Gulf of Maine
Habitat Restoration Strategy

Restoring Coastal Habitat in the Gulf of Maine Region

Gulf of Maine Council
on the Marine Environment

October 2004

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Gulf of Maine

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GULF OF MAINE COUNCIL ON THE MARINE ENVIRONMENT
HABITAT COMMITTEE RESTORATION SUBCOMMITTEE

Gulf of Maine Council Mission

"To maintain and enhance environmental quality in the Gulf of Maine and to allow for sustainable resource use by existing and future generations..."

Gulf of Maine Council on the Marine Environment

Thanks to Our Artists!

Jim Dochtermann painted the salt marsh scenes on the front cover. Jim donated the artwork to the Gulf of Maine Council out of interest in conserving the Gulf of Maine's natural resources.

Mark McCollough, Endangered Species Specialist with the US Fish and Wildlife Service, drew all of the bird illustrations used in this document. **Ethan Nedeau**, science translator for the Gulf of Maine Council and freelance illustrator, drew all of the fish and invertebrate illustrations used in this document. Special thanks to all of those who contributed photographs.

The Gulf of Maine Council would like to thank the members of the Habitat Restoration Subcommittee who volunteered many hours assisting with drafting, editing and producing this document. This document provides a blueprint for restoration efforts in the Gulf of Maine that would not have been possible without the commitment of the many partners involved, which are too numerous to list. In particular, the NOAA Habitat Restoration Center staff in Gloucester, MA provided invaluable financial and technical support from beginning to end. The GOMC/NOAA Partnership is funded through the Habitat Restoration Partnership Grant from the National Marine Fisheries Service (award number: #NA17FZ1390). Thanks to Ethan Nedeau for document design and layout.

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The document is also available in PDF format on the Gulf of Maine Council's website at www.gulfofmaine.org.

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Gulf of Maine
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EXECUTIVE SUMMARY

Habitat restoration is necessary to support aquatic resources in the Gulf of Maine to meet both biological and socioeconomic needs. The socioeconomic advantages associated with habitat restoration are significant. Restored habitats provide communities with opportunities for sustainable commercial fishing, recreation, and nature-based tourism. Habitat restoration projects have been conducted in each of the Gulf of Maine Council's five member jurisdictions (Maine, Massachusetts, New Hampshire, New Brunswick, and Nova Scotia). These restoration projects, developed to meet individual state or provincial goals, may have addressed shared resources within the Gulf of Maine, however, this usually happened as a byproduct of individual efforts rather than as part of a Gulf-wide vision. While laying the groundwork for that vision, this document will meet the following objectives:

- State the purpose and scope of regional habitat restoration in the Gulf of Maine
- Identify habitat types, impacts, and restoration needs
- Develop recommendations for enhancing habitat restoration

A regional restoration strategy will provide benefits to many interests in the Gulf of Maine. Implementation of the strategy will increase community interest in natural resources and restoration efforts, improve the effectiveness of resource utilization, enhance local restoration projects, generate more funding, increase the capacity of restoration practitioners, and focus limited resources to priority needs.

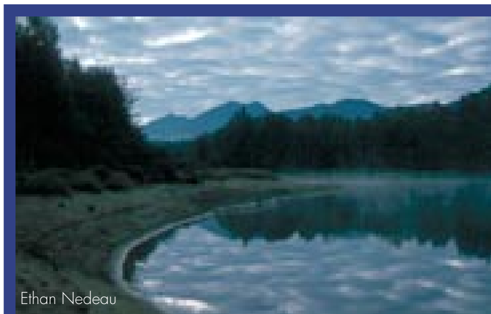
This document does not serve as a prescriptive list of restoration projects, but rather identifies resources of regional significance and promotes habitat restoration that is needed to support the viability of these resources. The strategy focuses on four categories of habitats: (1) riverine, (2) intertidal, (3) subtidal, including nearshore and offshore waters, and (4) beaches, sand dunes, and islands. Other issues of regional concern—such as stormwater management, toxins reduction, conservation and protection, riparian buffer improvement, stewardship, and land use regulation—are not covered in this document but are being addressed by the Gulf of Maine Council and other organizations in the region.

The policy recommendations provided in this document are shared policy objectives around the Gulf of Maine for each of the habitats described in this strategy. Restoration techniques and project objectives vary depending on the resource and the socioeconomic factors at play. The following are recommendations for continued success with habitat restoration efforts in the Gulf of Maine:

- Restore the four coastal marine habitat types identified in this document using a regional strategy to prioritize projects
- Improve our ability to identify habitat restoration sites, focus regional efforts, understand regional trends, and develop effective long-range planning
- Increase development and management capacity in all jurisdictions in the region to make restoration more efficient and effective
- Enhance outreach efforts to federal, state, local governments and the private sector to create a common understanding of the social, economic, and environmental benefits of habitat restoration
- Complete and maintain a database of restoration projects in the region to evaluate progress and ensure accordance with the US National Estuary Restoration Inventory (NERI)
- Refine existing salt marsh monitoring protocols and develop monitoring protocols for other habitats identified in this document

Introduction

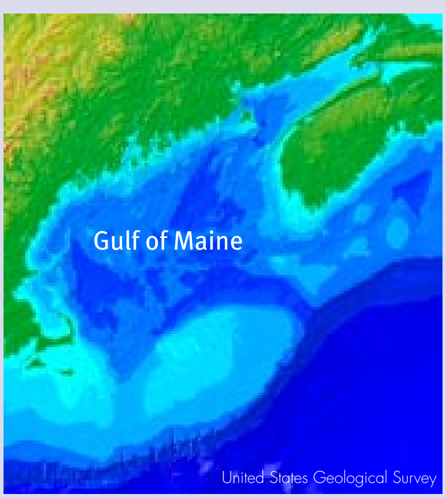
The primary reason for developing a Gulf of Maine habitat restoration strategy is to focus restoration activity on regional riverine, estuarine, coastal, and marine habitats. Currently, Maine, New Hampshire, Massachusetts, New Brunswick, and Nova Scotia are developing, funding, and implementing habitat restoration projects. While these projects have undoubtedly improved habitat, it is difficult to develop restoration projects that address Gulf-wide issues when each jurisdiction has different goals, objectives, funding resources, and restoration capacity. Land use planning laws and management practices in each jurisdiction differ due to different social, political, and economic situations. A regional approach to habitat restoration provides the opportunity to meet common goals and objectives for restoration despite the challenge of managing natural resources that span five jurisdictions and two countries.



In **ecological restoration**, we seek to return an ecosystem, as closely as possible, to its structure and function prior to human disturbance. The goal is to develop a self-sustaining ecosystem that resembles the structure and function of a natural system.

The primary focus of habitat restoration efforts in the Gulf of Maine is to ensure that degraded habitats for migratory and resident marine species are improved and protected. Many fish, bird, and mammal species use the Gulf of Maine as part of their annual migration routes—their needs are irrespective of political boundaries. This strategy covers four habitat categories that are the focus of the Council's restoration efforts, including (1) riverine habitats including freshwater and estuarine systems, (2) intertidal habitats, (3) subtidal habitats and deep-water marine areas, and (4) beach, dune, and island habitat. Not considered in this document are other habitats such as forests and grasslands, the restoration of which may improve the health of the Gulf of Maine watershed.

The socioeconomic benefits of Gulf-wide habitat restoration are significant in terms of creating employment opportunities and improving quality of life. Sustainable commercial and recreational fisheries, for instance, provide local jobs and support local businesses, which improves the quality of life for everyone in the Gulf.



About the Gulf of Maine

The Gulf of Maine watershed encompasses Nova Scotia, New Brunswick, Maine, New Hampshire, Massachusetts, and a small portion of Quebec. The total land area is 69,115 square miles, or 165,185 square kilometers. Quebec does not have Gulf of Maine shoreline, and Maine is the only jurisdiction located entirely within the watershed. The Gulf of Maine is a semi-enclosed sea bounded to the south and east by Browns Bank and Georges Bank, and includes the Bay of Fundy. The shaded-relief map shows some of the diverse underwater landscapes of the Gulf of Maine, which were largely created by glaciers 10,000 to 20,000 years ago. The darker blues represent the deepwater areas and the lighter blues indicate shallow water. Underwater valleys plunge to depths of 1,500 feet (500 meters) and mountains rise from depths of 800 feet (266 meters) toward the surface of the sea.

The Gulf of Maine Council on the Marine Environment

The Gulf of Maine Council on the Marine Environment (GOMC) is a collaboration between public and private entities around the Gulf of Maine that was developed to enhance, improve, and protect the estuarine, coastal, and marine resources of the Gulf. In 1989, the Governors of Maine, Massachusetts, and New Hampshire, as well as the Premiers of New Brunswick and Nova Scotia, passed a resolution indicating that each jurisdiction within the Gulf of Maine is committed to the mission of the Gulf of Maine Council. The Council's mission is "to maintain and enhance environmental quality in the Gulf of Maine and to allow for sustainable resource use by existing and future generations."

The GOMC Habitat Restoration Subcommittee, made up of restoration practitioners from throughout the Gulf of Maine, has facilitated the development of this regional habitat restoration strategy and provides technical and financial assistance for restoration projects. The Subcommittee's activities support the Council's restoration objectives as stated in the Action Plan 2001-2006:

GOAL

Restore 3,000 acres of coastal and marine habitats by 2006.

STRATEGIES

- Increase rate and improve effectiveness of habitat restoration
- Promote habitat restoration by creating a regional restoration plan, funding restoration activities, and pursuing additional funds for restoration projects throughout the Gulf of Maine.

