CHAPTER 4

Regional Analyses of Restoration Planning

The regional analyses that comprise Chapter 4 provide a snapshot of the level of planning for coastal and estuarine habitat restoration within six regions of the United States. They also provide a glimpse into future needs and directions for restoration. The regional analyses provide an overview of the following:

- original acreage and acres lost, conserved or preserved, and restored;
- key habitats and species in need of restoration and/or protection such as wetlands, marsh, riparian areas, and the various species that depend on these habitats;
- key threats to habitats and species of concern such as subsidence and sea level rise, filling, draining and invasive species;
- common restoration goals in the areas of land-use management, protection of essential fish habitat and improvement of water quality;
- successful restoration methods and techniques such as restoring tidal flow and planting native vegetation;
- key elements of successful restoration efforts such as site selection criteria, reference sites, and adaptive management;
- types of restoration in need of further research and testing, including beach renourishment and beneficial use of dredge material; and
- areas where more research is needed (e.g., better understanding of ecosystem structure and function, and the potential causes and effects of habitat alterations) to better inform restoration planning and increase the likelihood of restoration success.

Analyses of estuarine habitat restoration plans have been developed for six regions within the United States.

- **Northeast Atlantic:** Maine, N.H., Mass., R.I., Conn., N.Y., N.J., Del., Md., Va.
- **Southeast Atlantic:** N.C., S.C., Ga., Fla. (including south Florida, the Everglades, Florida Bay and the Florida Keys), Puerto Rico, U.S. Virgin Islands
- **Gulf of Mexico:** The Gulf Coast of Florida (excluding the Everglades, Florida Bay and the Florida Keys), Miss., Ala., La., Tex.
- **California and the Pacific Islands:** Calif., Hawaii, Pacific Protectorates
- **Northwest Pacific:** Ore., Wash., Alaska
- **Great Lakes:** Minn., Mich., Wis., Ind., Ill., Ohio, N.Y.

The analyses are based on an inventory of planning efforts related to coastal and estuarine habitat restoration in each region. Emphasis has been placed on estuarine habitats and those coastal habitats that directly impact estuarine areas. The information provided in these analyses is not meant to be inclusive of all information related to estuarine and coastal habitat within these six regions. Rather, it provides a picture of the status of coastal and estuarine habitats based on information gathered primarily from restoration plans and common themes within those plans. If certain information on coastal and estuarine habitats or restoration within a region was not identified in any of the restoration plans inventoried, it is likely that it is not included in the regional analyses presented here.

The information gleaned from the review of restoration plans is also available in a searchable on-line database on A National Strategy web site (http://restoration.nos.noaa.gov). Information available includes basic plan data (including plan description, geographic information and contact information) as well as technical information (for example, plan goals, partnerships, public outreach and habitat information).

Several national restoration programs also were identified in the review of restoration efforts. The U.S. Department of Agriculture, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, and the U.S. Army Corps of Engineers each have several programs that focus specifically on restoration. A description of some of these programs can be found in Appendix A of *A National Strategy*.

In addition to restoration, protection, preservation, acquisition and enhancement also are important mechanisms for conserving habitat. Although these issues are not discussed in great detail in the regional analyses, they are critical to the success of restoration and often occur in conjunction with habitat restoration activities.

Many other habitats were not considered here because they were outside the scope of this analysis. However, the protection and restoration of these habitats in many cases benefit the estuaries downstream.

Regional Analyses of Restoration Planning

PART 1 – PACIFIC NORTHWEST

ESTUARIES OF THE PACIFIC NORTHWEST

The Pacific Northwest region is defined here as the coasts of Alaska, Washington (including Puget Sound) and Oregon.

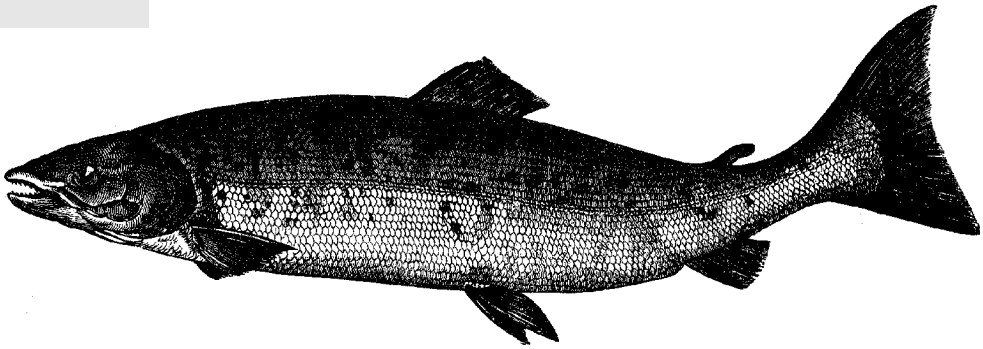
This region:

- Has more than 40,000 miles of shoreline that contain thousands of identified salmon streams, hundreds of estuaries, the largest known single stand of eelgrass in the world (37,000 to 39,000 acres) and the largest wetland complex (700,000 acres) on the Pacific Coast (Ward et al., 1997; Frost and Logan, 2001; McRoy and Goering, 1974).
- Contains more than 3,000 square kilometers (1,200 square miles) of tidal wetlands.
- Receives freshwater flow from approximately 25 percent of the land area of the United States.

