (Can) or specific species, maximum of 30 characters, e.g. E2EM/S.patens
- **Nature of Alteration:** select from following list: tidal restriction, fill, stormwater, bulkhead, ditching, salt hay, other; maximum of 40 characters, e.g. tidal restriction/stormwater
- **Impacts:** consequence of alteration from following list: drained marsh, impounded, flooded, invasive vegetation, other; maximum of 40 characters, e.g. drained marsh/invasive vegetation
- **Area:** practicable area of enhancement/restoration in square meters; this is the area improved, not just the area worked on (e.g. dam removal area would be large, but the area restored could be small) maximum 12 characters, e.g. 8,000 m^2
- **Restoration Action:** select from following list: fill removal, stormwater treatment, culvert enlargement, ditch plugging, other, maximum 40 characters, e.g. fill removal/ stormwater treatment
- **Estimated Cost:** three ranges, (<10K), (10K – 100K) or (>100K), maximum 10 characters, e.g. 10K – 100K
- **Actions:** check all that apply from the following list and record date of entry: none, pre-monitoring, permitted, implementation, post-monitoring, e.g. pre-monitoring, permitted, implementation, 9/00
- **For More Information:** two names and contact info. for additional information, e.g.John Catena, NMFS, 1 Blackburn Drive, Gloucester, MA 01903, P: 978-281-9313, Email: John.Catena@noaa.gov

Baseline Habitat Mapping

Work Group Participants

Summary by: Charles Roman-USGS, and Ted Diers-NH Coastal Program, Sarah Allen-Normandeau Assoc., Bruce Carlisle-MA CZM, Carolyn Currin-NOAA, Pam Morgan-UNH, Frank Richardson-NH DES, Peter Shelley-Conservation Law Foundation, Lee Swanson-NB DNR.

Rationale

The base map provides a foundation for monitoring activities. The purpose of the core variables defined below is to provide the basic minimum information on the location and fundamental features of the restoration site (locus map, key physical and cultural features, latitude and longitude), the general ecological condition of the marsh (cover type mapping), and potential stresses on the marsh (adjacent land use). The base map provides a template for location of specific sampling sites and offers a baseline for spatial change analyses (e.g. cover type changes over time).

Core Variables

- **Locus Map:** state, province, city or town of salt marsh monitoring site
- **Key locator and cultural features associated with monitoring site:** e.g. rivers, roads, culverts
- **Delineated wetland area/cover types:** salt marsh, fresh/brackish marsh, forested wetland, shrub dominated wetland, open water (creeks, pannes, pools, ditches), invasive species or species of interest, e.g. Phragmites. If available, National Wetland Inventory (US) or Canadian Wetlands Atlas (Can.) delineations would be appropriate
- **Manipulations:** pre- and post-restoration, e.g. culverts, dredging, removal of fill, excavations, addition of fill, etc.
- **Sampling locations:** pre- and post-restoration monitoring (transects, plots, etc.)
- **Base map documentation:** sources of base map (USGS or Canadian topographic maps, aerial photographs including scale, type, and date, tax maps, National Wetland Inventory database, other), scale of map and north arrow, latitude and longitude

Great Blue Heron, *Ardea herodias and*
Snowy Egret, *Egretta thula*
Photograph by B.A. King

Mapping Methods

Methods used to prepare the base map will be directly dependent on the capabilities and facilities available to the site participants. The most fundamental base map would be intitiated with a 1:24000 scale topographic map, whereas more sophisticated maps would use an orthophoto base and geographic information systems (GIS) capabilities. A base map developed with a GIS platform will have the greatest long-term utility and will be easily modified as data sets become available. It is strongly recommended that GIS be utilized if possible.

There are several approaches to cover type mapping. First, the US Fish and Wildlife Service National Wetland Inventory (NWI) database or the Canadian Wetlands Atlas may have mapped wetland cover types for the monitoring site. State and provincial resource managment agencies are also good sources of cover type maps. The NWI maps are presented on a 1:24,000 base. Oftentimes these maps are based on older photography (i.e., 1970's-80's) and may need to be field verified for accuracy. Recent aerial photographs (preferably vertical) are another highly useful source for developing or verifying the cover type base, but on-site ground truthing is always required. State and provincial agencies can also be good sources of aerial photography.

Skill Level

All components of the base map, except for cover type mapping, can be accomplished by volunteers, with minimal initial guidance by professionals. Cover type mapping will require involvement of professionals with training in photointerpretation and field ground-truthing; however, with training and oversight, volunteers could accomplish these tasks. The more sophisticated base maps or series of base maps will be developed through GIS platforms for which extensive training and computer facilities are required.

Cost

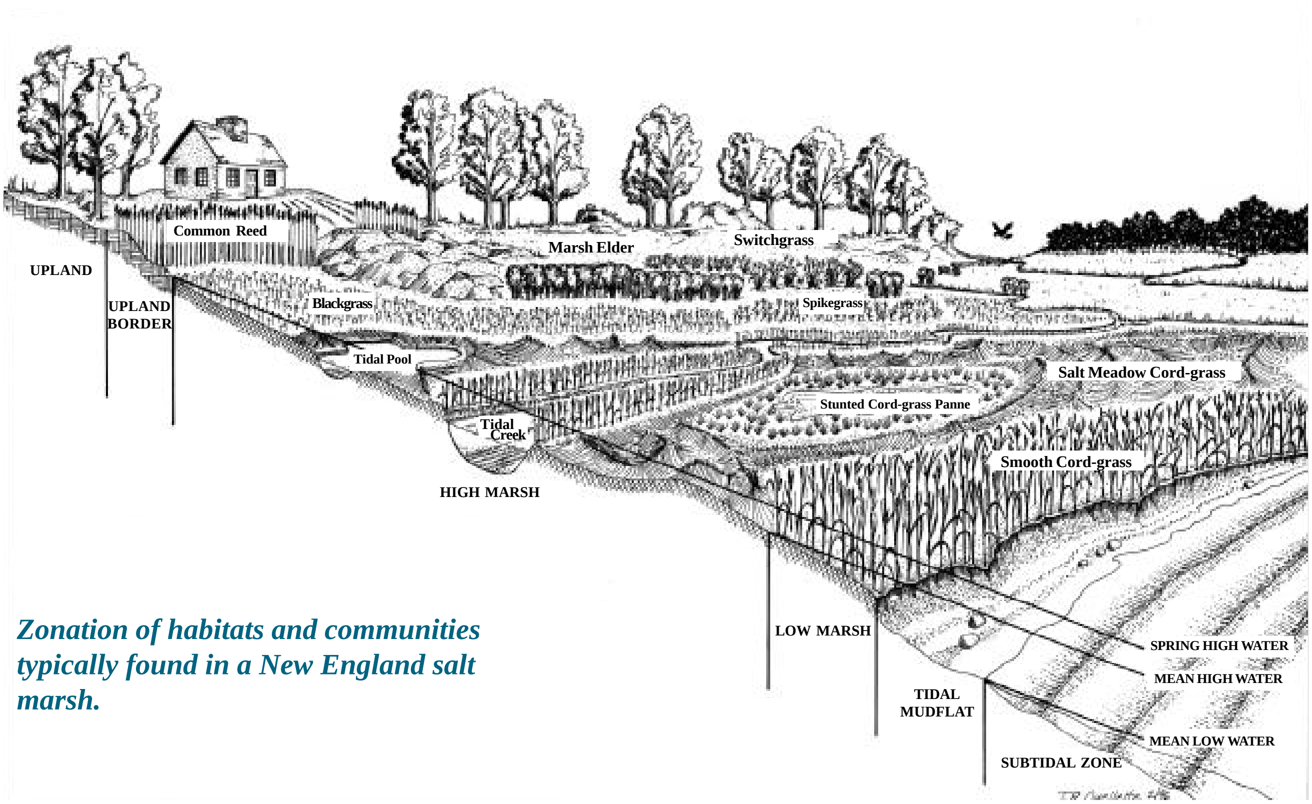
Costs for development of the base map will vary depending on the degree of professional involvement. It would be ideal to engage the time and facilities of a GIS professional for development of the base map. University environmental labs and environmental state, provincial, and federal agencies all have excellent GIS capabilities. The minimum base map could be prepared in 4-6 weeks time by a GIS professional at an estimated cost of up to $5,000 - $10,000. This includes compiling the spatial data, interpreting aerial photography, and ground-truthing. The cost could be reduced significantly through the use of trained volunteers. In addition, it may be possible to involve a GIS professional as a public agency's contribution to total project costs.

Additional Variables

Some sites and investigators with access to extensive map files, aerial photography libraries, and GIS capabilities may develop comprehensive base maps. Given these capabilities, it may be appropriate to include additional information on the base map including: detailed cover-type mapping, ownership boundaries, elevation contours, soil organic content, and 100 yr floodplain boundary.

Selected References

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deep-water habitats of the United States FWS/OBS-79-31. 103p.



Zonation of habitats and communities typically found in a New England salt marsh.

Thomas R. Ouellette

TIDAL MARSH RESTORATION MONITORING

The following monitoring protocol for tidal wetlands is based on a set of core variables within broad categories of wetland structural and functional responses to restoration. In selecting core variables, work group participants considered the integrative properties of various potential measures and the ease and cost of application on a regional scale. In some cases, certain variables and sampling schemes emerged as ideally suited for regional implementation; in others, trade-offs between information content and expediency were required.

The variables and methods identified here represent only one of several ways to characterize marsh response. Collectively, these variables provide a cost-effective and scientifically valid approach for monitoring restoration projects in a consistent manner throughout the Gulf of Maine region.

The core variables included in the protocol are the minimum deemed necessary to evaluate responses of tidal marsh ecosystems to restoration. These variables should be monitored at all sites included in the regional network. Restoration projects differ in goals, scope, and availability of resources for monitoring, so that additional monitoring of individual projects may be warranted. Additional variables are recommended within each monitoring category for application to specific projects. Each section also lists several key references that provide more thorough background and rationale for variable selection and some overviews of sampling methods.

Restoration sites should be paired with "undisturbed" natural reference marshes for monitoring, and ideally, restored and reference systems should be monitored both before and after the restoration is completed. Natural wetlands are not true controls, but serve as reference systems for determining whether restoration goals are being met, and they may be essential for distinguishing responses to restoration from natural background variability.

Natural marshes used as reference systems must be in a similar physical setting as the restoration projects to which they are being compared. Thus salt marsh reference sites should be selected to be similar to restoration projects in terms of uncontrolled variables such as temperature, geomorphology, potential tidal range, elevation, landscape position, adjacent land use, and water quality. Many restoration efforts in the Gulf of Maine focus on removing obstructions to tidal flooding caused by roads, dikes, or undersized culverts. In some instances, an appropriate reference site may be found downstream from the tidal restriction, although it is recognized that downstream and upstream portions of marshes may exhibit different salinity regimes and support different ecological communities. A well-studied marsh may also serve as an appropriate reference.

Robert Shetterly

Valid statistical comparisons between pre- and post-restoration conditions and between restored and reference marshes depend in large part on the independence of replicate samples and consequent experimental error terms. More generally, statistical models assume zero correlation among experimental replicates. Truly random sampling provides necessary and sufficient insurance against violating this assumption. All of the sampling methods described here that depend on statistical tests to make inferences about the marsh ecosystem assume some type of random sample allocation. The number of samples needed depends on the size and complexity of the marsh being described, the variability of the parameter being measured, and the desired precision of the estimate. If preliminary sampling is possible, then the number of observations needed to achieve a certain statistical power can be based on the estimated population variance. Practically, given that the precision of estimates increases with sample number, more samples are usually better. In general, the sample sizes included in the protocol were intended for typical Gulf of Maine marshes up to about 20 ha in size. Large systems with complex hydrologies and broad elevational ranges may require greater sampling efforts.