Gulf of Maine Council and National Oceanic and Atmospheric Administration Partners in Restoration

Habitat Restoration Partnership

The GOMC/NOAA Habitat Restoration Partnership was established in 2001 to solicit restoration projects in the Gulf to be funded using a competitive process. A review team with representatives from Massachusetts, New Hampshire, Maine, and the NOAA Restoration Center review grant proposals annually. The Partnership has funded 33 projects for a total of $766,035, with roughly $3.6 million from other sources. This partnership has been an effective method of restoring regionally significant habitat in the Gulf of Maine.

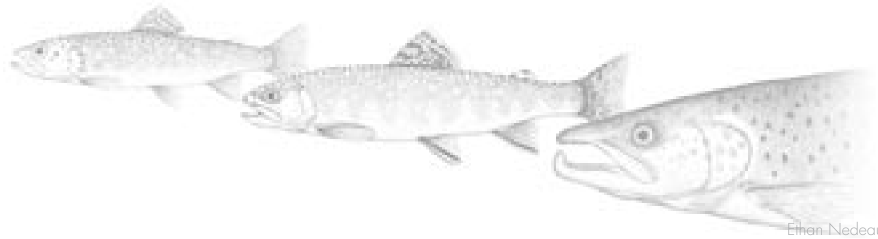
Gulf of Maine Habitat Restoration Web Portal

GOMC and NOAA are developing a regional habitat restoration web portal. This effort brings together information about restoration projects from the US and Canadian jurisdictions of the Gulf of Maine. The web portal will include the Gulf of Maine Habitat Restoration Strategy, a restoration database, project vignettes, and general information on identifying, planning, and funding habitat restoration projects within the Gulf of Maine. The database section of the web portal will be a geographic module of the National Estuary Restoration Inventory (NERI) and will be accessible through the GOMC web portal and through NERI. This will allow GOMC to leverage NOAA's technical capacity to develop the restoration inventory and provide NOAA with essential restoration data for three New England states and two Canadian provinces.

GOMC/NOAA Habitat Restoration Partnership Projects

See Appendix B for complete list

Rivers



The conservation and restoration of riverine habitat is of special concern to the GOMC because rivers have great economic, recreational, and environmental importance. Rivers sustain the Gulf of Maine's anadromous and catadromous fish species, which are valuable members of the region's biological diversity. Anadromous fish are those that spend their lives in salt water and migrate into freshwater to spawn. Catadromous fish spend their lives in freshwater and migrate to the ocean to spawn. Collectively, anadromous and catadromous fish are called diadromous. Only 87 of 24,700 species of fish in the world are anadromous (Atlantic Salmon Federation, 2002). The Gulf of Maine supports 12 diadromous species, including the Atlantic salmon, rainbow smelt, alewife, and striped bass. The catadromous American eel was historically found in almost all waterbodies in the watershed.

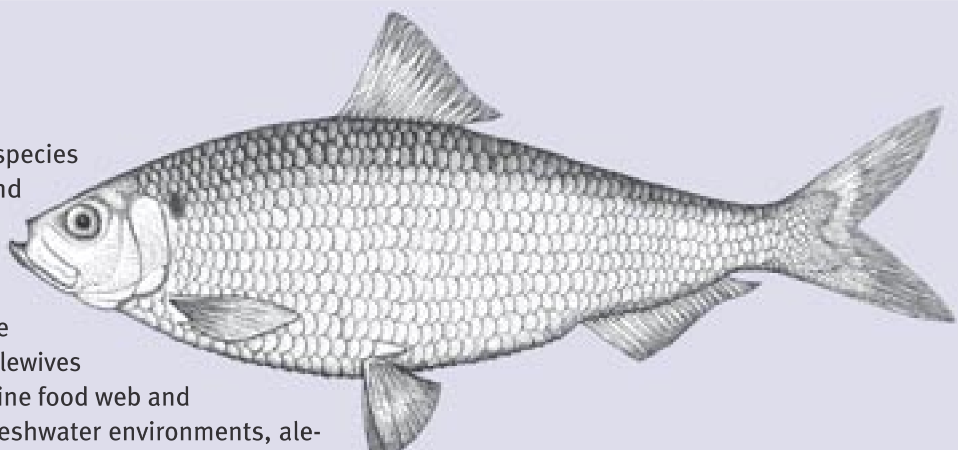
Rivers support various species and life stages of freshwater and diadromous fish. The rich diversity of habitats—particularly different substrate types, flow conditions, adjacent wetlands, and floodplain forests—are vitally important for aquatic biological diversity. For example, sea-run brook trout prefer cold, fast flowing streams; blueback herring and alewife prefer larger streams, backwater areas, and lakes; and American shad prefer large rivers. Riparian vegetation is an important food source for aquatic invertebrates and influences the growth and survival of many fish. Healthy riparian habitats are essential to maintain water quality conditions, such as cool water temperatures preferred by Atlantic salmon and brook trout.

Riverine Habitat Policy Objective

The Council's objective is to support restoration and enhancement of riverine habitats, and improve access for fish and wildlife. Emphasis will be placed on restoration of migratory fish, whose historic spawning habitat has been greatly diminished.

Gulf of Maine Highlight

ALEWIFE

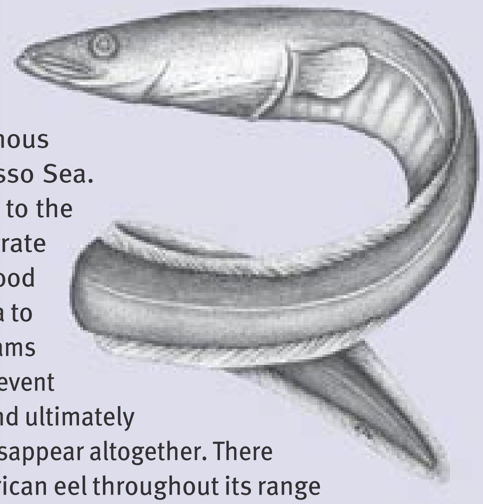


The alewife is an anadromous species that is vital to freshwater and marine habitats in the Gulf of Maine. Alewives depend on coastal rivers for spawning habitat and range offshore in the Gulf to forage on zooplankton. Alewives are important to the Gulf of Maine food web and marine ecosystem health. In freshwater environments, alewives provide forage for bass, salmonids, eels, ospreys, eagles, kingfishers, loons, and many mammals. Spawning alewife heading upriver provide cover for out-migrating salmon smolts in the spring. In the marine environment, alewives are eaten by commercially and recreationally important fish, such as bluefish, striped bass, cod, pollock, and silver hake. The alewife is an important commercial species in the Gulf of Maine because it is used as lobster bait. People enjoy watching their spring spawning migrations in coastal streams and rivers.

Illustration Credit: Ethan Nedeau

Gulf of Maine Highlight

AMERICAN EEL



The American eel is a catadromous species that spawns in the Sargasso Sea. Ocean currents distribute juveniles to the eastern seaboard, where they migrate into freshwater and grow to adulthood before returning to the Sargasso Sea to spawn. Migration barriers—such as dams and improperly designed culverts—prevent eels from reaching critical habitats and ultimately cause their numbers to diminish or disappear altogether. There is international concern for the American eel throughout its range from northern Canada to the Gulf of Mexico. In 2004, due to continued declines in their populations, the Atlantic States Marine Fisheries Commission recommended that the US Fish and Wildlife Service and the National Marine Fisheries Service consider designating the entire coast-wide stock of American eel a candidate for federal listing under the Endangered Species Act. Restoration of American eel numbers will require providing upstream and downstream passage in freshwater habitats—an effort that will also benefit other diadromous species and native ecosystems.

Illustration Credit: Ethan Nedeau

Diadromous Fish in the Gulf of Maine

- Shortnose sturgeon
- Atlantic sturgeon
- Blueback herring
- Alewife
- American shad
- American Eel
- Tomcod
- White perch
- Striped bass
- Rainbow smelt
- Sea lamprey
- Atlantic salmon
- Brook Trout (sea run)

Threats and Restoration Opportunities

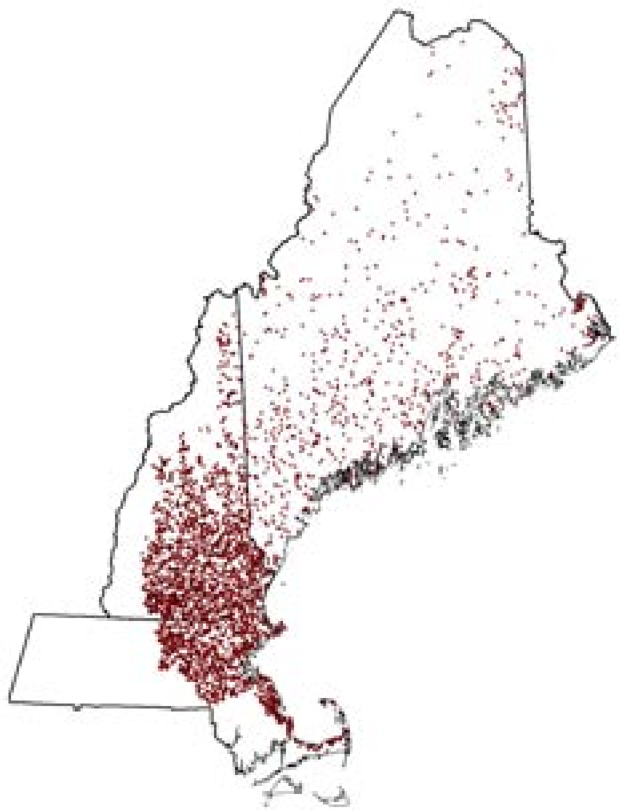
Dams and Fish Passage Barriers

According to current databases, the U.S. side of the Gulf of Maine has 4,867 dams: 2,506 in New Hampshire, 782 in Maine, and 1,579 in Massachusetts. States categorize and inventory dams in different ways, and this is reflected in state totals. In New Hampshire, all dams are counted regardless of height, size of impoundment, and use. In Maine, dam owners voluntarily registered dams between 1983 and 1993—registration required a minimum dam height and a minimum water capacity behind the dam. There are undoubtedly many more dams in Maine since some owners may not have registered their dams, and many abandoned log driving dams or milldams were not included in the inventory.