These estuaries support more than 90 percent of the nation's harvest of wild and hatchery-raised salmon, as well as rapidly growing coastal communities such as the recreational and seaport towns of coastal Oregon and Washington, the greater Seattle area in Puget Sound and the coastal communities of southeast Alaska, including Anchorage.

SUMMARY

The Pacific Northwest region has experienced extensive habitat loss in Puget Sound and other coastal estuaries of the Northwest. Invasion and spread of Spartina alterniflora is a growing concern in this region. In Alaska, the *Exxon Valdez* oil spill in 1989 acted as a catalyst for intensive ecosystem research. As a result, an abundance of information relating to marine resources has been compiled. Significant damage to the Oregon and Washington coasts and the Columbia River Estuary has occurred over the past years. For example, more than 50 percent of the tidal marshland in the Columbia River Estuary has been destroyed. Although regional estuarine restoration planning is still developing in the Pacific Northwest, examples of regional planning include the Salmon Recovery Plan in Washington and the Lower Columbia River Estuary Plan for Oregon and Washington. Plans also exist for individual estuaries and sub-basins. A national estuarine restoration strategy and federal funding would contribute significantly to the development and implementation of comprehensive, regional estuarine restoration strategies.



Introduction to the Pacific Northwest

Description

The following analysis provides a brief overview of the state of estuarine restoration planning in the Pacific Northwest. It is intended to support *A National Strategy* by highlighting the losses of, and threats to, key Pacific Northwest habitats; the current efforts to set and achieve restoration goals; and some of the research needs that have been identified for effective restoration.

For purposes of this analysis, the Pacific Northwest has been divided into three subregions: Alaska, Puget Sound, and the Oregon and Washington coasts and Columbia River Estuary.

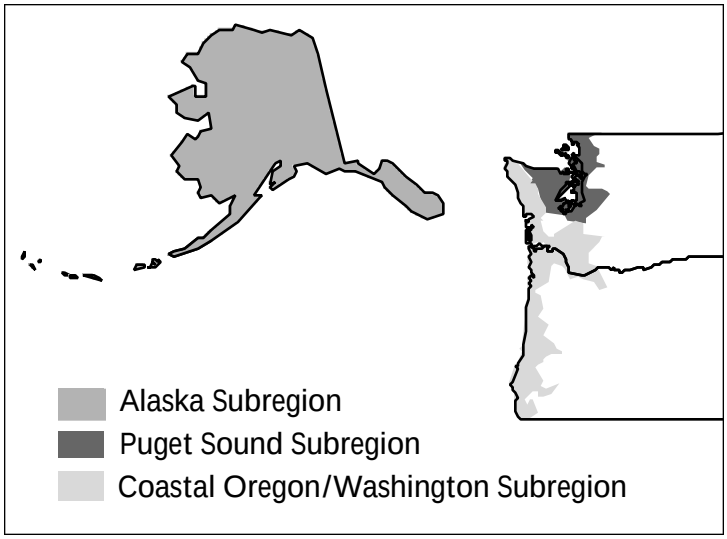


Figure 1. Pacific Northwest Region and Subregions

Key Habitats and Species

A tremendous diversity of ecosystems characterizes the Pacific Northwest region. These include tidal marshes and wetlands, intertidal and mud flats, kelp beds, the largest bed of seagrass along the Pacific coast of North America and the largest known single stand of eelgrass in the world—located in the Izembek Lagoon (Ward et al., 1997). These habitats are essential for several estuarine-dependent species and serve as spawning and rearing habitat for a number of fish. In the Alaskan subregion, habitats include intertidal flats, salt marshes, streams and riparian habitats, rocky substrates, mud flats, eelgrass beds and kelp beds which provide rockfish habitat (USDOC, 1998). Intact nearshore ecosystems (including adjacent upland, intertidal and shallow subtidal habitats), riparian habitat/sloughs, gravel beds and streams (which act as tidal freshwater spawning and rearing areas), tidal marshes, mud and sand flats, freshwater wetlands, eelgrass beds, and gravel beaches are key habitats in the Puget Sound subregion (Dean et al., 2000; HRPC, 1998; USFWS and NOAA, 1996; USFWS, 2000;). In the Coastal Oregon and Washington subregion, habitats that are primary candidates for restoration and conservation efforts include tidal marshes and wetlands, rivers and streams, mudflats, and eelgrass beds (Donnelley, 1994; Hoffmann, 2001; LCEMP, 1982; McColgin, 1979).