Ecosystem Indicator: Hydrology

Robert Shetterly

Work group Participants

Summary by: David Burdick-UNH Jackson Estuarine Lab., Kim Hughes-NB Dept of Environment, Hilary Neckles-USGS, Richard Orson-Orson Environmental Assoc., Edward Reiner- US EPA, Henry Rines-Applied Science Associates, Inc., Jan Taylor-USF&WS, Larry Ward-UNH Jackson Estuarine Lab.

Rationale

The fundamental control on the structure and function of salt marsh habitat is flooding with salt water. Hydroperiod is the amount of time, in terms of frequency and duration, that the area is flooded. The hydroperiod within a marsh is determined by the tidal signal and elevation.

The most common impacts to salt marshes in the Gulf of Maine are caused by hydroperiod alterations resulting from tidal restrictions caused by roads, railroads, or other obstructions to tidal flow; restoration focuses on increasing tidal exchange. Hydroperiod alterations can also result from mosquito ditching, an extensive practice in Gulf of Maine marshes. Methods are being developed to restore natural hydrology to ditched marshes.

Although tidal predictions may be available for astronomical tides affecting coastal areas close to the restoration site, local variation (naturally and resulting from human activities) makes it imperative to obtain actual measurements at the specific location to be restored. Similarly, the elevation of the marsh surface relative to the tidal height must be measured.

The monitoring methods outlined are appropriate for many types of salt marsh restorations. Because of the prevalence of tidally restricted marshes in the Gulf of Maine, data collection for this type of restoration is stressed.

Tidegates deprive salt marshes of essential tidal flow. These gates, on Back River Creek, Woolwich, ME have been removed.

Core Variables

- **Tidal Signal:** The pattern of water level change (maximum of 15 minutes between measurements) with respect to a reference point
- **Surface Elevations:** Marsh surface elevation (contour intervals of 15 cm or less)

Sampling Methods

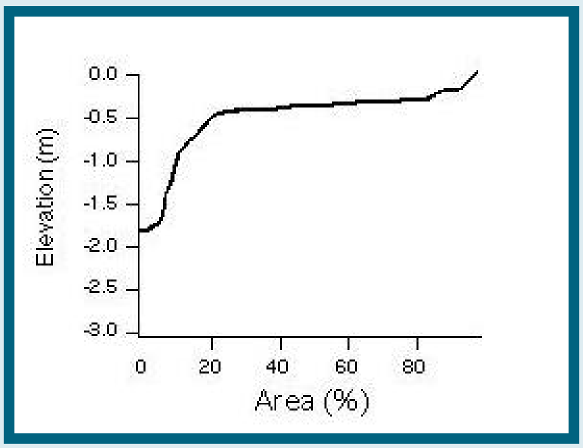
Two types of data are needed to describe the hydroperiod; each must be collected within the entire area affected by the planned restoration. These data will be used to assess the potential hydroperiod, to understand the relationship between flooding and habitat type and to predict the habitat that could result under different restoration and management options.

Tidal Signal

Automatic water level recorders should be operated simultaneously for a minimum of two weeks, i.e., one lunar cycle of spring and neap tides (one month, or two lunar cycles is better) near the source of tidal influx. For tidally restricted marshes, recorders should be installed both upstream and downstream of the tidal restriction. Either a water level gauge or pressure transducer would produce a tidal curve yielding the necessary data. Lacking access to an automated water level recorder, 10-minute measurements over 13-hour periods using a simple tide staff (a vertical ruler fixed in the tidal channel) for three spring and three neap tides would provide adequate information. Using either method, the elevations of the upstream and downstream devices are required, preferably referenced to NGVD (National Geodetic Vertical Datum). At a minimum, the relative elevations of the water level recorders in the impacted and reference marshes must be known.

Surface Elevations

There are two acceptable approaches to obtain this second type of data needed to calculate hydroperiod. Both require the skills of professionals. The preferred approach is to produce a contour map of marsh elevations throughout the entire area to be restored, e.g. both upstream and downstream of a restriction. The contours must be at 15 cm intervals or smaller to make meaningful predictions regarding habitat. The area of marsh flooded by a particular tide or the amount of time it is flooded per month can then be calculated (hydroperiod). Lacking the resources to produce such a map, relative elevations of 40 to 100 randomly selected points can be used to produce a hypsometric curve. These points can be obtained by taking measurements at regular 5-10 m intervals, e.g. every 5 meters along transects running across the marsh from high tide line to high tide line, as delineated by the wrack line around the marsh perimeter. Application of the hypsometric curve to marsh surface area provides an estimate of the amount of marsh area flooded for any particular tidal height and, coupled with the tidal signal, can yield the hydroperiod.



Example of a hypsometric curve.

Sampling Design

Tidal signal data should be collected for a period of 2-4 weeks prior to the restoration and soon after restoration. The number of elevation data points needed to generate a contour map or hypsometric curve will depend on the area and the morphology of the marsh. Elevations need to be measured only once, but close to the date of restoration. Subsequent measures of tidal signal or surface elevations can be left to the discretion of the responsible management agency, but should be performed at least every 5 years. For tidally restricted marshes, information should be obtained both above the restriction and in an adjacent area of marsh below the restriction.

Skill Level

Tidal signal measurements using pressure transducers or tidal gauges require professionals for installation, data collection, data reduction and interpretation. Tidal staffs installed by professionals may be read and recorded by volunteers, but data should be reduced and interpreted by professionals. Marsh surface elevations and correction to NGVD as well as map or hypsometric curve generation require professionals.

Cost

Costs are estimated for work performed in one sampling period (e.g. pre-restoration, post restoration year one, year five, etc.) at a site no larger than 10 hectares (22 acres). For variables that require more sampling at larger sites, costs will be greater. Collection of tidal signal data using 2 automated recorders requires about $1500 for equipment, 2-4 days of professional work for deployment and data collection and 1-3 days of professional work for data processing. Alternatively, use of tide staffs would require about $200 for equipment, and 2-4 days of professional work for data processing. Generating a contour map requires about $1500 for equipment, 3 days of field work and 2-4 days of professional work. Alternatively, generating a hypsometric curve of marsh elevations requires about $500 for equipment, 2 days of field work, and 2-4 days of professional work. Survey and other equipment can often be borrowed from agencies or academic institutions.

Additional Variables

Tidal Creek Cross-Sections

Cross-section profiles of major tidal creeks can be measured prior to restoration and at 2-3 year intervals post-restoration. Profiles are measured using standard survey techniques, with special care not to damage the escarpments. The position of the profile should be carefully marked so that the identical cross-section can be monitored following restoration.

Downloading water quality data collected by data logger

Water table depth

Under circumstances where an important goal of the restoration project is to increase tidal flooding to reduce invasive upland or wetland species, water table depth monitoring is recommended. Changes in water table can be monitored with wells or piezometers (wells open only near the base for the sole purpose of observing groundwater levels) placed deep enough in the soil to intersect the water table during drier periods. Piezometers can be constructed from PVC pipe with a screened, perforated interval that intersects the water table. Stations should be placed according to recommendations given for soil salinity stations (see Soils and Sediments section) as well as along the upland edge of the marsh or in populations of plants that should be affected by the restoration action. Sampling should occur at low tide about 6 times a year in the early to mid growing season and include neap and spring tides. Volunteers can assist with sampling.

Surface water quality, salinity, and other characteristics

If an important goal of the restoration is to improve water quality, water quality parameters should be included in project monitoring. Sample stations could be established along the main stem of the channel. Measurements of dissolved oxygen, salinity, temperature and pH may be accomplished using an automated data logger. Manual data collection can be accomplished with portable dissolved oxygen and pH meters. These should include pre-dawn and noon measurements collected on outgoing spring and neap tides. Carefully trained volunteers can measure surface water quality with a high degree of accuracy and precision.

The salinity of the water within tidally-restricted marshes should increase following tidal restoration. Stations could be established along the main stem of the channel and salinity measured in the flooding waters on spring and neap high tides. The water column is assumed to be unstratified (this should be verified on a flooding tide) and can be collected by canoe using a bucket or tube. Salinity can be measured using a temperature-corrected optical refractometer to the nearest 2 ppt or a hydrometer and thermometer in a graduated cylinder (nearest 1 ppt). Volunteers can collect water samples and measure salinity.

Current profiles in main channel

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

Extent of tidal flooding

If the hydroperiod (as described above) cannot be measured, it is useful to determine the high water mark. The perimeter of the flooded area can be walked and mapped at high tide during both spring and neap tides. Other methods can also be used to determine the extent of flooding such as measuring the height of water on sticks inserted near the high tide line and coated with cork dust, poster paint, or craft glue. The flooding water will make a line on the stick corresponding to the high water mark. Much of this work can be performed by volunteers.

Key References

Boumans, R.M.J., D.M. Burdick and M. Dionne. *In review*. Modeling habitat change in salt marshes following tidal restoration. Restoration Ecology.

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

Roman, C. T., R. W. Garvine and J. W. Portnoy. 1995. Hydrologic modeling as a predictive basis for ecological restoration of salt marshes. Environmental Management 19:559-566.

U.S.EPA. 1993. Volunteer estuary monitoring: a methods manual. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds, Washington, D.C. EPA 842-B-93-004.

Water table salinity monitoring well, with refractometer for measuring salinity and modified meter stick to measure water level

Ecosystem Indicator: Soils and Sediments

Work Group Participants

Summary by: David Burdick-UNH Jackson Estuarine Lab., Kim Hughes-NB Dept of Environment, Hilary Neckles-USGS, Richard Orson-Orson Environmental Cons., Edward Reiner- US EPA, Henry Rines-Applied Science Associates, Inc., Jan Taylor-USF&WS, Larry Ward-UNH Jackson Estuarine Lab.

Rationale

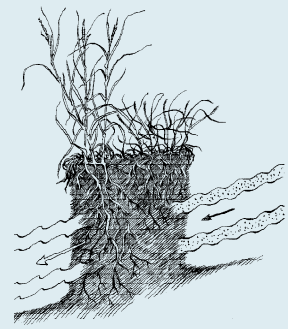
Soil salinity determines, to a large extent, the distribution and abundance of plant species in salt marshes. Many restoration projects are initiated with the goal of reestablishing plant communities characteristic of salt marshes, which also involves simultaneously reducing the abundance of fresh water plants, including invasive species like *Lythrum salicaria*, or *Phragmites australis*. Following restoration, plant distributions are expected to change in response to increased soil salinity. Measuring salinity several times during the early to middle growing season would provide the best indicator of changes in environmental conditions regulating plant growth, distribution, and abundance.