Dams can greatly restrict or prohibit upstream and downstream fish passage for resident and migratory fish. Migratory fish are vulnerable because barriers affect spawning behavior and success. From an ecological perspective, dams that block fish passage should be reengineered or removed to allow fish passage. Dam removal reconnects artificially fragmented river systems, restores habitat for migratory and resident fish, restores natural flow regimes, and improves water quality.

Dam removal may create economic and social benefits. Dam removal is a favorable option when the long-term costs of dam maintenance are high compared to financial returns. For instance, a state-regulated obsolete milldam may require significant investment to meet safety requirements, or a federally regulated power-producing dam that requires fish passage may only be marginally economical. Another consideration is the liability associated with dams that have deteriorated and are in danger of failure, causing downstream flooding, property damage or even loss of life. Restoring river habitat can create new social, economic, and recreational opportunities such as boating, fishing, and wildlife viewing. Angling for migratory sea run fish, such as American shad and striped bass—as well as festivals surrounding annual springtime alewife runs—provide tourist attractions and nature-based tourism opportunities in many areas of the Gulf.

Dam removal should be considered when evaluating project alternatives. A comprehensive analysis of dam removal options will enable well-informed decisions on the future of dams throughout the Gulf of Maine watershed. Dam



Location of dams in the U.S. portion of the Gulf of Maine watershed.

Sennebec Dam, in Union, Maine, before and after removal. Credit: John Catena, NOAA

removal may not always be feasible because of social and economic factors, such as water supply needs, hydropower production, recreational activity, and cultural desires. In these cases, installation of upstream and downstream fish passage may reduce the dam's effects on fisheries.

Installing a fishway on a dam can greatly improve fish migration. However, fishways do not provide the full benefit of dam removal because a fishway does not restore riverine function or habitat—only fish access. Fishways are often designed to improve access for specific species. Several types of fishways are highly effective, particularly for migratory species like American shad and river herring (e.g., Denil-type, Alaskan steep pass). There is increasing interest in innovative fishways that are designed to mimic nature, either in the form of a riffle (i.e., rock ramp fishway) or a tributary to the main river (i.e., bypass channel). These "nature-like fishways" have been shown to pass a broader diversity of fish species, and even reptiles and amphibians.

Regardless of the type of fishway, the design and placement must take into consideration many critical factors, such as adequate hydraulics within the fishway and proper attraction flow so that the fish are able to find and navigate the structure. Identifying an entity to take long-term maintenance and operational responsibility for the fishway is also critical to the success of the project.

Improperly designed or maintained culverts can be just as effective as dams at blocking fish migration. The following are a few guidelines for replacing culverts that are restricting or preventing fish passage:

- Match the culvert (pipe) dimensions to natural bank full stream channel hydraulic geometry
- Use corrugated elliptical pipe arches with the largest feasible corrugations
- Embed the pipe invert to 12-48 inches depending on the size of the pipe
- Place the pipe at zero slope
- The pipe should pass 50-year flood with capacity lost to embedding included
- If a culvert is being rehabilitated rather than replaced, hydraulic analysis is needed to calculate water veloci-

Sebasticook River channel restoration site.
Credit: John Catena, NOAA

Plymouth Pond Fish Ladder on the Sebasticook River in Plymouth, Maine. Credit: John Catena, NOAA

ties and depths under design flows, and to design mitigation measures needed to achieve velocities and depths that will pass fish

Techniques for Improving Fish Passage

Dam Removal: Selective dam removal is a highly effective way to restore fish passage in river systems, as well as improve water quality, restore spawning and rearing habitat, and reestablish nutrient transport. Significant repair work may cost three to five times as much as removing the dam. Appropriate construction methods are variable and dependent on a variety of factors, including dam type, river conditions, accessibility, and timing restrictions.

Replacing or Reconstructing Culverts: Reconstructing undersized or improperly placed culverts is a relatively low-cost and effective means of restoring fish migration to smaller rivers and streams. The preferred method is to install an adequately sized culvert with natural bottom habitat (where feasible), and to ensure that the hydraulics of the structure will not restrict fish movement.

Rock Ramps: These structures, built with cobble and boulders to replace an existing dam, retain water levels behind the structure but also provide a more natural flow of water to allow migrating fish to pass.

Rock Sills: Rock sills are built out from the riverbank on both sides of the river in an alternating pattern. The purpose of the sills is to create a riffle and pool environment that creates habitat for fish by concentrating water flow and providing opportunities for resting and spawning.

Fish Ladders: Fish ladders are engineered to allow fish passage over a dam. While these can successfully pass some species, they are not effective for all fish species.

By-pass Options: By-pass channels are constructed around dams to create a channel that has riffles and pools as well as stream channel bottom and riparian habitat that mimics the natural system. These structures can be designed to pass many species. However, they can require large areas of land since they often must overcome substantial elevation differences above and below the dam.

Degraded Stream Morphology and Riparian Buffers

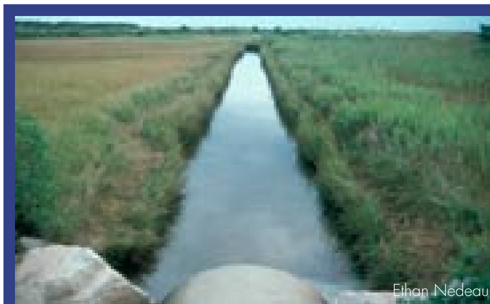
Gulf of Maine's rivers have been affected by a long history of environmental degradation. Portions of rivers have been straightened in a misguided effort to divert water to flush impoundments or reduce the incidence of floods. Log drives had drastic effects on natural stream morphology. Restoration of natural channel morphology is an effective technique for improving fish habitat and reducing flooding by reconnecting the natural absorption capacity of the floodplain to the river.

Natural riparian buffers moderate water temperatures, provide instream habitat and a food source for aquatic organisms, and reduce erosion by stabilizing riverbanks. Humans have removed or altered natural riparian vegetation thereby reducing their buffering capacity. Stabilizing riverbanks with native shrubs and trees is a valuable restoration technique for riverine habitats.

Intertidal Habitat

Ethan Nedeau

Gulf of Maine intertidal areas are comprised of three major habitats: salt marsh, rocky intertidal, and mudflat. The location and extent of these habitats are influenced by substrate, wave and tidal energy, tidal range, and slope. These habitats support several commercially important species. The softshell clam harvest in Maine was valued at $17 and $15 million, respectively, for 2001 and 2002 (Maine Department of Marine Resources, 2004). Irish moss is another commercially important species—it is harvested for carrageenan, which is used as a thickener, stabilizer, and gelling agent in many domestic products.



Ethan Nedeau

Intertidal Habitat Policy Objective

The Council's objective is to support restoration of natural tidal regimes—and thus the functions and values of tidal wetlands—to intertidal habitats through the removal of selected dikes, fill, water control structures, and inadequately sized culverts.

Salt marshes provide food and shelter for a variety of invertebrates, fish, and birds. Striped bass, flounder, mummichogs, and sticklebacks use salt marshes for food, shelter, spawning, and nursery areas. Food webs of the marshes and mudflats in the upper Bay of Fundy are important to the summer feeding of American shad. Clams and ribbed mussels inhabit salt marshes and adjacent tidal flats. Birds rely on salt marshes for breeding habitat and migratory rest stops, and thrive on the rich abundance of food. Sharp-tailed sparrows, Seaside Sparrows, Long-Billed Marsh Wrens, and American Bitterns all nest in salt marshes.

Salt Marshes

Salt marshes occur throughout the Gulf of Maine as large estuarine complexes or small fringing marshes. Salt marshes are flooded twice daily, and are characterized by widely fluctuating temperature, wetness, and salinity. Cordgrass, salt marsh hay, spike grass, and black grass are some of the hardy plants that characterize salt marshes. Despite harsh growing conditions and low plant diversity, salt marshes are among the most productive ecosystems on Earth. Ebb tides carry nutrients from the marsh into offshore waters where they influence marine food webs.

Ice scouring, which can retard the growth of a salt marsh, remains a natural threat to these habitats. From the time when cordgrass begins to take hold, it may take over 500 years for a salt marsh to reach maturity (Berrill and Berrill, 1981). The last glacial period wiped out the salt marshes that existed in the present-day Gulf of Maine. Today, about 61 square miles (158 km^2) of salt marsh is found around the Gulf of Maine, representing a small, but ecologically important fraction of the coastline.

Salt marsh pool in Little River Marsh, Maine. Credit: Peter Taylor

Freshwater Tidal Marshes

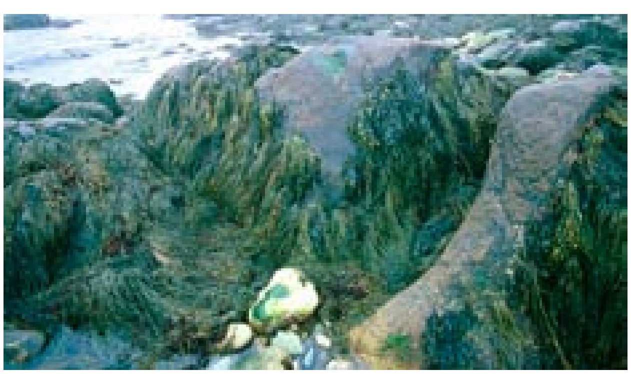
The hydrology of freshwater tidal marshes is tidally influenced. Typically, water levels in large rivers just upstream of estuaries will fluctuate with the tides, but saltwater does not normally extend into these waters. Plant diversity is much higher in freshwater tidal marshes than in brackish marshes or salt marshes. Dominant plants include wild rice, pickerelweed, water arum, reed canary grass, river bulrush, and the introduced purple loosestrife. Merrymeeting Bay in Maine is a classic example of a tidal freshwater wetland. Freshwater tidal marshes have been greatly affected by head-of-tide dams that restrict tidal flow.