Estuarine marshes constitute a complex ecosystem that is vital to a number of different species. These species include macroinvertebrates (clams, oysters, sea urchin and sea stars), shellfish (Dungeness crab), fish (Pacific salmon, capeline, flounder and sole, gaddids, rockfish, smelt and herring), mammals (seals, sea lions and whales) and birds. The estuarine habitats in the northwest are important for feeding, nesting, rearing and migratory staging for a number of birds throughout the year. In 1996, Kachemak Bay was dedicated as an international site of the Western Hemisphere Shorebird Reserve Network. An international site designation indicates that the site hosts more than 100,000 shore birds or a 10 percent flyaway population (USDOC, 1998).

The *Exxon Valdez* Trustee Council evaluated the recovery status of some organisms, particularly those found in the Alaska subregion. These labels designate certain species as "recovered," "recovering," "not recovered" or "recovery unknown." Some species that are listed as recovering include clams, mussels, Pacific salmon and Pacific herring. The killer whale and the harbor seal are two species that have been identified as not recovered (*Exxon Valdez* Oil Spill Trustee Council, 1999*b*).

The highest density of the large geoduck shellfish in the Pacific Northwest can be found in Puget Sound (WDH et al., 1999). This species uses the sandy mud of the lower intertidal and subtidal habitats and has been identified as a species in need of protection. Key fish species in the Puget Sound area, specifically mentioned for protection by the Washington Department of Ecology, include sandlance *(Ammodytes hexapterus)*, surf smelt *(Hypomesus pretiosus)*, Pacific herring *(Clupea harengus pallasi)*, gaddids (cod fishes), and rockfish (multiple species) (WDE, 1993).

Intertidal mudflats and beaches provide resting and feeding areas for gulls, herons, shore birds and waterfowl. Underwater kelp forests shelter snails, crabs, shrimp, starfish, sea anemones, sea cucumbers, brittle stars, sea squirts and many other marine organisms. Damage to eelgrass beds affects whole populations of finfish (including threatened salmon, herring, gunnels and pipefish) waterfowl, shellfish, Dungeness crabs, and nudibranchs. Shoreline stability also is jeopardized by damage to eelgrass beds.

Riparian corridors are another habitat that can have beneficial impacts on the estuarine environment. Because of their linear form, they are able to process large fluxes of energy and materials (e.g., nutrients, large woody debris, gravels and fines, oxygenated water) from upstream systems and are laterally connected to upslope (upland) and downslope (aquatic) ecosystems as well as upstream and downstream features. These riparian zones become refuge for a variety of animals as they provide a diversity of habitat and an abundance of water that allow for often distant migration. Primary productivity is generally higher in a riparian corridor than in the adjacent upland community due to the diversity and abundance of resources in riparian corridors. These ecosystems act as a nutrient sink for lateral runoff from uplands and as a nutrient transformer for in-stream flows (Mitsch and Gosselink, 1993). Riparian corridors contribute to the stability of global levels of available nitrogen, atmospheric sulfur, carbon dioxide and methane through nutrient cycling in living plant material. They also moderate the effects of floods; improve water quality; limit erosion by stabilizing streambanks; and provide shelter and spawning habitat for a variety of wildlife species including anadromous fish, waterfowl, reptiles, amphibians, insects and a variety of megafauna.

The major causes of stream and estuarine habitat degradation have been historical forestry practices, impediments to fish passage (e.g., dams and other obstructions), increased shoreline development and spill events. Many historical forestry practices did not take into consideration riparian management concerns in relation to fish habitat and water quality. Presently, forestry practices manage for the adequate preservation of fish habitat by maintaining a short- and long-term source of large woody debris, stream bank stability, channel morphology, water temperature, stream flows, water quality, adequate nutrient cycling, food sources, clean spawning gravels and sunlight-to-shade ratio. Depending on state regulations, current restrictions may apply to forested areas within 25 to 300 feet from streambanks and on steep slopes adjacent to riparian corridors. Urban shoreline development and port activities have placed an increased stress upon marine resources as in- and over-water structures, shoreline armament, accidental groundings (e.g., barges, log-booms, oil tankers, personal marine vessels), wood-waste accumulation from nearshore log transfer facilities, and the legal and illegal filling of wetlands and navigable waters have increased.

The Columbia River Basin provides habitat for six species of anadromous salmonids (chinook, coho, chum, sockeye, pink and steelhead). All of these species except the pink salmon are listed as federally threatened under the Endangered Species Act. Saltwater transition zones in rivers are extremely important for juvenile salmonids during the critical smoltification process, when they undergo behavioral, physiological and morphological changes to prepare for oceanic life. During this transition period and during residence, juvenile salmonids, particularly chum and under-yearling chinook, migrate to the more saline portions of estuaries and gain weight (USFWS, 2000). For more detailed information on habitat needs and threats for salmon species, refer to the discussion under California's Anadromous Fish Species section of the California and Pacific Islands regional analysis.