Core Variable

- **Pore Water Salinity:** parts dissolved salts per thousand (to the nearest 1 ppt); referenced against a Practical Salinity Scale

Sampling Methods

A minimum of five stations should be established for sampling soil salinity. Soil salinity could be sampled any number of ways (soil core, sipper, well), but wells may be the most efficient since there should be about six collection dates a year. Soil water should be collected from 5 to 20 cm depths (0 to 5 cm samples are not practical except with soil cores). Wells to determine soil salinity are constructed from 19mm diameter CPVC plastic pipe with 7 pairs of 4 mm holes at sediment depths between 5 and 20 cm. The base of the 35 cm pipe is sealed and the top is capped with two right angles in sequence. Salinity may be measured on site or at a laboratory using either a temperature-corrected optical refractometer (nearest 2 ppt) or a hydrometer and thermometer in a graduate cylinder (nearest 1 ppt). Sampling may be performed by volunteers once stations and methodology are established.



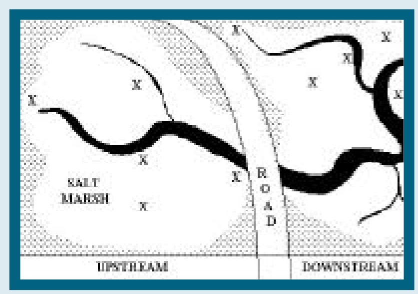
Robert Shetterly

Sampling design

Soil salinities should be obtained throughout the entire area to be restored and at an appropriate reference marsh. Sampling should be performed at low tide about six times a year between the beginning of the growing season (April or May) to mid-season (July or August) including both spring and neap tides. Sampling could be scheduled each year, but if annual assessments show positive results from the restoration, it could be omitted in some years (for example: pre-restoration, year 1, 2, 4, 5, 7 post-restoration).

A very simple layout of five stations per marsh unit (upstream and downstream of tidal restoration) should be established as a minimum for sampling soil salinity in areas restored by increasing tidal exchange. Along the axis of the main channel one station would be placed close to the restriction, one near the predicted head of tide (after restoration) and one equidistant between the two. These three stations would be located in high marsh approximately 3 to 4 meters from the tidal channel. Two more stations would be placed between the central station and the upland, in high marsh. In a simple circular or rectangular marsh, the stations would form a cross.

Example of a layout of site locations for soil and salinity samples



Skill Level

Once sample locations and methodologies for sampling and measurements are demonstrated, volunteers can collect the samples and measure soil salinity. Volunteers can also help organize this data for preparation of data reports.

Cost

Estimated costs for one sampling interval at a site no larger than 10 hectares (22 acres) include $200 for equipment, 1.5 days of professional work to build wells and establish stations, 4 days of volunteer or professional work to collect and reduce data, and 2 days of professional work to report data. Costs will be greater at complex sites requiring a larger number of stations.

Additional variables

Organic Matter

Both flooding and salinity control the decomposition rate of organic-rich sediments (i.e., peat) and rapid sediment rebuilding following restoration may be due to influx and deposition of inorganic sediments as well as growth of underground storage organs of plants (rhizomes). Thus determination of soil organic matter can reveal insights regarding pre-restoration impacts to the marsh (subsidence due to oxidation of organic matter in the sediments) and the process of recovery following restoration. Soil cores to 20 cm depths should be collected from the soil salinity stations and sectioned into 5 cm segments. Soil moisture (% of wet weight) and organic content (% of dry weight) are measured by weight loss after drying, then burning at 450° C, respectively. Soil organic matter should be determined once prior to restoration and as needed following restoration (e.g. years).

Sediment Accretion

Accretion of inorganic and organic material deposited onto the surface of marshes by flooding waters and vegetation is one of the important processes that allows marshes to build vertically, offsetting the rise in sea level. Accretion is most commonly measured using a marker on the horizon. A horizon marker is established by applying a known, identifiable material such as feldspar dust to the surface of the marsh. The amount of material that has accumulated above the marker can be measured from a sediment core taken at the same site at a later date. The sediment accreted can be reported in mm year $^{-1}$, or following drying and combustion, in g dry weight m^{-2} year $^{-1}$ of inorganic and organic components.

Sediment Elevation

Net balances in critical soil processes that allow salt marshes to persist over time may be assessed by measuring the surface elevation of the marsh. Loss in elevation indicates peat degradation, whereas gains may be due to accretion at the surface or peat development below the surface. Standard survey techniques are unable to measure short term changes in elevation (2 to 3 years), but are adequate for documenting long term change (10 years or greater). Short term changes in the sediment elevation of salt marshes around the world are being monitored using Sediment Elevation Tables (SET). Installation of the SETs is difficult and requires professionals. Usually only 2 to 4 stations are installed in a single marsh. In New England, more than 30 stations exist in several salt marshes from Rhode Island to Maine. Data are being collected to provide baseline information, assess projects to restore tidal flow, and assess impacts from dredging. These stations are located 10 meters from the high marsh edge of tidal channels or embayments and human traffic is kept to a minimum.

Redox Potential

The degree of chemical reduction/oxidation (redox) in the soil can provide information regarding paths (and relative rates) of organic matter decomposition in the peat soils of marshes. Redox potential is measured using commercially available or home-made half cell platinum probes calibrated prior to field deployment and equilibrated 30 minutes in the sediment. The potential is measured with a hand-held voltmeter connected to a calomel half cell. Raw data are corrected to obtain Eh values (the standard hydrogen electrode) by adding +242 mV to the raw readings. Redox potential should be measured at 1 cm and 15 cm depths at the same stations where soil salinity and organic matter are measured.

Sulfide Concentrations

Due to the great variability of redox potential, measurement of sulfide concentrations provides better information than Eh regarding oxygen status of the soils. Water extracted from soils can be fixed in a zinc-acetate solution and processed at a laboratory to yield sulfide concentrations using a spectrophotometer.

Soil salinitity tested using a refractometer

Key references

Boumans, R.M.J. and J.W. Day, Jr. 1993. High precision measurements of sediment elevation in shallow coastal areas using a sedimentation-erosion table. Estuaries 16:375-380.

Burdick, D.M., M. Dionne, R.M. Boumans and F.T. Short. 1997. Ecological responses to tidal restorations of two northern New England salt marshes. Wetlands Ecology and Management 4: 129-144.

Chambers, R.M. 1997. Porewater chemistry associated with *Phragmites* and *Spartina* in a Connecticut tidal marsh. Wetlands 17:360-367.

Portnoy, J.W. and A.E. Giblin. 1997. Effects of historic tidal restrictions on salt marsh sediment chemistry. Biogeochemistry 36:275-303.

Ecosystem Indicator: Vegetation

Work Group Participants

Summary by: Ted Diers, NH Coastal Program, and Charles Roman-USGS, Sarah Allen-Normandeau Assoc., Bruce Carlisle-MA CZM, Carolyn Currin-NOAA, Pam Morgan-UNH, Frank Richardson- NH DES., Peter Shelley-Conservation Law Foundation, Lee Swanson-NB DNR.

Rationale

The goal of vegetation monitoring is to track trends in plant abundance and species composition of the marsh community over time. A protocol for monitoring restoration projects must be capable of detecting changes in the vegetation of the restoring marsh and a reference marsh in the years following restoration actions, and of determining whether and how the vegetation of the restoring marsh differs from that of the reference system over that time period. In addition, frequently the purpose of a restoration project focuses on a specific plant species such as *Phragmites australis* or *Spartina alterniflora*. In these cases, more detailed information on individual species of concern may be warranted. The methods described below should be applied routinely to the marsh plant community in general, with additional data collected on species of concern as appropriate.

Core Variables

- **Abundance:** cover class per m^2, by species
- **Composition:** identity of species per m^2
- **Height of species of concern:** mean height of 3 tallest individuals of each species of concern per m^2
- **Stem density of species of concern:** # shoots per m^2, plots restricted to species of concern, by species

Sampling Methods

Plots

The general marsh community and species of concern are sampled using 1 m^2 quadrats. All sampling should be accomplished at the time of maximum standing biomass, in mid-summer (mid-July through August).

At each plot, take the following measures:

1) Identify all plant species (i.e.,species composition).

2) For each species, estimate percent cover by visual examination. Estimate percent bare ground as well.

   The estimate should be an integer number that can be categorized within standard Braun-Blanquet cover classes (<1%, 1-5%, 6-25%, 26-50%, 51-75%, >75%). Estimating cover by visual examination can be somewhat subjective; however, it has been demonstrated that these measures of cover are comparable to the more time intensive, quantitative measures of relative abundance, such as point intercept counts (Kent and Coker 1992).

3) Measure and then average the height of the tallest three individuals of each species of concern within each plot.

In addition, for plots restricted to species of concern (see Sampling Design, below), determine the stem density by species within a subsampled area of the plot.

Photo stations

Photographs taken from permanent stations can provide qualitative information on the changes in the plant community over time. Stations should be indicated on maps and with permanent field markers. The stations should include views of the restoration activity or structures. Two kinds of photo stations should be established – landscape or panoramic views and close-ups of plots. Landscape photos are taken at several compass bearings to cover a panorama of the entire marsh. For stands at the site of a tidal restriction, bearings showing the downstream marsh are desirable as well. Landscape photographs should include a person or an object for height scale. Close-ups are oblique views of a select number of the permanent vegetation plots. The corners of the plots should be identified with orange flagging and the photo taken from a height of about 1.2 m (4 ft). Photos should be taken at the time of vegetation sampling.

Salt marsh hay-
Spartina patens

Robert Shetterly

SAMPLING DESIGN

Marsh Community

The marsh plant community should be sampled using permanent plots positioned along transects in a systematic sampling design, following Elzinga et al. (1998). Use of permanent plots (re-sampled at each sampling interval) allows the application of powerful statistical tests for detecting change. Systematic sampling allows relatively easy positioning and relocation of quadrats and insures a fairly uniform distribution of quadrats throughout the study area.

Volunteers using transect to monitor vegetation

The marsh study area, or areas, should be identified and mapped. This may include a marsh that is bisected by a causeway, with one marsh area under the influence of reduced tidal exchange and another area open to full tidal exchange. Within each marsh study area, transects will be established perpendicular to the main marsh tidal creek; transects begin at the creek bank and extend to the upland. So that transects are dispersed fairly uniformly across the marsh, transects are positioned randomly within contiguous marsh segments. Divide the marsh into equal-sized segments along the axis of the main tidal creek, and randomly locate transects within marsh segments. Quadrats are then systematically located along transects. For each transect, the location of the first quadrat is selected randomly within the low marsh zone, or within the first 3 meters if no zone is apparent. Subsequent quadrats are located at consistent distance intervals along the transect. Given that the transects are established in a random manner, and assuming that there is adequate spacing between quadrats (>10 m) to insure that the plant communities of nearby quadrats are not correlated with each other, each quadrat can serve as a single sample unit (similar to a simple random sampling design).

The map or aerial photographs should be used to lay out the marsh segments, transects within segments, and quadrats along transects to achieve an appropriate dispersion of sample plots. In the field, the exact starting location of transects and quadrats can be determined using a random numbers table and meter tape.

What should be the total number of 1 m^2 quadrats sampled within each marsh area? This question should be resolved before the transects and quadrats are established. The ideal way to determine the appropriate number of plots required would be to conduct a power analysis. Using this approach, if the variability associated with the measurement and the desired level of change detection (i.e., subtle vs. major changes in the marsh community) are known, then the number of replicates required can be determined. A power analysis specific to New England salt marsh vegetation studies has been completed by the USGS-Biological Resources Division and is under review. Recognizing that this analysis is not yet final, and does not necessarily apply to all Gulf of Maine salt marshes, preliminary findings suggest that twenty plots within each study area of up to 50 ha would be adequate to detect subtle changes over time. Moreover, after several years of data have accumulated from specific restoration and reference sites, the investigator will be able to determine the level of variability at the site and then adjust to an appropriate number of replicates.