Photo Credit: Ed Friedman

Rocky Intertidal

Rocky intertidal zones are found throughout the Gulf of Maine but are most common along the coast of Maine and the lower Bay of Fundy. Rockweeds are dominant in rocky intertidal areas because they can attach to rocks with special structures called holdfasts. Common rocky intertidal rockweeds are knotted wrack, spiral wrack, and bladder wrack. Bladder wrack is prevalent in areas more exposed to wind and waves, while knotted wrack tends to dominate in more sheltered places (Conkling, 1995).

Rockweeds are keystone species that greatly influence intertidal communities. At high tide, the floating fronds form a canopy that provides protective cover for invertebrates and young fish. At low tide, the fronds collapse in heaps over the rocks, providing a wet and cool environment for marine invertebrates that might otherwise desiccate. Amphipod crustaceans are perhaps the most common invertebrates inhabiting the rockweed understory. Three periwinkle species are the dominant herbivores: smooth periwinkle, rough periwinkle, and common periwinkle, a non-native species likely introduced into the Gulf of Maine in the mid-1800s. Other common invertebrates include the acorn barnacle, a species capable of withstanding wide-ranging temperature fluctuations, and the blue mussel, an animal that can colonize a new area on a rocky shore faster than any other.



Rocky intertidal zone, with an abundance of rockweeds. Credit: Peter Taylor

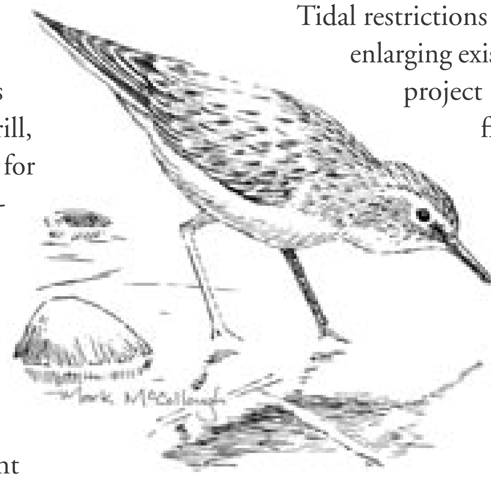
Rockweeds provide habitat for many fish and bird species. More than 30 species of fish utilize rockweeds for food or shelter, as do juvenile lobsters. More than 15 species of birds utilize floating rockweed during some part of their life cycle. For example, Black Ducks and Common Eiders forage extensively for periwinkles and amphipods in rockweed gardens. Rockweed fronds may live for two decades, but will eventually break off, float (often in huge mats) and get washed ashore. Rockweed detritus can contribute from 30-40% of available nutrients in some estuaries and bays (Platt, 1998).

Mudflats

Mudflats may be found where an intertidal area is protected from waves or currents, or the where slope of the seafloor is low, or where there is significant sediment accumulation. Mudflats are found everywhere in the Gulf of Maine, and are particularly prevalent in Cape Cod Bay and in the upper reaches of the Bay of Fundy. The Bay of Fundy has some of the world's largest mudflats, totaling more than 180,000 acres (74,000 ha) (Harvey *et al.*, 1988).

Fluctuating salinity, summer heat, winter cold, and the raking of severe storms limit the diversity of organisms that can survive in mudflats. Microorganisms such as diatoms, dinoflagellates, and blue-green algae are extraordinarily abundant near the surface of the mud, and support tremendous populations of invertebrates. Mud shrimp can occur in densities of more than 5,000 per ft^2

(60,000 per m^2) (Platt, 1998), and slender burrowing nematode worms can reach densities of 2,000 individuals per in^2 (310 per cm^2) (Berrill and Berrill, 1981). These organisms provide forage for fish such as American shad, and numerous shorebirds and wading birds. Nearly one million Semipalmated Sandpipers—most of the global population—migrate through the upper Bay of Fundy each year, gorging on thousands of mud shrimp per day per bird, and doubling their weight in two weeks (Gordon, 1994).



Sandpiper
Credit: Mark McCollough

Mudflats are economically and culturally important. Bloodworms are harvested as fish bait, and soft-shelled clams are harvested by commercial and recreational clam diggers for human consumption. The clam industry is economically important to residents of the Gulf of Maine. There is also a unique cultural aspect to shellfish harvesting that is evidenced by recent efforts to open mudflats to commercial and recreational harvesters.

Threats and Restoration Opportunities

The threats identified below are the focus of restoration efforts in the Gulf of Maine. There are other threats to intertidal areas that are beyond the scope of this document, such as dredging and non-point source pollution.

Hydrology

The natural hydrology of tidal wetlands is affected by tidal restrictions, dikes, and fill deposited on the wetland. Tidal restrictions occur where man-made structures block or restrict natural tidal flow to wetlands. They are usually caused by roads, causeways, dikes and filled areas. Tidal restrictions are common throughout the Gulf of Maine. Inventories of tidal restrictions are completed or underway in all jurisdictions surrounding the Gulf of Maine.

Ecosystems that once supported salt marsh vegetation often become freshwater-dominated environments when much or all of the tidal influence is restricted. Tidal restrictions prevent fish from entering the marshes, change the physical and chemical properties of tidal wetlands, and cause erosive scour pools on either side of the restriction because of increased water velocity.

Tidal restrictions can often be reduced or eliminated by enlarging existing culverts or installing bridges. Each project must measure the degree of restricted flow and estimate the tidal heights that would result from increased flows. In highly developed areas of the Gulf of Maine, it may be necessary to regulate tidal flow to protect infrastructure that might be affected if flow were unrestricted.

Self-regulating tide gates (SRT) are devices that regulate the flow through culverts. SRTs are used in situations where there is risk of tidal flooding (and property damage) from unrestricted ocean water flow. The SRT usually remains open to allow free exchange of tides if the tides are not abnormally high. If the tide reaches the maximum setting of the SRT (during storm surges or spring tides), the gates will close and stop the inland flow of water until the water level recedes to the preset height. SRTs are an alternative in highly developed areas of the Gulf of Maine. See Appendix C for tidal restriction information by jurisdiction within the Gulf.

One method of salt marsh restoration is to replace undersized culverts (top) with larger culverts that allow greater tidal exchange (bottom). Top Photo: Massachusetts Wetland Conservation Program; bottom photo: Jon Kachmar

Three examples of self-regulating tidal gates (SRTs).

Diked, Filled and Ditched Coastal Wetlands

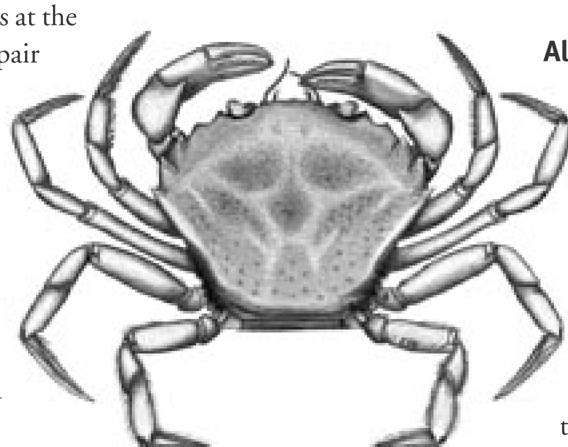
Many salt marshes have been filled, diked, and ditched. Marshes often show evidence of sediment fill from nearby dredging for navigation purposes. Dumping dredge spoils on salt marshes was a common practice throughout the Gulf of Maine into the 1970s. This practice kills the native vegetation and raises the elevation of the marsh to an unnatural height. Since salt marshes depend on regular influxes of saltwater and natural peat accumulation, sediment placed on top of the marsh is detrimental to the marsh ecosystem. Removal of dredge sediments from salt marshes may restore a marsh to a natural condition. Grading the surface elevation of the marsh is critical to restoring the native vegetation since different plant species rely on varying salt regimes and saltwater inundation.

Diked marshes have berms designed to hold back saltwater. The berms are often created to convert part of the marsh to agricultural land. This occurred throughout the Gulf, but is particularly common practice in the upper Bay of Fundy in New Brunswick and Nova Scotia. Many of the largest salt marshes in the Gulf of Maine are in the Bay of Fundy region and large areas have been diked for agricultural use. Many of these areas remain diked, and in Canada, the agricultural agencies at the Provincial level are obligated to repair the dikes to maintain farmland. In some instances, diked marshes have failed because dikes were not maintained, causing serendipitous habitat restoration by allowing saltwater back onto the marsh. There is considerable opportunity for removal of dikes from salt marshes that are no longer used for agriculture.

Ditching was common practice throughout the Gulf to drain marshes for agriculture and to manage mosquitoes. When viewing aerial photographs, ditches will appear as a grid pattern. Natural habitats and predators (fish) in healthy marshes will control mosquito populations—often, ditching actually enhanced mosquito populations. Ditches are sometimes plugged to return the natural hydrological regime to the altered salt marsh.

Invasive Species

Several invasive species inhabit the Gulf of Maine, and are usually indicative of anthropogenic disturbance. The invasive common reed is an indicator of salt marsh disturbance. Common reed can create a monoculture environment that eventually will reduce the diversity of the native plant community by crowding out other species. Typically, this results in a reduced diversity of fish, birds, and other species that rely on salt marshes. Common reed can grow so densely that vertebrates have a difficult time utilizing the marsh. In addition, common reed can be a fire hazard since the dry stems can fuel large fires. Common reed can be managed by eliminating tidal restrictions and allowing adequate saltwater to enter and exit the marsh system. Cutting, and sometimes herbicide treatment, can slow the growth of common reed and allow native vegetation to return.