Habitat Status and Trends

The Pacific Northwest region has experienced extensive habitat loss in many of its coastal estuaries. Between 50 and 90 percent of riparian habitat in Washington has been lost or extensively modified (WDNR, 2000). Threats such as diking, draining, filling, development, pollution, and the invasion and spread of Spartina alterniflora all contribute to estuarine degradation in this region.

In the Alaska subregion, a major cause of estuarine habitat degradation has been the Exxon Valdez oil spill in 1989. The spill contaminated about 1,500 miles of Alaska's coastline. Since then, significant efforts have been made to protect and restore the Alaskan shoreline. Thousands of acres of wetlands and estuaries in Alaska also have been impacted by fill, port development and sewage disposal for example.

Puget Sound has experienced rapid estuarine habitat loss, especially in urban areas (e.g., Commencement and Elliot Bays). The Sound functions as vital nursing and foraging grounds for wildlife and fisheries resources, such as the endangered chinook salmon. Restoration efforts in the Sound include transplanting eelgrass and removing invasive species. Because Canada geese forage on eelgrass, it is often necessary to surround transplanted eelgrass with Geese Excluder Devices (GEDs) to protect young plants. Organizations such as People for Puget Sound are developing models to engage in large-scale estuarine restoration projects in the Sound.

In the Coastal Oregon and Washington subregion, there has been extensive loss of coastal and estuarine habitat. Large expanses of tidal marshland and wetlands have been lost due to diking, draining, filling and development. Regional approaches to estuarine restoration are underway, such as the Lower Columbia River Estuary Plan. This plan is a multi-agency effort to restore habitat along the Lower Columbia River. Restoration projects will benefit endangered salmon species and other fish and wildlife resources that inhabit estuaries of the Lower Columbia River.

Regional Planning Efforts

Restoration efforts in the Pacific Northwest region occur under the auspices of federal, tribal, state and local authorities, as well as through the efforts of nongovernmental entities such as business and industry groups, academic institutions, nonprofit organizations and community groups. These efforts have different levels of coordination depending on whether they are located within National Estuary Programs or have other coordinating mechanisms. A specific discussion of planning efforts in each subregion can be found in the sections to follow.

Pacific Northwest Subregions

For purposes of this analysis, the Pacific Northwest has been divided into three subregions: Alaska, Puget Sound, and the Oregon and Washington coasts and Columbia River Estuary.

The following sections summarize the habitat issues and highlight certain restoration planning efforts for each of the Pacific Northwest subregions. Additional information and detailed information about these documents are available through the National Strategy Restoration Plan Database at http://restoration.nos.noaa.gov.

Alaska Subregion

Description

Various types of coastal and estuarine restoration projects occur in Alaskan waters. These include restoration of wetland, riparian (including shoreline and riverbank stabilization) and instream (including salmon spawning) habitats; non-native predator removal projects; water quality monitoring in relation to forest harvesting activities; and seagrass restoration.

Since the *Exxon Valdez* spill in 1989, much has been learned about the marine environment of Alaska. The disaster provided a catalyst for intense ecosystem research and led to an abundance of information about resources in the waters that was previously unknown. Not only did this research assist in restoring critical areas of Prince William Sound, but the event promoted the importance of contingency measures leading to the creation of safer oil transportation systems. The *Exxon Valdez* Oil Spill Trustee Council continues to work to restore and protect affected areas.

In close proximity to the spill site in Prince William Sound lies Kachemak Bay National Estuarine Research Reserve, which promotes education, research and interpretation of information about estuaries. Institutions such as this may serve as representative entities of restoration in Alaska, with their emphasis on an ecosystem approach toward restoration, the development of strong monitoring programs, and the inclusion of the public throughout the restoration process.

Under the Alaska National Interest Lands Conservation Act of 1980 and The Wilderness Act of 1964, protection and restoration is continually proposed to benefit watersheds and their associated marine resources. Two examples of recent proposals include the Alaska Rainforest Protection Proposal for the Chugach National Forest (www.inforain.org/maparchive/chugach_proposal.htm) and the Alaska Rainforest Protection Proposal for the Tongass National Forest (www.inforain.org/maparchive/tongass_forest_proposal.htm).

Habitat Issues

Status and Trends

Significant damage to Alaska's coasts and estuaries has been caused by various threats in this subregion including the *Exxon Valdez* oil spill. Since then, efforts have been made to repair the damage done and to prevent further degradation. More than 1,400 miles of shoreline, including haul-out areas for harbor seals, the mouths of more than 300 salmon streams, and nesting and foraging habitat for black oystercatchers have been protected. In February 1999, the Eyak Corporation completed a package with the Trustee Council to protect 75,452 acres in eastern Prince William Sound. In addition, the Large Parcel program of the Trustee Council protects a total of 635,770 acres of land in Alaska.