Vegetation should be sampled before restoration, 1 and 2 years following restoration, and every 3-5 years thereafter. There are several data analysis techniques that can be applied to detect changes in the vegetation community over time. Ordination techniques, such as Detrended Correspondence Analysis, or an analysis of similarity, are just two of the techniques that can be used (see Kent and Coker 1992).

Species of Concern

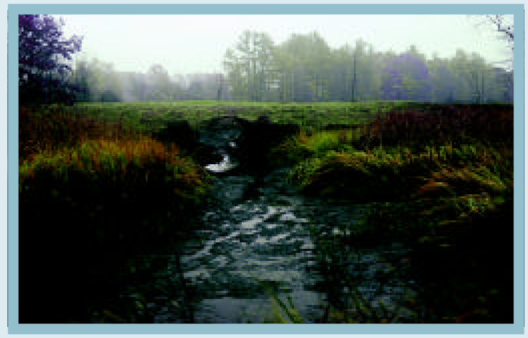
There are two ways to monitor species of special concern, such as *Phragmites* or *Lythrum*. First, in the routine vegetation community sampling described above, the height of the 3 tallest plants species of concern should be measured in all quadrats in which it occurs. If species of concern are not adequately represented in the marsh community samples, then a minimum of 5 additional 1 m^2 plots should be permanently established within distinct stands. Data on all core variables are then collected from these plots as well during vegetation sampling.

Skill Level

Vegetation sampling can be done by trained volunteers. A professional should design the monitoring plan and assist with training.

Cost

Sampling equipment is inexpensive, including compasses, tape measures, PVC piping to construct quadrats, some permanent marker stakes, and some meter sticks. Total equipment cost is less than $500. More expensive is the camera equipment and film developing cost for the photostations. The most expensive aspect of the vegetation sampling may be the aerial photography analysis to locate species of concern and marsh water bodies. If the photography is not available, then the area may have to be flown. Two to three days of professional involvement are needed for designing the sampling regime and interpreting data. Aerial photo interpretation would require additional professional involvement.



Additional Variables

Additional measurements to determine vegetative response to restoration include aboveground biomass, stem density, and proportion of stems that are flowering.

Key References

Elizinga, C.L., D. W. Salzer and J.W. Willoughby. 1998. Measuring and monitoring plant populations. BLM Technical Reference 1730-1, BLM/RS/ST-98/005+1730. Bureau of Land Management, National Business Center, BC-650B, PO Box 25047, Denver, CO. 477p.

Kent, M. and P. Coker. 1992. Vegetation description and analysis: A practical approach. J. Wiley and Sons, Chichester. 363 p.

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

Photo series to the right shows restoration of tide-gated salt marsh on Mill Brook in Stratham, NH. Sequence from top to bottom: abundance of purple loosestrife prior to restoration; tide-gate replaced by culvert in October, 1993; saltwater flooding of fresh marsh, spring,1994; colonization by salt marsh plants, summer, 1994; low marsh and high marsh well established by October, 1999.

Ecosystem Indicator: Nekton

Work Group Participants

Summary by: Michele Dionne-WNERR, Robert Buchsbaum-MA Audubon, Sean Ballou-SWAMP, Inc., Alan Hanson-Waterfowl & Wetlands Ecology, Env. Can, Eric Holt-MA Audubon, Mike Morrison-SWAMP,Inc., Judy Penderson-MIT Sea Grant College Program, Kenneth Raposa-URI, Chris Rilling- CT DEP, Greg Shriver-SUNY College Env. Sci., Jan Smith-MA Bays Program, Geoff Wilson-Northeast Wetlands Restoration, Ray Whittemore-Ducks Unlimited

Rationale

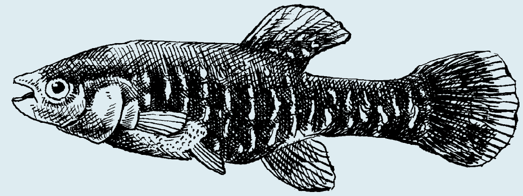
Fish are useful indicators of tidal marsh ecosystem functions. Their placement in the upper levels of the marsh food web, the wide age and size range of species occuring in marsh habitats, and the wide range of food and habitat resources utilized, are all characteristics that serve to integrate salt marsh ecosystem elements, processes and productivity. Fish and other nekton (e.g. macrocrustaceans) also serve as important ecological links with fisheries in nearshore and potentially offshore waters in the Gulf of Maine.

Core Variables

- ❖ **Identity:** genus and species of each animal sampled (number of fish and crustaceans by species)
- ❖ **Density:** # of animals per area of sample, by species
- ❖ **Length:** total animal length/width of individual fish to the nearest 0.5 mm, by species
- ❖ **Biomass:** wet weight of animals in sample, by species
- ❖ **Species Richness:** # of nekton species represented

Sampling Methods

Fish are highly mobile vertebrates that spend all or much of their time in the water column. In general their senses of sight, hearing, and touch are well developed. These attributes make them a challenging group when it comes to quantitative sampling, especially in vegetated salt marsh habitats.



Mummichog -*Fundulus heteroclitus*

After discussing numerous fish sampling techniques, the throw trap was selected for sampling in the open water of creeks and channels and the fyke net for use on the vegetated marsh surface.

Throw Trap

The trap is a 1 m^2 x 0.5 m high frame made of thin aluminum bar (2.5 cm width flat stock) with 3 mm mesh hardware cloth surrounding the four sides, open at the top and bottom. A 0.5 m wide apron of flexible 3 mm bar mesh netting can be attached around the top of the box, with a float line fixed to the upper edge. This allows sampling in water up to 1 m deep. To deploy the trap, the sampling station is approached slowly from the marsh surface, and the trap is tossed 3-4 m through the air into the water. The bottom of the trap is immediately pushed into the substrate to prevent animal escapement. All animals are removed with a 1 m x 0.5 m dip net (1 mm mesh) that fits snugly into the trap, dipping from all four sides of the trap. After three consecutive net passes devoid of nekton, the trap is considered empty. Animals are placed in a bucket of water for identification and measurement, and then released. Water depth is measured (to the nearest cm) to determine the volume of water sampled. This sampling method works best for smaller fish. Larger fish (> 15 cm) are unlikely to be captured.

Fyke Net

This is a nylon mesh net consisting of a series of four compartments held open by square frames or fykes, with 15 m wings attached to the first and largest (1.2 m X 1.2 m frame) fyke opening. After the first compartment, each compartment contains an internal net funnel connected to the previous fyke frame, with the smaller end of the funnel emptying into the middle of the compartment, 3 inches from the bottom. This design channels fish into the net's cod end with little chance of escape. The wings and first three compartments are made of 1.27 cm bar mesh, with the final cod end made of 0.63 cm bar mesh. To measure fish use of the marsh surface, the net is set at low tide at the lower edge of the marsh with wings at 45°, fykes upright, and cod end and wings anchored. The wing top line is buoyed and set so that nekton can enter the marsh area by the side. At high tide, the area of flooded marsh to be fished by the net is staked to calculate the area fished.

The catch is placed into buckets of water once the tide has receded below the level of the first funnel. To measure fish use of creeks, the net is set at slack high tide across the creek mouth, to fish the outgoing tide, and the volume of water sampled by the net is estimated from creek dimensions. This sampling method works equally well for both small and large fish.

For both the throw trap and fyke net, decapod crustaceans will be captured as well as fish. When captured, identity, density, size and biomass of crabs and shrimp should be included in the results.

Data Collection

Species Identity and Richness

Each individual fish and crustacean collected is identified to genus and species. A list of species likely to occur in Gulf of Maine salt marsh estuaries is included in Appendix E.

Density

In order to quantitatively compare fish use of different marsh sites, fish abundance is adjusted to reflect the volume of water sampled with the throw trap, and the area of vegetated marsh fished with the fyke net. Fish numbers per sample are divided by the appropriate volume (m^3) or area (m^2).

Length

Individual fish length is measured from the tip of the snout to the tip of the caudal fin (total length), recorded to the nearest 0.5 mm. When possible, 30 individuals of each fish species should be measured, selected haphazardly from the sample bucket with an aquarium net. For shrimp, length is measured from the tip of the rostrum to the tip of the telson. For crabs, maximum carapace width is measured.

Biomass

The relationship between length and biomass can vary considerably depending on species identity and individual condition. Biomass provides an estimate of standing stock, and can be used to calculate fish condition (length/biomass), providing a more complete interpretation of fish size data. Total wet weight of all individuals for each species is recorded to the nearest gram with an electronic field balance. The number of individuals for each species is also recorded.

Sampling design

The occurrence of smaller fishes at mid-tide in marsh creeks is estimated with randomly placed throw trap samples, 10 samples each in restoration and reference sites, on each of two dates in August during the spring tide cycle. Larger fishes using the creeks are sampled with fyke nets set across small creeks (up to 15 m wide) at slack high tide on the same two dates in August, as well as on two spring tide dates during the spring migrations of diadromous fish. Fish using the marsh surface are sampled with fyke nets on one date in August during the spring tide cycle. A pair of nets should be used so restoration and reference marshes can be sampled at the same time. Until results from long-term monitoring define the appropriate time frame, we suggest a minimum of one year pre-restoration data, and data from years 1,3 and 5 post-restoration.

Fyke Net

Skill Level

Fish are relatively easy to identify and handle, and the data described above can be collected by volunteers after training. Throw traps can be used by a single person, but fyke nets are bulky and best transported and deployed by a team of two or three.

Cost

Throw traps are inexpensive to construct (<$50) and allow rapid collection of a large number of samples. Estimated personnel costs are less than $500 per year. Fyke nets can be purchased for about $500 each. Since they are passive sampling devices, most of the time associated with their use is in the set up and take down of the nets. Other sampling (such as throw trap sampling) can be conducted while the fyke nets are fishing. Estimated cost for a team of one technician/student and two volunteers to collect 8 channel samples and two marsh surface samples annually is $600.

Additional Variables[1]

Fish Growth

Further understanding of fish growth trajectories over time can be obtained by calculating fish condition (length/biomass) within size classes for selected species. This requires that fish be graded by size class (a surrogate for age class) and each size class weighed separately.

Fish Diet

An assessment of fish gut contents would indicate whether diets of fish captured in restored marsh sites differed from that of fish in the reference marshes. Differences in diet would indicate differences in the availability of food resources. Similarities in diet would suggest similarity in food resources between restoration and reference marshes. However, if many reference and restoration sites are close together, fish captured in one site may well have obtained their food from the other site. The source of the food eaten by the fish would need to be determined before gut contents could be used to infer similarity between restoration and reference sites in regards food availability.

Larval Mosquitos

Although the distribution of most tidal marsh invertebrates is too patchy in time and space to obtain accurate density estimates given the sampling effort envisioned for these protocols, larval mosquitos can be used as indicators of some aspects of tidal marsh hydrology. Information on mosquito densities is particularly warranted for restoration projects that include mosquito control as a primary goal.