Green Crab
Credit: Ethan Nedeau

Altered Water Quality and Benthic Conditions

Shellfish habitat is often degraded by non-point or point source runoff. Fecal coliforms are often too high to allow consumption of shellfish unless depuration is employed, which allows the pollutants to be purged from the shellfish. Another problem in the Gulf of Maine is that tidal restrictions may reduce or eliminate saltwater flow to clam flats. Tidal restrictions will usually lower shellfish productivity in a mudflat.

Subtidal Habitat

The feature that unites subtidal habitats is the constant presence of water, unlike intertidal habitats that are periodically dewatered. Aside from the presence of water, however, subtidal habitats are remarkably diverse and support unique biological communities adapted to different combinations of light, temperature, and physical habitat. The subtidal habitats discussed here include estuaries, eelgrass and kelp beds, deepwater benthic habitats, and the water column.

Subtidal Habitat Policy Objective

The Council's restoration objective is to restore eelgrass to improve subtidal water quality, thus supporting social, biological and economic needs in the region.

Estuaries

Estuaries are places where freshwater rivers meet the ocean, and are prominent features in the Gulf of Maine. Estuaries are comparatively rare worldwide, making up less than one percent of Earth's coastline. However, about 30 significant estuaries—17 in the U.S. and 13 in Canada—cover at least 3,000 miles (5,000 km) of the Gulf of Maine's coastline, making the Gulf as a whole (and especially the Bay of Fundy) somewhat estuarine in character. The Merrimack, Kennebec and Saint John rivers are three significant estuaries in the Gulf of Maine. Major bays include Massachusetts Bay, Ipswich Bay, Great Bay, Casco Bay, Muscongus Bay, Penobscot Bay, Blue Hill Bay, Frenchman Bay, Cobscook Bay, the St. Croix Estuary and Passamaquoddy Bay, Shepody Bay, Cumberland Bay, Minas Basin, and Chignecto Bay.

Estuaries receive high concentrations of nutrients that are exported from watersheds, particularly during late winter and early spring snowmelt. Land-derived nutrients combine with nutrients derived from salt marshes, rockweeds, and oceanic sources to stimulate phytoplankton growth throughout the year. Other primary producers include seaweeds, sea grasses, marsh grasses, and benthic algae. Collectively, these primary producers make estuaries among the most productive ecosystems on Earth.

Estuaries are critically important to many species. Estuaries are nurseries for larval and juvenile invertebrates and fish, and feeding and nesting areas for migratory fish and birds. For example, the Sheepscot River estuary is a highly productive spawning ground for Atlantic cod (Maine Coastal Program, 1991). Penobscot Bay supports the highest densities of the American lobster yet recorded in North Atlantic waters (Platt, 1998). Scientists postulate that many commercially important marine fish in the

Underwater photographs of eelgrass and associated animals. Left: pipefish. Center: Canopy of eelgrass. Top right: Hermit crab. Bottom right: bay scallop. Photo credit: US Geological Survey

Aerial view of intertidal and shallow subtitdal habitats; the dark green outer fringe is eelgrass. Credit: Seth Barker

Gulf of Maine spend part or all of their life cycles in estuaries. Migratory birds that use the North Atlantic Flyway find estuaries for feeding and resting. Estuaries also support a diversity of water birds including loons and ducks that seek ice-free estuarine habitat in winter after lakes freeze over. For these reasons, Gulf of Maine’s estuaries have regional and even hemispheric ecological importance.

Eelgrass and Kelp Beds

Eelgrass is a keystone species in shallow estuarine and coastal marine habitats. Eelgrass is a long and slender-leaved plant that flowers and is pollinated underwater. Eelgrass habitat ranges from North Carolina to the Canadian Maritimes and requires adequate light conditions and relatively low turbidity in the water column. Eelgrass filters and traps sediment, improves water quality, provides nursery habitats for many species of fish and invertebrates, and helps sustain migratory waterfowl—particularly American Brant (Maine Coastal Program, 1991; Short and Burdick, 1994). Eelgrass is the basis for the estuarine food web.

Kelps are important to coastal marine ecosystems, including hollow-stemmed kelp, edible kelp, and sea colander. The broad, thick-leaved kelps form dense beds or “forests” up to ten feet (3 m) tall, and may grow in depths of 65-100 feet (20-30 m) and outward five miles (8 km) from the coast. Green sea urchins graze kelps, and are in turn hunted by lobsters. Lobsters prefer kelp beds for shelter when they are molting.

Deepwater Habitats

In deep waters, where marine plants cannot live, substrate types—rather than vegetation—characterize bottom habitats. Common substrate types include sand, mud, gravel, cobble, and boulder, and each supports different faunal communities. For example, gravel beds support invertebrates that prefer large and loosely packed sediments with interstitial spaces large enough for animals to live within the sediments (Watling *et al.*, 1988). A variety of “small-scale” habitats—such as depressions, shells, burrows, and sand wave crests—occur within larger habitat types and create unique environments for certain species. For example, the long-finned squid and the scup utilize the depressions produced by species such as red hake and American lobster (Langton *et al.*, 1994).

Water Column

Many organisms live in the water column, from microscopic plankton to enormous pelagic fishes such as swordfish and bluefin tuna, the largest bony fishes found along the northwest Atlantic coast (Berrill and Berrill, 1981). Also present, although rarely seen, are four endangered species of sea turtles. More than 30 species of marine mammals live in the Gulf of Maine. These include an estimated 30,000 harbor seals, and gray seals whose southern range extends to the Massachusetts coast. Five species of plankton-straining whales exist in the Gulf of Maine, with perhaps 3,500 individuals (from a pre-Colonial number of perhaps 25,000). Prominent among these is the endangered right whale, a large, slow-swimming species that migrates in summer to its only known nursery area, the Grand Manan basin in the Bay of Fundy.

Threats and Restoration Opportunities

Eelgrass Loss

Scientists estimate that 50% of the eelgrass in the North Atlantic has disappeared over the last century (Short, UNH). The reasons for eelgrass declines are nutrient overloading that deprives the species of light, competing algae that outgrow and shade eelgrass seedlings, boat propellers, anchors and dredging activities that dislodge the plants, drag fisheries that scour the bottom, and wasting disease that causes widespread die-offs. Some areas in New Hampshire and Maine have undergone eelgrass restoration (Short *et al.*, 2002), and many are considered candidates for restoration. Restoration methods include transplanting native plants and reseeding areas that once supported eelgrass.

Non-point Source and Dredging

Point and non-point source runoff from agricultural, residential, and urban areas affect subtidal habitat in the Gulf of Maine. Runoff may lower water quality and negatively affect subtidal habitats. Dredging affects water quality by increasing turbidity and possibly suspending and redistributing pollutants. This can destroy benthic habitats such as shellfish beds and eelgrass beds. Docks and piers limit the light reaching the bottom and initiate fragmentation and decline of eelgrass beds.

Opportunities for Restoration

Very little restoration activity is currently being conducted for subtidal habitats in the Gulf of Maine. Nonetheless, this is an emerging concern, and there is a need for identification of projects, funding, and monitoring. As national efforts to improve coastal water quality achieve their goals, the need emerges for reintroduction of eelgrass along with other types of subtidal habitat restoration.

Eelgrass Restoration in Great Bay, New Hampshire

The Great Bay Estuary begins at the mouth of the Piscataqua River (Short 1992) that forms the border between New Hampshire and Maine. The habitats of the Great Bay Estuary—eelgrass meadows, mudflats, salt marsh, channel bottom, and rocky intertidal—are home to 162 bird, fish, and plant species (23 of which are threatened or endangered), many invertebrate species and the occasional harbor seal. Historically, the estuary has been heavily impacted by human activity. Continuous anthropogenic impacts resulted in loss of many eelgrass areas in the Piscataqua River and almost complete loss of eelgrass in Little Bay. The inland portion of the estuary, Great Bay itself, has maintained a healthy eelgrass population due to its relative isolation. In attempts to restore eelgrass to areas of historic loss, and to mitigate for ongoing impacts to eelgrass beds from dredging for Port development, 7 acres of eelgrass were transplanted along the Piscataqua River and Little Bay in the mid-1990s. Of these efforts, 3.3 acres of eelgrass were successfully restored and continues to maintain viable habitat. In 2000, 5.5 acres of eelgrass were transplanted at the mouth of the Piscataqua River and in Little Harbor, again to compensate for dredging destruction of eelgrass beds, meeting project goals by yielding 50% success. As part of these transplanting efforts, new methods and techniques for restoration have been developed which improve restoration success and decrease the cost (Davis and Short 1997, Short *et al.*, 2002). Additionally, these methods allow citizen participation in community based restoration of eelgrass (Burdick-Whitney and Short, 2002). Transplanting can establish eelgrass habitat decades before natural processes might permit recolonization. Many parts of the Great Bay Estuary that historically had eelgrass are still in need of restoration.

Islands, Beaches, and Dunes

Mark McCollough

Islands, beaches, and dunes are home to many of our region's seabird populations, including globally-rare populations of Roseate Terns. The protection and restoration of islands, beaches and dunes will help ensure the recovery of rare species, and preserve the recreational, cultural, and economic values of these habitats.

Islands

The Gulf of Maine has over 5,000 islands, most of which (4,617) are in Maine. Islands cause upwelling of deep, nutrient-rich water to the sea surface, enriching nearby waters. Currents driven by tidal action swirl around islands and surge through passages, "creating a funnel effect that increases the volume of feed available to filter feeders, as well as those species that prey on the filter feeders" (Conkling, 1995). In this way, the physical presence of islands augments the productivity and biodiversity of the Gulf of Maine.