Threats

Within the Alaska subregion, losses and degradation of key habitats may be attributed to the following threats: used oil, household hazardous waste and scrap metals; mass wasting from forestry practices; urban and port development; roads and roadway runoff; wastewater and sewage disposal; oil and gas development, including associated pipelines and underwater utility lines; impacts associated with tourism development; gravel mining; and natural events.

Restoration Plans

Several planning efforts with a regional focus exist in the Alaska subregion. Brief summaries of these efforts are outlined below. A full listing of plans and additional information can be found on the National Strategy Restoration Plan Database (http://restoration.nos.noaa.gov).

Kachemak Bay National Estuarine Research Reserve

The Kachemak Bay National Estuarine Research Reserve was established in 1999 and currently encompasses 365,000 acres

of protected estuarine lands and waters. The reserve management plan was approved by the National Oceanic and Atmospheric Administration in 1999. Important habitats that may be useful as reference sites include upland forests, glaciers and glacial streams, tidal flats, brackish marshes and rocky intertidal areas.

Exxon Valdez *Oil Spill Restoration Plan*

This plan provides long-term guidance for restoring the resources and services injured by the 1989 oil spill. It contains policies for making restoration decisions and describes how restoration activities will be implemented.

Alaska's Refuges, Critical Habitat Areas and Sanctuaries

The Alaska State Legislature has classified certain areas as being essential to the protection of fish and wildlife habitat. These areas are managed by the Alaska Department of Fish and Game and designated as either a refuge, critical habitat area, or sanctuary. While they suffer from a variety of historical and current disturbances, all of these designated areas maintain high floral and faunal diversity. The level at which conservation and/or restoration practices are applied differ from region to region with an emphasis placed on shoreline, nearshore and estuarine habitats. It has been largely those areas which have been affected by either oil spill damage or by the threat of commercial development and/or commerce that have received a majority of these efforts to date. For more information, see www.state.ak.us/adfg/habitat/geninfo/refuges/refuges.htm.

Plan Elements

Goals

Several goals were identified in the plans for the Alaska subregion. It was emphasized that restoration should contribute to a healthy, productive and biologically diverse ecosystem within the spill area that supports the services necessary for the people who live in the area. Another goal is to take an ecosystem approach toward restoration to better understand what factors control the populations of injured resources. Restoration goals also focused on full ecological recovery; a recovered ecosystem provides the same functions and services that would have been provided had the spill not occurred. In this system, populations of flora and fauna are again present at former or pre-spill abundances, are healthy and productive, and represent a full complement of age classes at the level that would have been present had the spill not occurred. Another goal is to provide opportunities for long-term research, education and interpretation of trends in estuarine conditions.

Methods

Several methods have been used or recommended for achieving the subregion's restoration goals. Among these are replanting seagrasses, macroalgae, creating fish passes to restore fish populations, redirecting hunting and fishing harvest, managing human disturbance around sensitive bird colonies, and reducing marine pollution.

Elements of Success

Common principles of successful estuarine restoration are apparent in the planning efforts for the Alaska subregion. These include statements of clear, measurable and achievable endpoints; protection of habitat at the watershed level; designation of criteria for setting priorities for projects (e.g., cost effectiveness, likelihood of success, possible harmful side effects, etc.); and multi-disciplinary, interagency or collaborative partnerships.

Monitoring also has been identified as an important element of successful restoration. The Gulf Ecosystem Monitoring Program for the northern Gulf of Alaska, to begin in October 2002, covers Prince William Sound, lower Cook Inlet, Kodiak Island and the Alaska Peninsula. Its mission is "to sustain a healthy and biologically diverse marine ecosystem in the northern Gulf of Alaska and the human use of those resources through greater understanding of how productivity is influenced by human activities and natural changes." Successful monitoring programs focus on more than resource-specific investigations; they include a long-term approach to understanding the physical and biological interactions that affect an injured resource or service. The System-Wide Monitoring Program (SWMP) collects information on abiotic parameters, biodiversity and land use patterns to create a system of national reference sites for estuarine trends.

Public participation and education also can play an important role in successful restoration. Documentaries (e.g., the Alaska SeaLife Center anniversary exhibit), inclusion of an annual report in school curricula, radio and newspaper reports, and newsletters (e.g., The Restoration Update) can increase the effectiveness and ultimate success of a restoration effort. Establishment of a public advisory group is an important aspect as well. The *Exxon Valdez* Trustee Council has its own public advisory group that advises the trustees on all matters related to planning, evaluation and allocation of funds, as well as the planning, evaluation and conduct of injury assessments and restoration activities. Other key elements include community involvement programs, public participation in projects at all levels, and timely release of and reasonable access to information about restoration projects.

Adaptive management can be an important element in a successful restoration project. Restoration priorities need to embody a long-term, ecosystem view that is continually updated as new information is acquired so that the most current ecological, social and economic information is used in formulating decisions.