Salt marsh mosquito species reproduce in shallow standing water on the high marsh surface, with the larvae of different species occurring in fresh, brackish and higher salinity water. The larvae can only persist in pannes that do not contain fish, due to the lack of spring tidal flooding, or due to the loss of standing water through drainage and evaporation. Salt marshes that have been invaded by cattail (*Typha sp.*) or *Phragmites* often harbor freshwater mosquito species, while *Aedes cantator* is typical of brackish water and *Aedes sollicitans* is typical of higher salinities. Larval mosquitos are sampled with a white cup on a long handle known as a “dipper” which is used to scoop up water from the marsh surface. Sampling should occur weekly from April through August along transects that intersect standing water on the marsh. The number of dips, the number of positive dips, and the number and species of mosquito larvae in each dip are recorded. The distribution and abundance of mosquito species relative to the distribution and abundance of standing water can be mapped and used to indicate patterns of tidal flooding on the marsh surface.

[1] We include here one variable based on sampling of salt marsh mosquitos.

Additional Methods

To obtain a more complete picture of fish utilization of restored and reference sites, lift nets can be used to sample the marsh surface. These nets enclose a relatively large area of marsh (6 m x 6 m), and are folded into a trench on the marsh surface, beneath rigid vertical supports. At high tide, ropes are used to raise the netting vertically on the supports to trap fish. As the tide recedes, fish are captured in a cod-end set into a pit dug in the marsh surface. Cost estimate for one lift net is $300. Once constructed, they are relatively easy to use and maintain, so that personnel costs are low (1-2 person-hours per sample).

Key References

Dionne, M., F.T. Short and D.M. Burdick. 1999. Fish utilization of restored, created, and reference salt marsh habitat in the Gulf of Maine. American Fisheries Society Symposium 22:384-404.

Irlandi, E.A. and M.K. Crawford. 1997. Habitat linkages: the effect of intertidal salt marshes and adjacent subtidal habitats on abundance, movement, and growth of an estuarine fish. Oecologia 110:222-230.

Kneib, R.T. 1997. The role of tidal marshes in the ecology of estuarine nekton. Oceanography and Marine Biology 35:163-220.

Minello, T.J. and J.W. Webb, Jr. 1997. Use of natural and created *Spartina alterniflora* salt marshes by fishery species and other aquatic fauna in Galveston Bay, Texas, USA. Marine Ecology Progress Series 151:165-179.

Raposa, K.B. and C.A. Oviatt. 2000. The effects of contiguous shoreline type, distance from shore and vegetation biomass on nekton community structure in eelgrass beds. Estuaries 23:46-55.

Rountree, R.A. and K.W. Able. 1993. Diel variation in decapod crustacean and fish assemblages in New Jersey polyhaline marsh creeks. Estuarine, Coastal and Shelf Science 37:181-201.

Rozas, L.P. and T.J. Minello. 1997. Estimating densities of small fishes and decapod crustaceans in shallow estuarine habitats: a review of sampling design with focus on gear selection. Estuaries 20:199-213.

Szedlmayer, S.T. and K.W.Able. 1996. Patterns of seasonal availability and habitat use by fishes and decapod crustaceans in a southern New Jersey estuary. Estuaries 19:697-709.

Varnell, L.M. and K.J. Havens. 1995. A comparison of dimensional-adjusted catch data methods for assessment of fish and crab abundance in intertidal salt marshes. Estuaries 18:319-325.

Ecosystem Indicator: Birds

Work group Participants

Summary by: Robert Buchsbaum-MA Audubon, Sean Ballou-SWAMP, Inc., Michele Dionne-WNERR, Pascal Giasson-NB DNRE, Alan Hanson-Waterfowl & Wetlands Ecology, Env. Can, Eric Holt-MA Audubon, Mike Morrison-SWAMP, Inc., Judith Penderson-MIT Sea Grant College ProgramKenneth Raposa-URI-USGS, Chris Rilling- CT DEP, Greg Shriver-SUNY College/Env. Sci., Jan Smith-MA Bays Program, Geoff Wilson-Northeast Wetlands Restoration, Ray Whittemore-Ducks Unlimited

Robert Shetterly

Rationale

Birds are highly visible organisms that are popular with the general public, therefore they are an obvious group to include in a monitoring program. In cases where increasing the bird use of salt marsh habitat is a major rationale of a restoration project, monitoring birds is essential for measuring success. In addition, there are a number of nonprofessional birders who are excellent at identifying birds and are likely to be competent and enthusiastic volunteers.

On the other hand, a difficulty in monitoring birds on restored marshes relates to the question of scale. Most birds, particularly those charismatic species that are usually of most interest (e.g. herons, shorebirds, waterfowl, raptors), have home ranges much larger than the size of typical salt marsh restoration projects in the Gulf of Maine. Thus it is difficult to get a large enough number of observations of individuals to draw conclusions about habitat use in a restored marsh compared with that of a suitable control. In addition, wetlands birds in particular have specific habitat preferences (such as a large percentage of open water or pannes) that may or may not be present in a particular restoration site.

Abundance by species and number of species (richness) provide information on overall value of the habitat to birds in a simple, direct way. Behavioral observations provide an even better indicator of the value of the habitat to birds, but the information is more difficult and time-consuming to collect. More detailed studies of individual species, such as salt marsh sharp-tailed sparrows and other small passerines, may be important depending on the particular goals of the restoration, but are beyond the scope of routine monitoring of individual restoration sites.

Core Variables

- **Abundance:** # of birds per ha, by species
- **Species richness:** # of species
- **Feeding and breeding behavior:** type of feeding behaviors per 20 minute observation interval by species; type of breeding behaviors per 20 minute observation interval, by species

Sampling Method

Observations of birds will be made from vantage points that provide an uninterrupted view of at least a portion of the salt marsh. The exact location and number of vantage points will be site specific. An observer will remain at each vantage point for 20 minutes, recording the number of birds of each species within view in the restored and control marsh. Flying birds that are foraging over the marsh, such as swallows, are to be included in the survey, but those simply in transit are not. The data sheet will include space to record behavioral observations, such as whether the birds are feeding, involved in nesting, loafing, roosting, etc. Sampling will be carried out only in the morning. Information will be collected on stage of tide, time of day, and weather during each observation period. General information on the site will be collected, including dominant plant species and estimated cover of each, number of pannes, area of pannes, and area of unvegetated surface.

Pannes on the high marsh

Sampling Design

Conduct sampling two times during the breeding season (May and June), once per week during migration of waterfowl (late March through the end of April and again in October and November) and shorebirds (late July through early September). Such sampling would also incorporate waders. Sampling should encompass both high and low tides. Sampling should begin at least one full season before the restoration is initiated.

Skill Level

Part of the attraction of monitoring birds is that there is a cadre of skilled amateur birders who could participate in a project as volunteers. This would hopefully enable the relatively frequent sampling suggested above. A professional is likely to be needed for data analysis, particularly when comparing marshes that differ in area.

Cost

Two weeks of direct professional involvement is required to set up the sampling design, train volunteers, and analyze results. Equipment costs are negligible, since the assumption is that the volunteers would provide their own optical equipment.

Additional Variables

Small passerines and other cryptic birds of the salt marsh

Small passerines, rails, and bitterns will likely be under-represented in observations taken from a high point above the marsh. They can be measured by setting up 50-m radius counting circles in the salt marsh. An observer enters the circle and records all birds seen or heard within a 20 minute time period. If possible, the observer will use a tape recorder to broadcast songs of several species of most interest.

Birds in the Buffer

Counting circles, as described above, can be set up in the buffer habitat adjacent to the salt marsh. This will enable evaluation of the importance of the buffer zone to birds of both the salt marsh and the upland.

Waterfowl in winter

The marsh will be sampled throughout the winter as long as it is ice free. This will provide information about the use of the restored marsh by wintering waterfowl.

Key References

Bibby, C.J., N.D. Burgess and D.A. Hill. 1992. Bird census techniques. Academic Press, New York.

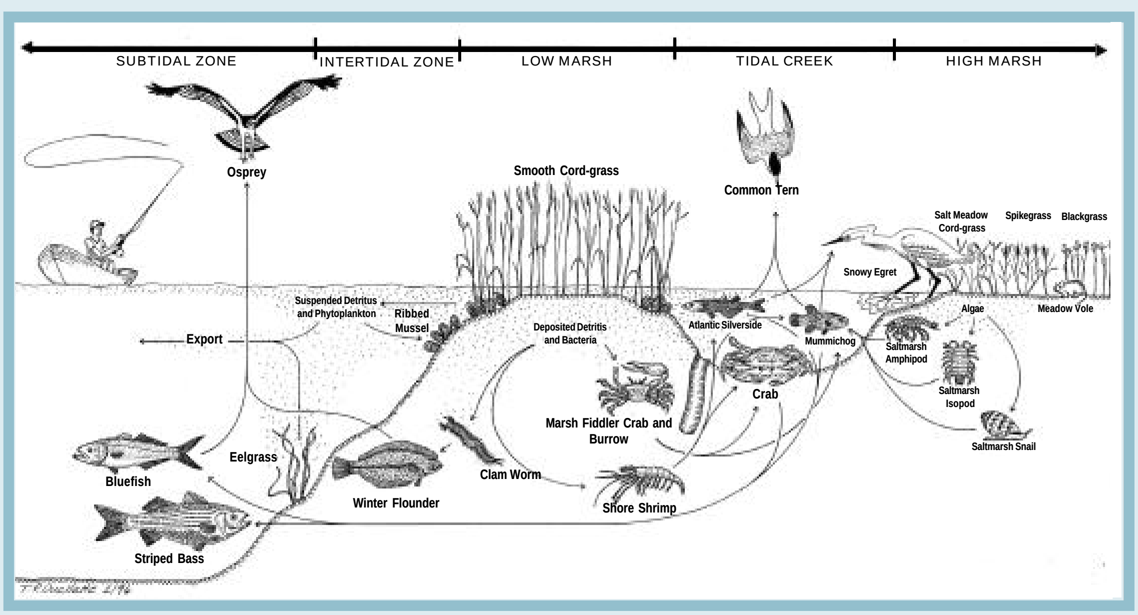
Hanowski, J.M. and G.J. Niemi. 1990. An approach for quantifying habitat characteristics for rare wetland birds. New York State Museum Bulletin 471:51-56.

Hutto, R.L., S.M. Pletshet and R. Hendricks. 1986. A fixed-radius point count method for non-breeding and breeding season use. Auk 103:593-602

Reinert, S.E. and M.J. Mello. 1995. Avian community structure and habitat use in a southern New England estuary. Wetlands 15:9-19.

Sibley, D. 1996. Field identification of the sharp-tailed sparrow complex. Birding 23:196-208.

Habitats, inhabitants, and food web linkages in a typical New England estuarine ecosystem. This figure was originally designed to illustrate a southern New England salt marsh. In the Gulf of Maine, the blue crab is replaced by the non-native green crab.



Thomas R. Ouellette

Workshop Summary:
Tools for Region-wide Site Selectionand Monitoring

Our goal at the workshop was to develop standardized and realistic methods for 1) identifying Gulf of Maine tidal marshes suitable as reference or restoration sites, and 2) assessing the response of Gulf of Maine salt marsh ecosystems to restoration efforts. The models and protocols presented in this report were the outcome of discussion fueled by the combined experience of nearly fifty tidal marsh scientists and resource managers. This group worked diligently to achieve consensus regarding the specific parameters, core variables and methods that would form an acceptable minimum set of data and information with which to achieve the workshop goals. The details of these protocols will undoubtedly be modified as they are put into practice and reviewed, in order to fine-tune their ability to quantify regional gains and losses in the functions and values of tidal marshes. Although the workshop focused specifically on the Gulf of Maine coastline, there is no obvious reason to restrict the use of the inventory and monitoring protocols to this region.