Islands that are free of predators and human disturbance provide habitat for nesting and migratory birds. Maine's island-nesting birds include 13 species of seabirds, eight species of wading birds, many neotropical migrants, and birds of prey such as osprey and bald eagle. As habitat disturbance on the mainland increases, islands will become more important as feeding and roosting areas for shorebirds.

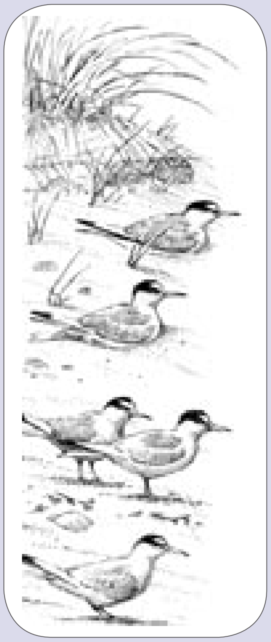
The seabirds—such as gulls, terns, cormorants, petrels, guillemots, and puffins—have special habitat requirements for nesting. Only about ten percent of the islands in the Gulf of Maine provide suitable seabird habitat. Machias Seal Island off Grand Manan, a number of islands in Maine (e.g. Libby, Brothers, Schoodic, Great Duck, Matinicus Seal, Metinic), and sandy islands off Cape Cod (e.g. Manomet, Monomoy) are among the best islands for seabirds (Conkling, 1995). On some of these islands, thousands of seabirds blanket the rocks, cliffs, and scant grasses.

Ethan Nedeau

Island, Beach, and Dune Habitat Policy Objective

The Council's objective is to support island, beach, and dune restoration above the high tide line. This includes restoration of beach, dune and island systems by revegetating with native plantings where feasible, or controlling populations of predators such as gulls. Restoration is primarily aimed at habitat for plovers and terns that utilize beaches and dunes for feeding and nesting purposes and island nesting habitat for several species of seabirds including Atlantic puffins and roseate terns.

One of thousands of islands in the Gulf of Maine. Credit: Peter Taylor



Mark McCollough

Nesting Island Suitability

Nesting island suitability depends on several factors:

- **Abundance of suitable prey species**
  Maintaining healthy marine fisheries is vitally important for maintaining healthy seabird populations.
- **Lack of predators**
  House pets, raccoons, mink, fox, and black-backed gulls greatly affect seabird populations.
- **Lack of human disturbance during the nesting season**
  Human disturbance can frighten birds, make them abandon nests, or leave eggs and chicks vulnerable to predation. During the nesting season, people should stay off nesting islands and direct their activities to non-nesting islands.
- **Appropriate vegetation**
  Nesting seabirds, wading birds and eagles have different nesting requirements. Cormorants nest in tall trees or rocky ledges. Gulls nest on ledges or grass. Terns typically nest in short grass. Eiders nest in shrubby thickets. Puffins nest in burrows among large rocks. Leach's Storm Petrels nest in burrows dug in the soil in grassy and forested areas. Glossy Ibis and some herons prefer nesting in the tops of small trees.

Among the most sensitive of the seabirds in the Gulf of Maine are its four species of terns, including the endangered Roseate Tern. Terns do not breed exclusively on islands, and will breed and nest on sandy beaches and sand dunes on the mainland (Berrill and Berrill, 1981). However, disturbance on the mainland increases the importance of suitable island sites—and fewer than 30 islands are suitable for tern nesting in the Gulf of Maine. Terns are excellent indicators of the health of the Gulf of Maine ecosystem because of their sensitivity to habitat degradation and reliance on healthy fish communities.

Beaches and Dunes

Beaches, pounded by an average of 8,000 waves a day, are high-energy, climatically extreme environments where only highly specialized organisms can survive. They vary in nature from long shorelines of fine-grained silt or sand to boulders wider than a catcher's mitt. Large sand beaches are mostly confined to the southern part of the Gulf of Maine, from southern Maine to Cape Cod. Beach slope is the principal factor that determines the size of beach particles—the greater the slope, the larger the size of sand grains or rock fragments. The size of beach particles determines the organisms that can exist in the beach environment. For example, fine-grained sand beaches are inhabited by bacteria, diatoms, and blue-green algae, as well as meiofauna less than 1-2 mm in diameter, such as nematodes. Coarse-grained sands provide habitat for the same species, but also many larger invertebrates such as copepod crustaceans.

Dune and salt marsh at Sandy Neck, Cape Cod.
Credit: Ethan Nedeau

Sand dunes are often located upslope of sand beaches. Dunes are hillocks of wind-blown sand originally brought to the rear of beaches by ocean waves, and stabilized primarily by American beachgrass. Beachgrass is a remarkable sand-trapping plant that must be covered by almost 3 inches (7 cm) of sand per year to survive, and it responds to sand coverage by rooting deeper, thus stabilizing the dune. Sand dune plants include sea rocket, black cherry, and pitch pine. Piping Plovers are a prominent endangered species that inhabit sand dunes that are devoid of vegetation.

Major dune systems in the Gulf of Maine are located in the

Dune grass. Credit: ??

Provincelands area of Cape Cod (including the older dunes of Mt. Ararat which rise to over 100 feet [33 m] in height), the Parker River National Wildlife Refuge on Plum Island in northern Massachusetts, Scarborough Beach State Park, Popham Beach, and Reid State Park in Maine.

Threats and Restoration Opportunities

Islands

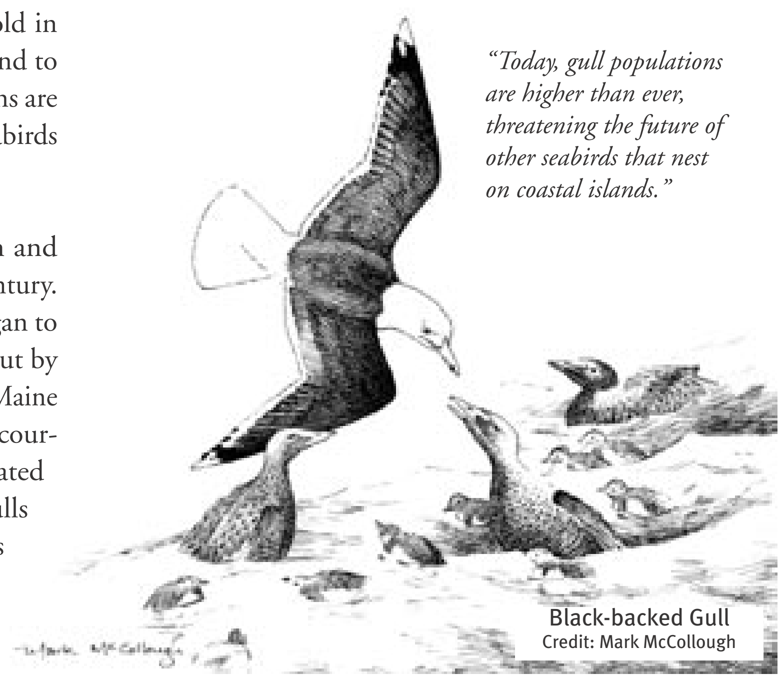
By the end of the 19th century, Gulf of Maine's seabird populations were decimated by nearly 300 years of habitat degradation and overharvesting for food and feathers. Today, Common Eider, Double-Crested Cormorant, Herring Gull, and Black-Backed Gull are relatively abundant on coastal islands. Unfortunately, human activity such as garbage dumps provide Herring Gulls and Black-Backed Gulls with a dependable but unnatural food supply, and gull numbers have risen eight-fold in the last 60 years. Gulls are large, aggressive, and tend to usurp the best nesting habit. Today, gull populations are higher than ever, threatening the future of other seabirds that nest on coastal islands.

Populations of other species (Roseate, Common and Arctic Terns) began to rebound in the early 20th century. But since the 1930s, when the gull populations began to increase significantly, terns began to be squeezed out by gulls. By the 1970s, terns had abandoned nearly all Maine islands—except a few where lighthouse keepers discouraged gulls from roosting. However, when automated lights replaced lighthouse keepers, marauding gulls devastated the remaining terns. Today, populations of all three species of island-nesting terns have begun to increase due to active habitat protection and restoration programs. Populations of other seabirds (Atlantic puffins, Razorbill Auks, Black Guillemots, Leach's Storm-Petrels, Laughing Gulls) appear to be stable, but like other island nesting birds, they merit careful attention because their range is limited to a small number of islands.

Only about 10% of islands in the Gulf of Maine are suitable for nesting seabirds. In Maine, only 630 of the 3,500 islands have nesting populations (USFWS). Of those 630 islands, approximately 330 have been recognized as "nationally significant" based on indices of species diversity or the percentage of the statewide population of each species. The small percentage of suitable islands for nesting seabirds indicates the importance of habitat protection and management. Currently, only half of the 330 "nationally significant" islands in Maine are under some form of conservation ownership, and few are actively managed to minimize threats and maximize nesting potential. In Maine, 45 islands are currently owned and managed as part of the U.S. Fish and Wildlife Service's Petit Manan National Wildlife Refuge. The Maine Department of Inland Fisheries and Wildlife owns more than 300 islands and ledges as part of its Coast of Maine Wildlife Management Area. The remaining islands are owned or held in easement by national, state, and local conservation agencies or groups.

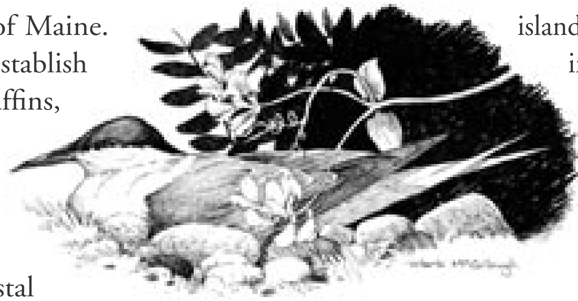
The Gulf of Maine Seabird Working Group, a coalition of local, state, and federal partners from the United States and Canada, meets twice a year to share information

"Today, gull populations are higher than ever, threatening the future of other seabirds that nest on coastal islands."