Information Needs

Most of the information needs in the Alaska subregion relate to understanding the impact of human activity on estuarine habitats and the function of these habitats for fish and essential fish habitat. Also needed is a comprehensive inventory of Alaska's estuarine habitats.

Puget Sound Subregion

Description

The geographic scope of the Puget Sound subregion covers subestuaries and nearshore habitats of the entire Puget Sound basin, including but not limited to the water bodies of the Straits of Georgia and Juan de Fuca, Admiralty Inlet, Hood Canal and adjacent waters.

Puget Sound is one of the most unusual estuaries in the United States, in that deep marine waters invade a heavily urbanized lowland region to form a vast inland sea. Many economic benefits are incurred from shipping, fishing, and residential and commercial development. Furthermore, the cultural and aesthetic values we associate with the Sound and its natural resources are celebrated by both tribal and nontribal communities.

Estuaries like Puget Sound embody the interface between freshwater and saltwater. These areas are usually sheltered from the forces of the ocean and harbor large quantities of plant and animal life. The Sound is used as nursing and foraging grounds by many animal species. Natural regimes of tidal influence and freshwater input are vital to the ecology of the estuary, and changes in the tidal flow or freshwater quality and quantity as a result of human disturbance can alter and eradicate many plant and animal communities. Drying of wetland areas can have a dramatic effect, as can the introduction of exotic species. Changing conditions push out native species and upset ecosystem relationships. It is therefore important to maintain local native relationships (water, soil, plants, and animals) to prevent the disappearance of some species or the disruption of the healthy functioning of others.

Habitat Issues

Status and Trends

Puget Sound has experienced an immense amount of wetland loss:

- More than 70 percent tidal wetlands were lost in the past century, and 33 percent of marine shorelines have been modified (PSWQAT, 2000; Belcher, 2000).
- In Skagit Valley, 37 of the original 40 square miles of wetlands are estimated to have been lost, resulting in a 93 percent total loss (Belcher, 2000).
- In urban areas such as Seattle and Tacoma, the loss of salt marsh is close to 100 percent (WDE, 2000).
- At least 35 percent of Washington's threatened and endangered species require healthy wetlands for survival (PSWQAT, 2000).

Puget Sound's shorelines have been severely altered by development:

- Human activities have modified about 800 miles, or one-third, of Puget Sound's shoreline; 25 percent of these modifications have occurred in intertidal areas (Belcher, 2000).
- Up to 52 percent of central Puget Sound's shoreline and about 35 percent of the shorelines of Whidbey Island, Hood Canal and south Puget Sound have been modified (Belcher, 2000).
- Since the arrival of settlers in the early 1800s, at least 50 percent and as much as 90 percent of riparian habitat in Washington has been lost or extensively modified (Belcher, 2000).

In the Puget Sound area, specific degraded habitats need to be highlighted because of their importance to estuarine functions. These include eelgrass beds, shellfish beds and benthic habitats:

- 33 percent of eelgrass beds have been lost as a result of dredging, filling and diking (White, 1997).
- Eelgrass in Elliott and Commencement Bays is all but absent (some does exist in subtidal areas).
- The Snohomish River Delta has lost 15 percent of its original eelgrass beds (Belcher, 2000).
- Eelgrass beds in Bellingham Bay have declined by about 50 percent over the past 100 years (Belcher, 2000).
- Since 1980, roughly 25 percent of the area classified for commercial shellfish harvesting has been downgraded and taken out of production because of high water concentrations of pathogenic bacteria (WDH et al., 1999).
- A focused study of urban embayments revealed that 35 percent (5,250 acres) of 15,000 acres are contaminated above state sediment quality standards (PSWQAT, 2000).

- More than 3,000 acres of Puget Sound's sediments are so contaminated that federal law requires that they be cleaned up (Belcher, 2000).
- Between 1992 and 1996, Washington discharged 1.5 million pounds of potentially cancer-causing pollutants directly into the water—more than any other state (Belcher, 2000).

The spread of invasive species presents a great threat to native organisms, and their control remains a challenge in restoration efforts. More than 52 invasive species were discovered in Puget Sound in 1998 (Belcher, 2000).

Threats

Within the Puget Sound subregion, losses and degradation of key habitats can be attributed to the following threats: dredging and disposing of sediments; nonpoint source pollution, toxic chemicals (PCBs, PAHs, etc.) metals; shellfish contaminants (marine biotoxins, bacteria and viruses, chemicals); marinas and recreational boating; population growth; agricultural practices; aquaculture development; erosion; urban development and shoreline armoring; forestry management practices; altered drainage patterns from filling, dredging, ditching, and diking; invasive species (*Spartina, zostera japonica* [eelgrass], *Sargassum muticum* [kelp]); culverts, dams, and tide gates; septic system failure; nutrient enrichment; port development, shipping, and transportation; protection of newly established plants from geese and other herbivores; and discarded debris in intertidal and subtidal habitat.