The group charged with developing the template for the restoration and reference site inventory (Inventory workgroup) began with several local inventories and a long list of candidate parameters. They worked their way through the list to select 14 identifiers and descriptors to create the minimum necessary information base. The template contains six parameters that identify the name, location and ownership of the site; three that describe disturbances and impacts to the system; four parameters that outline the size, type, cost and nature of potential or actual marsh restoration; and a final entry to identify points of contact.

The remaining work groups (Hydrology and Soils, Vegetation and Mapping, and Animals) focused on identifying those ecosystem indicators sufficient for monitoring the success of tidal marsh restoration projects. At the outset, we agreed the general goal of restoration is to produce a self-sustaining ecosystem that closely resembles the natural system in structure, function and value. The Hydrology and Soils group identified the elements of hydroperiod, consisting of tidal signal and marsh cross-sectional elevations, as core hydrologic variables. For soils and sediments they identified pore water salinity as the key indicator. The Vegetation group discussed the creation of baseline habitat maps and vegetation monitoring. The baseline map they propose includes cover types, adjacent land use, impacts and sampling locations. Core variables for vegetation monitoring are the % cover of plants by species, and plant height and density for species of special concern. The Animal group identified core variables for both birds and nekton. For nekton (captured with traps), these variables are species densities and wet weights, species richness, and individual fish length. For birds (observed at a distance), the core variables are abundance by species, species richness, and feeding and breeding behavior.

The template for the restoration and reference site inventory can be used to develop a regional database from existing maps and inventories. This database will be extremely useful as salt marsh restoration continues to become a more common element of Gulf of Maine coastal resource management. The database will also serve to identify information gaps on a regional scale. The design of the restoration success monitoring program is based on the comparison of indicator variables among restoration and reference sites both before (when possible) and during/after restoration. Some marsh functions and values may recover more quickly than others, and the rate of change for any given variable may not be uniform. Once the proposed monitoring protocols are implemented across a representative range of marsh types and locations throughout the Gulf of Maine, it will be possible to determine the appropriate frequency and duration of monitoring (i.e. number of years sampled, and interval between samples). It may also be possible with sufficient data to develop a range of reference values characterizing natural tidal wetland systems across the region.

Next Steps

The workshop products presented here provide the foundation for developing a Gulf of Maine inventory of salt marsh restoration opportunities and a monitoring network of restored and reference salt marshes. Implementation of regional inventory and monitoring programs is expected to occur through partnerships between estuarine professionals and volunteer members of community based organizations. Broad participation by all individuals working in Gulf of Maine tidal marshes is invited.

The standard inventory model will be used to populate a regional database of potential tidal marsh restoration sites throughout the Gulf of Maine. Federal, state, and provincial agencies charged with tidal marsh protection and restoration have agreed to use the regional inventory model for describing and cataloging restoration opportunities within their jurisdictions, and community organizations are also urged to use this format for local projects. Site-specific inventory data from all sources can then be submitted to a regional database, which will be maintained by the U.S. Fish and Wildlife Service Gulf of Maine Program. Regional inventory coordinator contact information is included in Appendix D. The resulting comprehensive inventory of restorable sites will provide a basis for prioritizing among potential restoration sites and identifying those most appropriate for restoration projects. This inventory will offer consistent baseline information for gauging overall restoration progress in the region.

Organizations are also urged to use the standard protocols presented here for monitoring tidal marsh restoration projects throughout the Gulf of Maine. Additional funding is being sought to apply the protocol to 30 pairs of restored and reference marshes throughout the region. Professionals will guide data collection efforts, compile data from the site network, and synthesize resulting information. On site data collection will involve members of community based organizations and be facilitated by volunteer coordinators with access to state and provincial repositories of scientific equipment. Ultimately, comparisons of standard monitoring variables between a large number of restored and reference sites can be used to identify reliable indicators of restored marsh functions and to suggest regionally applicable success criteria for restoration projects. Such information will be valuable for evaluating the effectiveness of tidal marsh restoration in the Gulf of Maine to date and for guiding future restoration efforts.

Inquiries regarding these salt marsh monitoring protocols can be directed to the contacts denoted with an "*" in Appendix B.



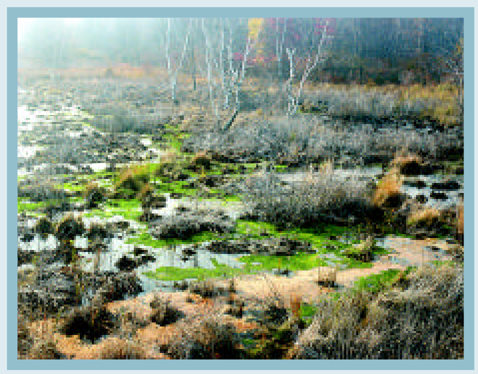
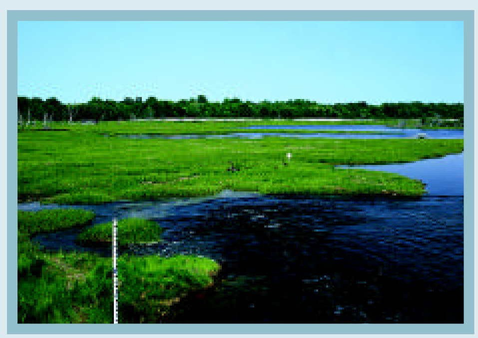




Photo series to the right shows restoration of impounded salt marsh on Webhannet River in Wells, Maine. Sequence from top to bottom: Cows in drained marsh, 1950's; colonization by Spartina alterniflora (short form) and Salicornia europea in 1991, 3 years after partial restoration of tidal flow; close up showing salt-killed plants and filamentous green algae in 1991; S. alterniflora short form covers much of the area in 1994; S. alterniflora increases in density and Spartina patens becoming more abundant by 1999.

APPENDIX A: Workshop Agenda

WORKSHOP ON RESTORATION OF COASTAL WETLAND ECOSYSTEMS IN THE GULF OF MAINE

June 2-3, 1999
Wells National Estuarine Research Reserve
Sponsored by the Global Programme of Action Coalition for the Gulf of Maine
AGENDA

Wednesday, June 2

8:30 COFFEE

9:00 WELCOME TO WORKSHOP
Hilary Neckles, USGS Patuxent Wildlife Research Center - Augusta, ME

9:05 WELCOME TO WELLS RESERVE
Kent Kirkpatrick, Director, Wells National Estuarine Research Reserve

9:15 INTRODUCTION TO GPAC
Katie Ries, Deputy Director, International Programs Office, National Ocean Service, NOAA

9:30 WORKSHOP PURPOSE: BACKGROUND, GOALS, AND OBJECTIVES
Michele Dionne, Research Director**,** Wells National Estuarine Research Reserve

10:15 BREAK

10:30 WORKGROUP BREAKOUT SESSIONS

1. Inventory Development
2. Monitoring protocol development: Plants
3. Monitoring protocol development: Animals
4. Monitoring protocol development: Physical components

12:00 LUNCH

1:00 WORKGROUP BREAKOUT SESSIONS (CONTINUED)

3:00 BREAK

3:30 WORKGROUP REPORTS AND PLENARY DISCUSSION

5:30 SOCIAL HOUR AND FIELD TOUR

7:00 BANQUET

WELCOME**: Kathryn S.B. Davis**, President, Laudholm Trust

INTRODUCTION: **Kent Kirkpatrick,** Director, Wells National Estuarine Research Reserve

GUEST SPEAKER: **Jeffrey R. Benoit**, Director, Office of Ocean and Coastal Resource Mgmt., NOAA

Thursday, June 3

8:00 COFFEE

8:30 PLENARY SESSION: REVIEW AND FOCUS
Kim Hughes, NB Department of the Environment, New Brunswick, Canada

9:00 WORKGROUP BREAKOUT SESSIONS (CONTINUED)

11:00 PLENARY SESSION: SYNTHESIS
Michele Dionne, Research Director, Wells National Estuarine Research Reserve

12:00 WORKSHOP ENDS

1:30 NOAA – MEETING FOR THE REGIONAL HABITAT RESTORATION PROGRAM
John Catena, National Marine fisheries Service, Gloucester, MA

APPENDIX B: Participants and Steering Committee Contact Information

Sarah Allen
Normandeau Assoc.
25 Nashua Road
Bedford, NH 03110

Sean Ballou
SWAMP, Inc
2 Winterbrook Ave.
York, ME 03909
(207)363-9240

Arnold Banner
US Fish &Wildlife Service
4R Fundy Road
Falmouth, ME 04105
(207)781-8364
arnold_banner@fws.gov

Jeffrey R. Benoit
Office of Ocean & Coastal Resource Mgmt., NOAA
1305 EW, Hwy, SSMC #4, Rm 10414
Silver Spring, MD 20910
(301)713-3155x200
jeff.benoit@noaa.gov

****Robert Buchsbaum***
Massachusetts Audubon
346 Grapevine Road
Wenham, MA 01984
(978)927-1122
rbuchsbaum@massaudubon.org

****David Burdick***
Jackson Estuarine Laboratory
85 Adams Point Road
Durham, NH 03824
(603)862-2175
dburdick@christa.unh.edu

Bruce Carlisle
MA Coastal Zone Mgmt
100 Cambridge Street
Boston, MA 02202
(617)727-9530
bruce.carlisle@state.ma.us

John Catena
National Marine Fisheries Service
One Blackburn Drive
Gloucester, MA 01930
(978)281-9251
john.catena@noaa.gov

Lou Chiarella
National Marine Fisheries Service
1 Blackburn Drive
Gloucester, MA 01930-2298
(978)281-9277
lou.chiarella@noaa.gov

Richard Cook
Audubon Society of New Hampshire
3 Silk Farm Road, PO Box 528-B
Concord, NH 03302-0516
(603)224-9909
r_cook@conknet.com

Carolyn Currin
NOAA's Beaufort Laboratory
101 Pivers Island Road
Beaufort, NC 28516-9722
(252)728-8749
carolyn.currin@noaa.gov

Kathryn Davis
Laudholm Trust
PO Box 1007
Wells, ME 04090
(207)646-4521
kdavis@cybertours.com

Ted Diers
NH Coastal Program
2 1/2 Beacon Street
Concord, NH 03301
(603)271-2155
t_diers@osp.state.nh.us

****Michele Dionne***
Wells NERR
342 Laudholm Farm Road
Wells, ME 04090
(207)646-1555x136
michele.dionne@maine.edu

Stewart Fefer
US Fish &Wildlife Service
Gulf of Maine Program
4R Fundy Road
Falmouth, ME 04105
(207)781-8364
stewart_fefer@fws.gov

Christy Foote-Smith
Mass. Wetlands Restoration & Banking Program
100 Cambridge Street
20th Floor
Boston, MA 02202
(617)292-5991
christy.foote-smith@state.ma.us

Pascal Giasson
Mgr. Wetlands & Coastal Habitat, NB DNRE
PO Box 6000
Fredericton, NB E3B 5H1
Canada
(506)453-7107
pagiasson@gov.nb.ca

Jennifer Graham
Ecology Action Centre
1568 Argyle Street, Suite 31
Halifax, NS B3J 2B3 Canada
(902)422-8771
grahamja@is2.dal.ca