Black-backed Gull
Credit: Mark McCollough

on seabird activity in the Gulf of Maine. The Working Group seeks to reestablish healthy populations of terns, puffins, and razorbills to Gulf of Maine islands. The Seabird Working Group, with technical support from the U.S. Fish and Wildlife Service's Gulf of Maine Coastal Program, maintains a database of nesting island activity. The Working Group supports habitat protection and restoration projects to restore and maintain nesting populations. Projects often involve discouraging gull populations from overtaking island habitat and providing decoys to attract desirable birds. In Maine alone, since the mid-1990s, nearly $6 million in federal funds and $2 million in non-federal funds have been spent to acquire 44 nationally significant nesting islands. Restoration activities continue on 12 islands.



Roseate Tern
Credit: Mark McCollough

A new threat to islands is sea-level rise associated with climate change. Sea level rise results from melting of glacial ice and thermal expansion of ocean water. Sea levels have already risen 10-20 cm (4-8 inches) in the 20th century, and climate models predict an additional 9-88 cm (4-35 inch) rise by 2100 (IPCC 2001). Many low-elevation islands that are important resting, perching, and nesting habitats for seabirds or marine mammals could be inundated by rising sea levels, or overwashed more frequently by storm surges.

Beaches and Dunes

Seawalls, jetties, roads, trampling of beach grass by people, ATVs, driving on beaches, housing developments on coastal dunes, predators (particularly those that flourish near humans, including gulls, crows, cats, and dogs), trash, and artificial barriers all threaten beach and dune ecosystems. These impacts limit access for birds and other wildlife that utilize this habitat for feeding or nesting, increase habitat loss through fragmentation and degradation, and increase human disturbance of wildlife. Dunes need over wash to sustain them, but rarely get it. Artificial barriers in dune systems (snow fencing, dune stabilization projects using Christmas trees) are also threats. Anything that prevents the formation and maintenance of the critical foredune section is detrimental to nesting plovers. In addition, the removal of wrack is a threat to the beach ecosystem because wrack provides nutrients and beach stability.

Razorbill Auks Catherine Devlin

Double Crested Cormorants Mark McCollough

Laughing Gulls Mark McCollough

Seabird Nesting on Maine Islands

Between 1972 and 1980, the Petit Manan National Wildlife Refuge was established to protect migratory birds, principally colonial nesting seabirds. Islands are still being acquired to protect nesting habitat. The Service has focused on tern restoration because their populations were particularly low. The Roseate Tern, a federally endangered species, prefers to nest within large colonies of Common or Arctic Terns. Therefore, saving Roseate Terns will require assisting Common Terns and Arctic Terns.

Tern restoration may require discouragement of Herring Gulls and Great Black-Backed Gulls if terns have recently abandoned an island; terns may return rapidly once the gulls are gone. In many cases, terns may have not nested on an island for decades. To entice them back, the Service plays recordings of a tern colony and scatters tern decoys in suitable nesting habitat. This method has been highly effective on several islands in the Gulf of Maine.

Tern restoration began in 1984 on Seal and Petit Manan islands, which now support large colonies of Common and Arctic Terns. Roseate Terns have returned to Petit Manan. Recently, restorations have occurred on Pond, Metinic, and Ship islands. The goal is to establish tern colonies on numerous refuge islands. This will ensure that a catastrophic event—such as disease, an oil spill, or a hurricane—will not wipe out a species. Other colonial nesting seabirds have benefited from tern restoration efforts—Atlantic Puffins, Black Guillemots, Laughing Gulls, Leach's Storm Petrels, and Common Eiders have recolonized some islands.

Source: US Fish and Wildlife Service website for Petit Manan

Potential Restoration Projects

The GOMC Habitat Restoration Subcommittee has identified several potential restoration projects as having large-scale environmental benefits for the Gulf of Maine. Though the scale of these projects varies widely, they are similar in important ways. They are all being considered for restoration; they are all somewhat controversial; they are large in impact or set an important precedent; they will require significant resources to complete; and they will benefit from additional regional focus. This list is not exhaustive; rather it points Gulf of Maine Council restoration resources toward certain focal areas. Finally, this list does not provide a precise habitat restoration plan for these projects. Each one of these projects needs to be assessed and all of the factors—both biological and human—should be brought into the decision making process before a restoration plan can be developed.

Riverine

Penobscot River, Maine

The Penobscot River historically supported a large Atlantic salmon population. However, dams have affected fish migration on the river and greatly reduced usable habitat. There is currently an agreement to reduce the number of dams on the Penobscot and improve fish passage where needed. This may help restore a significant salmon population—as well as other anadromous populations—to the Gulf of Maine.

Recommendation: Evaluate enhanced fish passage on the Penobscot River to restore Atlantic salmon and other migratory fish species.

St. Croix River, Maine and New Brunswick

The St. Croix River presently has dams that impede anadromous fish runs. Water quality and habitat is also degraded because of industrial uses of the river. The St. Croix River represents an opportunity to restore a sizable river and estuary along the international border between the U.S. and Canada.

Recommendation: Evaluate enhanced fish passage for anadromous fish species and restore riparian habitats and water quality degraded by industrial activities and other human alterations.

Ipswich River, Massachusetts

This highly degraded river in northeastern Massachusetts is currently undergoing assessment for fisheries restoration. The Ipswich River is listed as one of the most endangered rivers in the U.S. by American Rivers due to flow alteration, low dissolved oxygen, and other factors.

Recommendation: Restore anadromous fish runs by reestablishing flow between the riverine and estuarine systems.

Intertidal

West Branch Pleasant River, Addison, Maine

The tide gate in Addison on the West Branch of the Pleasant River, in place since 1940, has restricted saltwater from reaching a nearly 500-acre salt marsh behind the gate. The salt marsh is highly degraded due to lack of regular tidal flow.

Recommendation: Evaluate the tidal flow upstream of the existing gate to restore the functions and values of the salt marsh habitat.

Herring River, Wellfleet, Massachusetts

The Herring River and associated salt marshes in Wellfleet represent the largest riverine estuarine system in the Cape Cod National Seashore. The local conservation commission is supporting a marsh restoration plan that will evaluate a tidal restriction from a dike and tide gate, considering flooding and infrastructure.

Recommendation: Evaluate increased tidal flow upstream of the existing dike and tide gate to restore the functions and values of the salt marsh habitat.

Cheverie Creek, Cheverie, Nova Scotia

This is a classic example of an undersized road culvert that greatly restricts tidal flow to a salt marsh. The restoration of this 30-acre marsh has been the focal point for the GOMC/NOAA Partnership funding for restoration efforts in Canada. The partnership has been successful at raising awareness of the importance of this type of project. Regardless of the resources used to complete this project, it is important to conduct intensive post-restoration

The Petitcodiac River Causeway

The Petitcodiac River, which flows into Shepody Bay, drains a 3,000-km² watershed situated in the inner Bay of Fundy. The aboriginal Micmacs named the river Pet-Kout-Koy-ek, meaning "the river that bends like a bow." The Petitcodiac River and the Shepody Bay estuary are important tidal systems influenced by the phenomenal tides of the Bay of Fundy (from 9 m to 14 m), uncovering kilometers of mudflats at low tide and nourishing one of the world's most productive estuaries. Shepody Bay is home to a unique hemispheric shorebird refuge and the feeding grounds of the entire East Coast American shad population.

Petitcodiac River in 1954 before the causeway was constructed (top) and 1996 following habitat degradation resulting from the causeway.

monitoring to better understand the benefits of restriction removal for upper Bay of Fundy marshes.

Recommendation: Increase tidal flow upstream of the undersized road culvert to restore the functions and values of the salt marsh habitat.

Petitcodiac River, Moncton, New Brunswick

The Petitcodiac River has been highly altered by a causeway that blocks tidal movement upstream of that structure (see photos in box above). The area downstream of the culvert acts as a settling pond for the sediments suspended in the tidal water. Since the installation of the causeway in 1968, over 100 hectares of salt marsh have been created downstream of the causeway on the accumulated sediment. Several dozen such situations exist around the Bay of Fundy, including the Avon River Causeway in Windsor, Nova Scotia (Wells, 1999). These causeways and associated dykes protect vast acreage of agricultural land, formerly salt marsh, from tidal flooding.

Recommendation: Consider options for reconnecting the riverine and estuarine environments.

Subtidal

Great Bay & Little Bay Eelgrass, New Hampshire

Scientists have completed extensive eelgrass assessments in this area to determine the extent and health of the resource, and have conducted some eelgrass transplant projects. Additional restoration efforts are needed to restore and protect eelgrass resources in Great Bay, Little Bay, and the Piscataqua River. This is an example of an area that is known to have historic eelgrass beds and adequate water quality to support beds today. Areas with these characteristics should be identified around the Gulf of Maine, and resources should be allocated to restore eelgrass in such locations.

Recommendation: Assess subtidal restoration for Great Bay, Little Bay, and the Piscataqua River and expand support of eelgrass restoration.

Boston Harbor, Massachusetts

Major efforts have been undertaken to improve water quality of Boston Harbor. Now, with clearer water, many parts of the harbor could support eelgrass, but these areas have no source of new eelgrass recruits. Identification of the suitable areas for restoration and establishment of source eelgrass populations for seed recruitment are essential to restore eelgrass ecosystems and greatly accelerate the return of ecological functions to the harbor.

Recommendation: Initiate restoration of eelgrass in Boston Harbor by identifying the best restoration sites and by supporting community-based eelgrass transplanting.