Restoration Plans

An overall management plan exists for the Puget Sound area that contains specific tasks for federal, state, tribal and local governments: the Puget Sound Water Quality Action Team's Marine and Freshwater Habitat Protection Program Long-range Plan (www.wa.gov/puget_sound/Programs/Habitat.htm). Additional subregional plans have been developed and some are included in the discussion below. A full listing of plans and detailed information can be found on the National Strategy Restoration Plan Database (http://restoration.nos.noaa.gov).

2000 Puget Sound Water Quality Management Plan

This plan is the state of Washington's long-term strategy for protecting and restoring Puget Sound. This plan provides the framework for managing and protecting the sound and coordinating the roles and responsibilities of federal, state, tribal and local governments.

1999-2001 Puget Sound Water Quality Work Plan

This plan lays out a two-year strategy to continue work to protect the Sound's health in the face of new and continuing problems. The plan provides the framework for an ongoing comprehensive and coordinated approach to protect and restore the Sound.

Plan Elements

Goals

The Puget Sound Water Quality Action Team, the National Estuary Program for Puget Sound, coordinates agencies involved in restoration and protection of Puget Sound. The Action Team developed and maintains a comprehensive management plan with the goal of preserving, restoring and enhancing the ecological processes that create and maintain marine and freshwater habitats and to achieve a net gain in ecological function and area of those habitats within the Puget Sound basin. Due to the large geographic area and the number of entities involved in restoration, this broad goal is designed to set the standard for restoration into the future but does not replace the need to develop individual restoration goals that are more geographically distinct or site specific.

Other goals that have been identified in restoration plans for the Puget Sound area are to:

- Improve water quality.
- Achieve no net loss of wetlands function and acreage.
- Use best shoreline development practices (erosion control).
- Follow holistic ecosystem management.
- Conduct restoration on an estuary-wide basis.
- Ensure adaptability to new developments in science and restoration technology.
- Provide for management by a panel representing federal, state, tribal and local governments to maximize joint opportunities.
- Limit the amount of funding spent on planning and studies.
- Integrate and coordinate sediment remediation, habitat development and source control.
- Set priorities for projects and implementation of cost-effective methods.
- Have a regional jurisdictional entity (e.g., port district, county, state) eventually absorb responsibility for monitoring and stewardship.
- In the long term, achieve a measurable net gain of wetlands function and acreage and a net gain of aquatic and riparian habitat important to protection of water quality.

Methods

Several methods have been used or recommended to achieve the subregion's restoration goals.

- Breach dikes, open dikes to restore natural flood cycles, redivert water and control drainage.

- Develop and implement marine protected areas (MPAs) or marine sanctuaries.
- Evaluate potential sites and criteria for regional management plans and provide evaluation to determine success.
- Provide management at the local level.
- Revegetate, retaining detritus and salmon carcasses for nutrient cycling.
- Install and maintain streamside fencing, bioengineering approaches to bank stabilization; apply fill removal, excavation, and for stream daylighting, create a new surface water channel and mouth to provide intertidal habitat.
- Maintain and/or provide large woody debris in riparian corridors that have been altered due to inappropriate land use activities.
- Modify substrate; amend upland soils, import soil for establishment of emergent marsh area.
- Control erosion (e.g., use logs, large rocks or other materials to protect the emergent zone from wave action; install wattling or shrub plantings for bank stabilization).
- Remove and control *Spartina* (use "Integrated Weed Management approach" as suggested by Washington's 1993 Noxious Emergent Management Plan EIS; use herbicide, mow and spray regime).
- Plant eelgrass in areas that have the appropriate physical characteristics (salinity, depth, substrate, water clarity, etc.).

Elements of Success

A variety of elements have proven successful in restoration efforts.

- Define roles for stakeholders and public participation.
- Creating a panel for each project of cooperating agencies to establish goals, review, set priorities for and recommend projects, collect and disseminate information, and address a variety of information specific to assigned areas.
- Developing and implement a long-term site management plan after restoration.
- Building on smaller restoration projects to increase rates of success.
- Designing and build projects in the context of a larger landscape approach.
- Using adaptive management to monitor sites and make appropriate changes over time; collect, evaluate, update and distribute information about ongoing programs and projects to improve water quality and salmon habitat.

Site selection and planning:

- Evaluate site elevation, tidal flow, freshwater input, and substrate type versus the habitat requirements of restored vegetation community.
- Establish selection criteria (current and historic locations, conditions, functional trajectories and ownership), use "space-for-time substitution," set priorities for projects (e.g., cost effectiveness, the relative potential of the cleanup or restoration to benefit fish and wildlife).
- Consider several reference sites as a model for restoration.
- Conduct thorough site planning that includes hydrologic analysis, grading plans, soil conditioning or amendment, planting plans and specifications, and timetables and schedules.
- Collect pre-project information in the context of the current and historic landscape. Through review of a historic and current habitat inventory, reconstruction of the current delta may be attempted.
- Conduct functional assessments before and after the project. Standardize data through hydrogeomorphological (HGM) assessments.
- Create a selection process that filters proposals for accurate assessment of a project's importance and feasibility.