Al Hanson
Waterfowl & Wetlands Ecology, Env. CN/CWS
PO Box 6227
Sackville, NB E4L 1G6 Canada
(506)364-5061
al.hanson@ec.gc.ca

Eric Holt
Mass Audubon Society
19 Marlboro Street
Newburyport, MA 01950
(978)465-4085
nfiske@massed.net

****Kim Hughes***
NB Dept of the Environment
PO Box 6000
Fredericton, NB E3B 5H1
Canada
(506)453-4409
kim.hughes@gov.nb.ca

Eric Hutchins
National Marine Fisheries Service
1 Blackburn Drive
Gloucester, MA 01930
(978)281-9313
eric.hutchins@noaa.gov

Chuck Katuska
Wetlands Restoration & Banking Program
One Winter Street
Boston, MA 02108
(617)292-5824
chuckkatuska@state.ma.us

David Kennedy
Office Of Response and Restoration, NOS,NOAA
1305 EW Hwy., #10409
Silver Spring, MD 20910
(301)713-2989x101
david.kennedy@noaa.gov

Kent Kirkpatrick
Wells NERR
342 Laudholm Farm Road
Wells, ME 04090
(207)646-1555 x124
kent@cybertours.com

Randy Milton
NS Dept. of NR;Wetlands& Coastal Habitats Prog.
136 Exhibition St.
Kentville,NS B4N 4E5
Canada
(902)679-6224
miltongr@gov.ns.ca

Pam Morgan
University of New England
85 Adams Point Road
Durham, NH 03824
(207)283-0170x2227
pmorgan@mailbox.une.edu

Mike Morrison
SWAMP, Inc.
2Winterbrook Ave.
York, ME 03909
(207)363-9240

****Hilary Neckles***
USGS Biological Res. Div.
26 Ganneston Drive
Augusta, ME 04330
(207)622-8205x119
hilary_neckles@usgs.gov

Rich Orson
7D Harbour Village
PO Box 921
Branford, CT 06405
(203)483-9234

Judith Pederson
MIT Sea Grant College Program
292 Main Street, E38-330
Cambridge, MA 02139
(617)252-1741
jpederson@mit.edu

Tim Purinton
Northeast Wetlands Restoration
P.O. Box 702
Rowley, MA 01969

Vic Pyle
Save The Sound, Inc.
185 Magee Avenue
Stamford, CT 06902-5906
(203)327-9786
savethesound@snet.net

Aviva Rahmani
Ghost Nets
Oatmeal Quarry,
PO Box 692
Vinalhaven, ME 04863
(207)863-0925
ghostnet@foxisland.net

Kenny Raposa
USGS Biological Resources Div. (Univ. of RI)
Naragansett Campus, South Ferry Road
Naragansett, RI 02882
(401)874-6617
kenny@gsosun1.gso.uri.edu

Ed Reiner
US, EPA Region I
JFK Federal Building
Boston, MA 02203
(617)918-1692
reiner.ed@epa.gov

Frank Richardson
NH Div Environ Services
P.O. Box 95
Concord, NH 03302
(603)271-4065
f_richardson@des.state.nh.us

Katie Ries
NOS, NOAA
1305 EW Hwy
SSMC4 Rm #13332
Silver Spring, MD 20910
(301)713-3078x171
kathryn.ries@noaa.gov

G. Chris Rilling
CT DEP
79 Elm Street
Hartford, CT 06106-5127
(860)424-3034x2770
chris.rilling@po.state.ct.us

Henry Rines
Applied Science Assoc.Inc.
70 Dean Knauss Drive
Naragansett, RI 02882
(401)789-6224
hrines@appsci.com

Lorrie Roberts
NB Dept of NR & Energy
Wetlands and Coastal Habitat Program
PO Box 6000
Fredericton, NB E3B 1T9
Canada
(506)453-2440
laroberts@gov.nb.ca

Charles Roman
USGS Biological Resources Div.
University of Rhode Island
Narragansett Bay Campus
Naragansett, RI 02882
(401)874-6885
croman@gsosun1.gso.uri.edu

Bob Rutherford
Dept Fisheries & Oceans
P.O. Box 550
Halifax, NS B3J 2S7
Canada
(902)426-8398
rutherfordb@mar.dfo-mpo.gcca

Peter Shelley
Conservation Law Foundation
120 Tillson Avenue
Rockland, ME 04841-3416
(207)594-8107
pshelley@clf.org

Greg Shriver
SUNY College of Enviro. Sci. and Forestry
1 Forestry Dr.
Syracuse, NY 13210

Alison Sirois
University of ME, Coop Extension
PO Box 309
Waldoboro, ME 04572

Jan Smith
Mass Bays Program
100 Cambridge St. 20th Floor
Boston, MA 02202
jan.smith@state.ma.us

Lee Swanson
NB DNR, Wetland & Coastal Habitat Prog.
PO Box 6000
Fredericton, NB E3B 5H1
Canada
(506)453-7108
laswanson@gov.nb.ca

Jan Taylor
USF&WS
336 Nimble Hill Road
Newington, NH 03801
(603)431-5581
jan_taylor@fws.gov

David Thompson
Conservation Council of NB
Box 568, RR#2
Lepreau,NB E0G 2H0
Canada
(506)659-2363

Larry Ward
University of New Hampshire
85 Adams Point Road
Durham, NH 03824
(603)862-2175
lgward@cisunix.unh.edu

Alison Ward
DEP, Bureau of Land & Water Quality
17 State House Station
Augusta, ME 04333

Geoffrey Wilson
Northeast Wetland Restoration
P.O. Box 702
Rowley, MA 01969
gmwilson@ttlc.net

Lois Winter
US Fish &Wildlife Svc.
Gulf of Maine Program
4R Fundy Road
Falmouth, ME 04105
(207)781-8364
lois_winter@fws.gov

Ray Whittemore
Ducks Unlimited
122 Joe English Road
New Boston, NH 03070
rwhittemore@ducks.org

Contacts shown in blue represented their respective organizations as members of steering committee for this workshop.

**** Denotes contacts to whom you may forward inquiries regarding monitoring protocol.***

APPENDIX C: Existing Inventory Models and Monitoring Protocols

- ❖ Bonnebakker, E.R., P. Shelley and K. Spectre. 2000. Return the tides handbook (review draft). Conservation Law Foundation, Rockland, ME.
- ❖ Bryan, R., M.Dionne, R. Cook, J.Jones and A.Goodspeed. 1997. Maine citizen's guide to evaluating, restoring and managing tidal marshes. Maine Audubon Society, Falmouth, ME.
- ❖ Bryan, R.R. 1999. Scarborough marsh: historical impacts, current conditions, and restoration potential. Maine Audubon Society, Falmouth, ME.
- ❖ Burdick, D.M.,R. Buchsbaum, C.Cornelisen and T. Diers. 2000. Monitoring restored and created salt marshes in the Gulf of Maine: framework and data collection methods to guide monitoring programs that use volunteers. Report based on a workshop sponsored by the Massachusetts Audubon Society and the Gulf of Maine Council on the Marine Environment.
- ❖ Buzzards Bay Project National Estuary Program. 1999. Atlas of tidally restricted salt marshes: Buzzards Bay, Massachusetts. Buzzards Bay Project, MA Coastal Zone Management, East Wareham, MA.
- ❖ Cornelisen, C.D. 1998. Restoration of coastal habitats and species in the Gulf of Maine. Gulf of Maine Council on the Marine Environment.
- ❖ Kooken, V., B. Carlisle, A. Hicks and J. Smith. 2000. Volunteer sampling program and assessment of salt marshes, North Shore of Massachusetts. WHAT Pilot Project, Salem Sound 2000, Salem, MA.
- ❖ Diers, T. and S. Wallace. 1998. Monitoring requirements for salt marsh restoration projects. New Hampshire Coastal Program. Concord, NH.
- ❖ Linnell, S. 1994. A survey of impounded salt marshes in southern Maine. Master's Project, Antioch New England Graduate School, Keene, NH.
- ❖ Little, M.J. 1995. Potential for the restoration of tidal salt marshes by restoring tidal flow: an overview with reference to the salt marsh at Locke Road, Rye, NH. Master's Project, Antioch New England Graduate School, Keene, NH.
- ❖ Niedowsky, N.L. 1999. Salt marsh restoration and monitoring guidelines (review draft). New York State Department of State Division of Coastal Resources.
- ❖ 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. 69 p.
- ❖ Robie, P., M. Hansen, M. Wildes and D. Paiva. 1994. A method to monitor the integrity of New Hampshire's tidal salt marshes (draft #2). Report prepared for U.S.D.A. Soil Conservation Service, Durham, N.H.
- ❖ Short, F.T., D.M. Burdick, C.A. Short, R.C. Davis and P.A. Morgan. 2000. Developing success criteria for restored eelgrass, salt marsh, and mudflat habitats. Ecological Engineering: *in press*.
- ❖ Tiner, R.W. 1999. Wetland monitoring guidelines (operational draft). U.S. Fish and Wildlife Service, Ecological Services, Region-5 Northeast, Hadley, MA 01305.
- ❖ United States Department of Agriculture Soil Conservation Service. 1994. Evaluation of restorable salt marshes in New Hampshire. Durham, N.H.
- ❖ Wade, S.D. 1999. The effects of tidal restrictions on marsh elevation and plant communities of five tidal salt marshes in Wells and Kennebunk, ME. Master's Project, Antioch New England Graduate School, Keene, NH.
- ❖ Wells, P. G. 1999. Environmental impacts of barriers on rivers entering the Bay of Fundy: report of an *ad hoc* Environment Canada working group. Technical report series No. 334, Canadian Wildlife Service. Dartmouth, Nova Scotia, Canada.

APPENDIX D: Regional Inventory Coordinators

The following individuals will coordinate the regional inventory of potential tidal marsh restoration opportunities in specific Gulf of Maine jurisdictions. Please contact a local coordinator to contribute tidal marsh inventory data or for more information. Inventory coordinators will compile data within their jurisdictions and submit to the regional database.

Lee Swanson **506-453-7108**
New Brunswick Dept. of Natural Resources & Environment
Wetlands and Coastal Habitat
P.O. Box 6000
Fredericton, NB E3B 5H1
laswanson@gov.nb.ca

Alan Hanson **506-364-5061**
Waterfowl and Wetland Ecology
Environment Canada/CWS
P.O. Box 6227
Sackville, NB E4L 1G6 Canada
al.hanson@ec.gc.ca

Randy Milton **902-679-6224**
Nova Scotia Dept. of Natural Resources
Wetlands and Coastal Habitats Prog.
136 Exhibition Street
Kentville, NS B4N 4E5 Canada
miltongr@gov.ns.ca

Lois Winter **207-781-8364**
USFWS-Gulf of Maine Program
4R Fundy Rd.
Falmouth, ME 04105
lois_winter@fws.gov

Kathleen Leyden **207-287-3261**
Maine Coastal Program
Maine State Planning Office
38 State House Station
Augusta, ME 04333
kathleen.leyden@state.me.us

Ted Diers **603-271-2155**
New Hampshire Coastal Program
2 ½ Beacon Street
Concord, NH 03301
t_diers@osp.state.nh.us

Alan Amman **603-868-7581**
USDA-NRCS
2 Madbury Rd
Durham, NH 02384
aammann@nh.usda.gov

Christy Foote-Smith **617-292-5991**
Mass. Wetlands Restoration and Banking Program
100 Cambridge St., 20th Floor
Boston, MA 02202
christy.foote-smith@state.ma.us

Eric Hutchins **978-281-9313**
National Marine Fisheries Service
One Blackburn Drive
Gloucester, MA 01930
eric.hutchins@noaa.gov

APPENDIX D: Regional Tidal Marsh Inventory Data Sheet

Site ID: __ __ __ __ __
(leave blank)

Date: ___/___/___
(fill in)

Regional Tidal Marsh Inventory Data Sheet

Please fill out the form as completely as possible. Your responses will help populate a searchable database, located at http://gulfofmaine.fws.gov, of potential and existing tidal marsh restoration projects in the Gulf of Maine watershed. Lines for additional notes are optional but will help clarify your responses, especially when "other" is chosen. If your project can be broken down into phases, please submit one form per phase. Thank you for your participation.