Beaches, Dunes, and Islands

Seabird Island Nesting, Maine

Most of the region's seabirds nest on islands in Maine. There are over 4,500 islands in Maine and many are affected by human activities. Restoring and protecting habitat for colonial seabirds is currently underway by various interests in the Gulf of Maine.

Recommendation: Promote seabird restoration in the Gulf by supporting activities that improve beach, dune and island habitats.

Next Steps for Improving Habitat Restoration

The GOMC Restoration Subcommittee has identified the following steps, which are consistent with the long-term goals and objectives of the GOMC, for continued success with habitat restoration efforts in the Gulf. These are not in priority order.

Inventory Restoration Sites

- Develop standard protocols and methods for defining and measuring progress
- Complete inventories of potential restoration sites by identifying remaining gaps in data collection and analysis, and work to reduce or eliminate data gaps
- Regularly update and distribute Gulf-wide database of existing restoration projects

Identifying potential restoration projects and maintaining a database of previously implemented projects will allow practitioners to focus restoration efforts using a coordinated regional approach. Since data collection and analysis is completed by different organizations in the region, standard protocols and methods will improve regional collaboration.

Build Capacity

- Increase technical capacity at the state/provincial government level for project development, management and monitoring
- Increase capacity at the local level for project development and management to improve the ability of local government and citizen organizations to implement restoration projects
- Evaluate and as necessary work to modify the regulatory processes that affect habitat restoration efforts

Habitat restoration in the Gulf is rapidly increasing. Capacities for restoration vary by jurisdiction due to political, financial, and regulatory constraints. Increasing capacity for project development, management, and technical resources will facilitate the transfer of expertise to individual projects throughout the region.

Outreach and Education

- Inform and educate policy-makers and managers about restoration in the Gulf of Maine
- Maintain and enhance relationships with NGOs and the private sector in the U.S. and Canada
- Encourage and promote community involvement in restoration projects
- Increase the ecological literacy of community members with respect to the functions and values of coastal ecosystems and the need for restoration
- Complete the Gulf of Maine Habitat Restoration Web Portal that is currently under development
- Develop GIS coverage for habitat restoration sites in the Gulf of Maine

There is a need for better understanding of habitat restoration in the Gulf of Maine. The Gulf of Maine Restoration Web Portal will provide a central clearinghouse for restoration projects and methods, and will provide general information on habitat restoration and provide contacts for additional information. Additional outreach efforts will help raise awareness of the need for and benefits of habitat restoration.

Research and Monitoring

- Develop monitoring protocols for riverine, subtidal, and islands, beaches and dune habitats
- Hold a workshop to re-evaluate and update Global Programme of Action Coalition for the Gulf of Maine (GPAC) protocols previously developed for salt marshes
- Ensure that restoration projects implement pre- and post-construction monitoring protocols
- Implement a regional assessment function to track projects, acquire and organize monitoring data, and report results to Gulf restoration practitioners

Monitoring is important for measuring the performance of restored sites and the efficacy of restoration techniques. Protocols are currently in place for salt marsh restoration projects; however, other habitats would benefit from similar standards for data collection. Standard protocols for research and monitoring allow for consistent evaluation of habitat restoration over time, and provide the basis for ongoing assessment of restoration outcome.

Appendix A
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Websites:

Great Bay National Estuarine Research Reserve
www.greatbay.org/heritage/

Gulf of Maine Aquarium
www.gma.org/

Gulf of Maine Council on the Marine Environment
www.gulfofmaine.org
Restoration: www.gulfofmaine.org/habitatrestoration

National Oceanic and Atmospheric Administration
www.nmfs.noaa.gov/prot-res-PR2/stockAssessmentProgram/sars.html

National Oceanic and Atmospheric Administration Restoration Center
www.nmfs.noaa.gov/habitat/restoration

Petit Manan National Wildlife Refuge
www.petitmanan.fws.gov/restoration.html

Petitcodiac Riverkeeper
www.petitcodiac.org

U.S. Fish and Wildlife Service – Gulf of Maine Coastal Program: www.gulfofmaine.fws.gov/

Appendix B

Summary of GOMC/NOAA Habitat Restoration Partnership Grants

Applicant	Year	Location	Project Title	Amount
Trustees of Reservations	2002	MA	Old Town Hill Salt Marsh Restoration Project	$10,000
Trustees of Reservations	2002	MA	Damde Meddows Salt Marsh Restoration Project	$15,000
Town of Dennis	2002	MA	Quivett Creek Salt Marsh and Fish Run Restoration	$35,000
Indian Ponds Assoc.	2002	MA	Marstons Mills Herring Ladder	$20,000
Town of Plymouth	2002		Town Brook Herring Run Restoration Project	$25,000
Mass. Dept. of Fisheries and Wildlife	2002	MA	Third Herring Brook Restoration	$20,000
Town of Rockport	2002	MA	Seaview Street Salt Marsh and Fishery Restoration	$8,505
Salem Sound 2000	2002	MA	Volunteer Wetland Health Assessment Toolbox	$12,000
Town of Barnstable	2003	MA	Bridge Creek Salt Marsh Restoration Project	$100,000
Salem Sound Coastwatch	2003 2004	MA	Coastal Habitat Invasive Monitoring Program Eastern Point Salt Marsh Monitoring	$12,500 $7000
City of Revere	2002	MA	Oak Island Marsh Restoration and Flood Control Project	$50,000
Barnstable County Resource Development Office	2003	MA	Sesuit Creek Herring Run Restoration	$10,361
Town of Barnstable	2003	MA	Oyster Habitat Establishment and the Utilization of Remote Setting Techniques	$18,450
North and South Rivers Watershed Association	2004	MA	Third Herring Brook Fish Restoration	$25,000
Mass. Dept of Marine Fisheries	2004	MA	Woolen Mill Dam Fish Passage Improvement	$18,500
York Conservation Commission	2002	ME	Wheeler Marsh Restoration Monitoring	$3,889
River Rehab, Inc.	2002	ME	Habitat Survey and Monitoring Effects of Dam Removal to Fishery	$10,575
Town of Newport	2002, 2004	ME	Sebasticook River Channel Restoration, Sebasticook Rriver Riparian and In-stream Improvements	$46,500, $30,000
Town of Harpswell	2002	ME	Dingley Island Tidal Flow Restoration	$20,000
Sheepscot River Watershed Council	2003	ME	Somerville Road NPS Reduction Project	$10,000
Wells National Estuarine Research Reserve	2003	ME	Harbor Road Marsh Restoration	$15,000
Casco Bay Estuary Project	2004	ME	Presumpscot River Restoration Inventory	$25,000
Coastal Conservation Assoc.	2004	ME	East Elm Street Fish Ladder / Water Flow Improvement	$4,400
Town of Bristol	2004	ME	Pemaquid Marsh Restoration	$38,500
Maine Rivers	2004	ME	Alewife/Smallmouth Bass Interactions Study	$30,650
NH Dept. of Environmental Services	2002	NH	Wiswall Dam Project: Study of Water Storage Mitigation Options	$10,000
Ducks Unlimited	2003, 2004	NH	NH Marsh Monitors/Volunteer Saltmarsh Monitoring Program	$25,000, $25,000
Ecology Action Centre	2003	NS	Cheverie Creek Salt Marsh & Tidal River Restoration Project	$34,555
Ducks Unlimited Canada	2004	NB	Musquash Marsh Salt Marsh Restoration	$25,000
TOTAL				**$766,035**

Appendix C
Summary of Tidal Restriction Assessments and Activities

Massachusetts

North Shore
The Atlas of Tidally Restricted Marshes: North Shore of Massachusetts was completed by MWRP in 1996 and identifies 190 potentially restricted tidal wetlands. To request a copy, contact MWRP at (617) 626-1177 or email: wetlands.restoration@state.ma.us

Buzzards Bay
Under agreement with MWRP, the Buzzards Bay Project National Estuary Program under Massachusetts Coastal Zone Management has completed the Final Atlas of Tidally Restricted Salt Marshes: Buzzards Bay Watershed Massachusetts which identifies and prioritizes 167 tidally restricted coastal marshes. To request a copy, contact the Buzzards Bay Program at (508) 291-3625 or visit their web site at: www.buzzardsbay.org

South Shore
Under agreement with MWRP, the Massachusetts Metropolitan Area Planning Council published the Final Atlas of Tidal Restrictions on the South Shore of Massachusetts in June 2001. The Atlas identifies and prioritizes 121 tidal restrictions. To request a copy, contact Bill Clark of the Metropolitan Area Planning Council at (617) 451-2770 or email: bclark@mapc.org

Cape Cod
Under agreement with MWRP, the Cape Cod Commission is currently preparing a tidal restriction atlas for the Cape Cod region. A Draft Atlas will be completed in fall 2001, followed by a Final Atlas over the winter. To request a copy, contact Stacey Justus of the Cape Cod Commission at (508) 362-3828 or email: sjustus@capecodcommission.org

Maine

The Maine Department of Transportation in conjunction with the Army Corps of Engineers created an inventory of bridges, culverts, tide gates, and railroad crossings in December 2002 to assess degraded tidal wetlands and the impact of tidal restrictions potentially caused by engineering structures.

Nova Scotia

Nova Scotia has completed the following inventories of tidal restrictions in their jurisdiction.

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Duffy, Dawn Marie. 2004. Tidal Barriers: Cumberland County (Draft). Ecology Action Centre, Halifax, Nova Scotia.

Appendix D

Gulf of Maine Council Habitat Committee, Restoration Subcommittee

Kim Hughes and John Catena are the co-chairs for the Restoration Subcommittee. Jon Kachmar is the coordinator. Complete contact information for all subcommittee members can be found at the Gulf of Maine Council website, www.gulfofmaine.org/council/committees/habitat_rest.asp. Members are listed alphabetically below.

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