PROJECT NAME *(subjective; fill in one letter/punctuation per box including blank boxes for space; e.g. Conomo Point-Phase1)*

CITY OR TOWN (e.g. Manchester-By-The-Sea)

STATE OR PROVINCE *(circle one):*
MA ME NH NB NS

AREA IMPROVED: ________ *m²* (practicable area of enhancement/restoration not just the area worked on e.g. a dam removal area would be large, but the area restored could be small)

WATER BODY (closest waterbody identified from a 1:24,000, 7.5 minute quadrangle map produced by the US geological Survey or a 1:50,000 map produced by Energy, Mines, and Resources, Canada; e.g. Saratoga Creek)

COORDINATES *(*of a point near the center of the restoration site; e.g. 40°E 18' 30" N, 70°E 34' 45" W)

LATITUDE ___ degrees ______minutes ______ seconds _____

LONGITUDE ____ degrees ______minutes ______ seconds _____

OWNER(S) check all that apply
and list owner acronym or abbreviation if known

❑private ______________________________
❑non-profit organization ___________________
❑public ______________________________

ESTIMATED COST (circle one*)* ***<$10K*** ***$10K-100K*** ***>$100K***

IS THE PROJECT FUNDED? (circle one) ***YES*** ***NO*** ***PARTIALLY***

Cut along dotted line to remove Tidal Marsh Inventory Data Sheet for copies, completion and submission.

HISTORIC CONDITION (pre-impact National Wetlands Inventory Classification (US) or Canadian Wetlands Atlas Classification (Can) or specific species (scientific); e.g. E2EM/S. patens)

note:____

NATURE OF ALTERATION (check all that apply)

❑*tidal restriction* ❑*bulkhead* ❑*stormwater* ❑*ditch* ❑*fill* ❑*salt hay*

❑*other*

note: ____

IMPACTS (consequence of alteration, check all that apply)

❑*drained marsh* ❑*impounded* ❑*flooded* ❑ *invasive vegetation*

❑*other*

note:____

RESTORATION ACTION *(check all that apply)*

❑*stormwater treatment* ❑*culvert enlargement* ❑*ditch plugging* ❑ *fill removal*

❑*other*

note:____

ACTIONS (check all that have been completed including the current status)

❑*none* ❑*pre-monitoring* ❑ *permitted* ❑ *implementation* ❑ *post-monitoring*

❑*other*

note:____

FURTHER INFORMATION (up to 2 contacts)

Name:	***Name:***
Organization:	***Organization:***
Address:	***Address:***
City:	***City:***
State/Province:	***State/Province:***
Zip Code:	***Zip Code:***
Phone:	***Phone:***
E-mail:	***E-mail:***

RETURN TO: (Regional Inventory Coordinator contact information goes here)

APPENDIX E: Gulf of Maine Marsh-Estuarine Fish Species

Fish Species Known to Occur in Salt Marsh Estuarine Ecosystems in the Gulf of Maine

- *Alosa aestivalis* (blueback herring)
- *Alosa mediocris* (hickory shad)
- *Alosa pseudoharengus* (alewife)
- *Alosa sapidissima* (American shad)
- *Brevoortia tyrannus* (Atlantic menhaden)
- *Clupea harengus* (Atlantic herring)
- *Ammodytes americanus* (American sand lance)
- *Anguilla rostrata* (American eel)
- *Apeltes quadracus* (fourspine stickleback)
- *Gasterosteus aculeatus* (threespine stickleback)
- *Gasterosteus wheatlandi* (blackspotted stickleback)
- *Pungitius pungitius* (ninespine stickleback)
- *Cyclopterus lumpus* (lumpfish)
- *Liparis atlanticus* (seasnail)
- *Decapterus macarellus* (mackerel scad)
- *Fundulus heteroclitus* (mummichog)
- *Fundulus majalis* (striped killifish)
- *Gadus morhua* (Atlantic cod)
- *Microgadus tomcod* (Atlantic tomcod)
- *Pollachius virens* (pollock)
- *Urophycis chuss* (red hake)
- *Urophycis tenuis* (white hake)
- *Pholis gunnellus* (rock gunnel)
- *Menidia beryllina* (inland silverside)
- *Menidia menidia* (Atlantic silverside)
- *Menidia peninsulae* (tidewater silverside)
- *Morone americana* (white perch)
- *Morone saxatilis* (striped bass)
- *Mugil cephalus* (striped mullet)
- *Hemitriperus americanus* (sea raven)
- *Myoxocephalus aeneus* (grubby)
- *Myoxocephalus oxtodecimspinosus* (longhorn sculpin)
- *Myoxocephalus scorpius* (shorthorn sculpin)
- *Cryptacanthodes maculatus* (wrymouth)
- *Osmerus mordax* (rainbow smelt)
- *Peprilus tricanthus* (butterfish)
- *Petromyzon marinus* (sea lamprey)
- *Pleuronectes ferrugineus* (yellowtail flounder)
- *Pseudopleuronectes americanus* (winter flounder)
- *Scopthalmus aquosus* (windowpane flounder)
- *Pomatomus saltatrix* (bluefish)
- *Salmo salar* (Atlantic salmon)
- *Salmo trutta* (brown trout)
- *Salvelinus fontinalis* (brook trout)
- *Scomber scombrus* (Atlantic mackerel)
- *Sphyraena borealis* (northern sennet)
- *Syngnathus fuscus* (northern pipefish)
- *Tautogolabrus adspersus* (cunner)

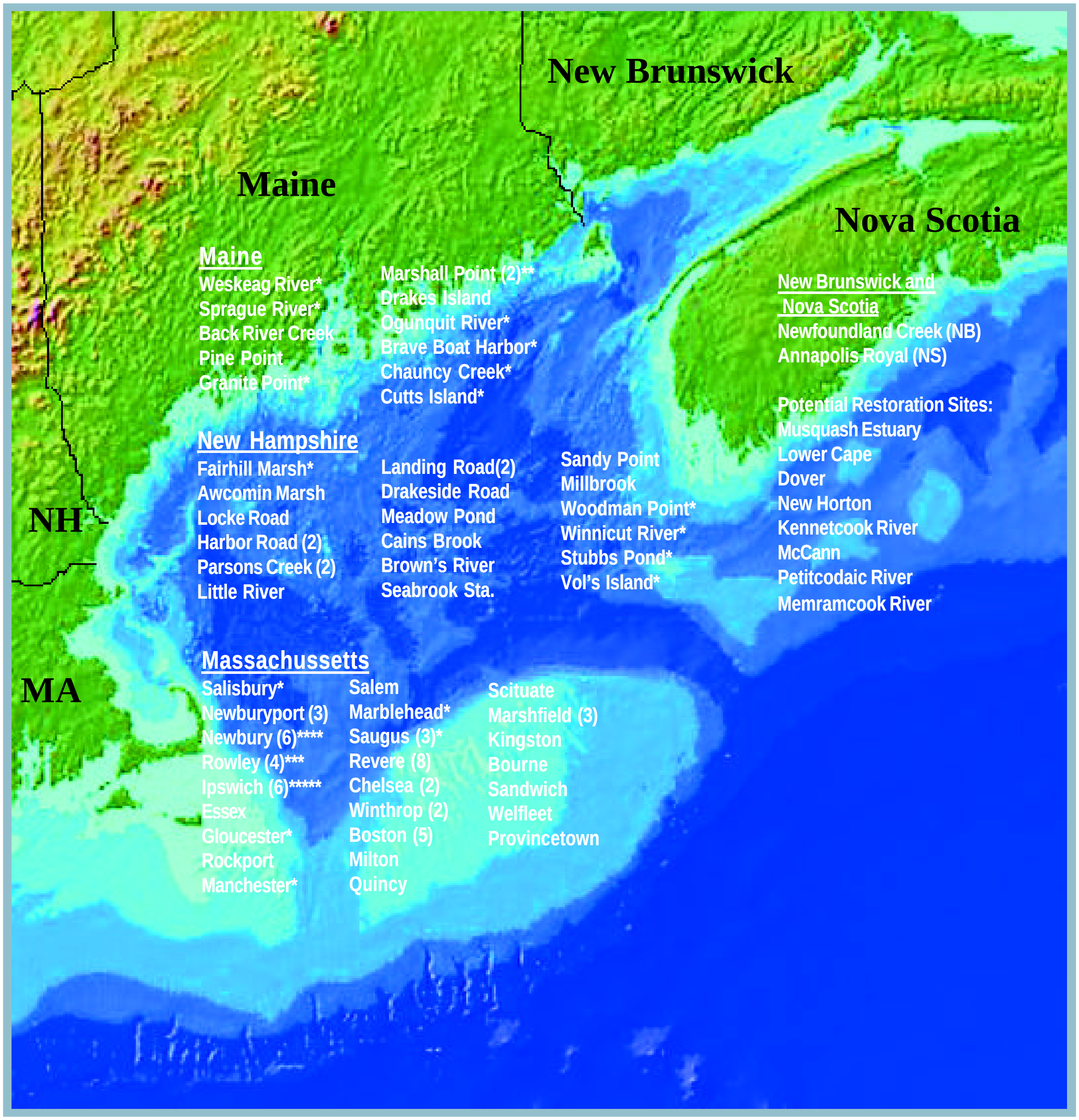
Key References

Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. Fishery Bulletin 74,Vol.53:577p.

Dionne, M., F.T. Short, and D.M. Burdick. 1999. Fish utilization of restored, created, and reference salt marsh habitat in the Gulf of Maine. American Fisheries Society Symposium 22:384-404.

Robins, C.R., G.C. Ray, and J. Douglas. 1986. A field guide to Atlantic coast fishes of North America. Houghton Mifflin Co., Boston. 354p.

Scott, W.B., and M.G. Scott. 1988. Atlantic fishes of Canada. Can.Bull.Fish.Aquat. Sci.219:731p.



Map courtesy of R.Signell and E. Roworth
U.S. Geological Survey

Tidal Marsh Restoration and Enhancement in the Gulf of Maine

Restoration projects in salt marsh ecosystems in the Gulf of Maine. The majority of projects are characterized by tidal flow restoration in tidally restricted marshes. Numbers within parentheses indicate multiple projects at a given site. Asterisks indicate the number of projects characterized by panne construction or ditching plugging (to create or replace open water habitat on the high marsh), or perimeter ditches (occasionally used to control invasive plants). For example, in Ipswich, MA, of the 6 projects, 5 were panne/ditch projects, and 1 was a tidal restoration.