Monitoring:

- Development of programs to monitor project effectiveness.
- Development of a quantitative approach for measuring progress.
- Designation of a lead entity to oversee site stewardship, monitoring and implementation of contingency measures.
- Involvement of volunteers in monitoring of restoration projects. Volunteer stewardship groups and conservation organizations should be tapped to carry out monitoring tasks, to control program costs and foster community support for stewardship of completed restoration projects. Reviews by a lead agency can ensure data quality. Programs need continual review so that as specific criteria have been met, the associated monitoring tasks cease.
- Adoption of standard protocols to which performance criteria can be compared. Possible monitoring could include below-ground and above-ground biomass, inventory of fish and amphibian resources, bird use by habitat type (point counts, breeding bird surveys), invertebrate surveys, vegetation surveys, and channel formation. Monitoring should be related to goals via a conceptual model.

Education and public participation:

- Educate and publicly involve all stakeholders to establish a sense of ownership in the restoration measures and educate the public about how to prevent further degradation. Educational initiatives should be tailored to each specific audience.
- Determine the role of the public in the project.
- Develop and distribute materials for a comprehensive edu-

cational program and maintain it through partnerships with other agencies. In Puget Sound, the Public Involvement and Education Fund supports educational programs.

- Provide educational workshops for landowners on implementing best management practices that protect water quality, streams, wetlands and fish habitat. At least half of the workshops will target livestock owners.
- Educate the public on the need for a large-scale framework for project selection and development
- Bring all stakeholders into the process of project screening and approval early to avoid problems and delays later.
- Create a Public Participation Committee, to allow people to comment early and throughout the planning program via meetings and workshops. Conduct interviews with stakeholders to extract opinions and recommendations. The long-term viability of restoration projects relies in part on community understanding and acceptance of restored natural features in the urban landscape.

Funding:

- The U.S. Environmental Protection Agency has provided financial assistance to tribes and local communities in the Puget Sound basin to develop aquatic habitat protection plans.
- The non-regulatory Natural Lands Plan provides financial incentives to individual property owners to preserve critical areas and agricultural and forestry activities. It also provides for restoration and protection of degraded wetlands and stream corridors and recommends various funding strategies to augment the capacity to acquire high-priority lands.
- Local cost-share of capital improvements.
- The Corporate Wetland Restoration Partnership, founded in 1999 by Gillette in Massachusetts, combines corporate contributions with federal and state funds to restore degraded tidal and freshwater wetlands.
- Having separate funds for construction and scientific research aspects of restoration projects ensures that goals for both will be met.
- The state of Washington's Salmon Recovery Funding Board has significant state and federal funds (tens of millions of dollars) available annually for habitat restoration and acquisition, and has language in its guidelines specifically soliciting estuarine and marine nearshore projects.
- Ports and port associations are possible sources of matching funds.
- The North American Wetlands Conservation Act of 1989 provides matching grants to private or public organizations or to individuals who have developed partnerships to carry out wetlands conservation projects in the United States, Canada and Mexico.
- The Coastal Wetlands Planning, Protection and Restoration Act authorizes the director of the U.S. Fish and Wildlife Service to grant funds to coastal states (including states bordering the Great Lakes) to carry out coastal wetlands conservation projects.

Information Needs

The analysis of plans identified the following common areas where additional research is needed on restoration techniques and methods:

- Estimates of recovery time for estuaries to determine what is attainable and sustainable over time (information about threshold sizes equilibrium points).
- Better tools for project evaluation and success criteria.
- Data to create a baseline map of potential wetlands within the watershed. Wetlands need to be characterized and functional attributes assessed so that changes in conditions can be recognized.
- Baseline monitoring: information about onsite conditions before construction of the restoration project; data collected in the first year after the restoration project; information from reference sites; information from literature reviews of similar situations; and information from studies of existing, undisturbed estuaries.
- More information on the interaction between natural coastal processes and human land use as they relate to salmon production.
- Spatial and computer models to establish links between human activities and conditions in marine and freshwater environments (e.g., to investigate and eliminate sources of pollution upstream that could affect work downstream).
- Overlays of key habitats (and other types) with land use zoning designations to predict areas that are likely to be degraded through addition of impervious area.
- The influence of upper watershed activities on lower watershed work.
- A sample subset of sites of different ages where dikes have been breached by natural means (e.g., storms) and monitoring of how long natural restoration of these sites takes.
- Examination of projects in the context of the greater watershed or a landscape approach. A method is needed for scientific classification of estuaries by their watershed characteristics.

Issues identified in need of further research and testing include:

- Cost-effective methods to study the survival of biological populations in habitats or the changes in survival caused by lack of refuge or other limiting factors like available food sources.

- Climate change and the rise of sea level may require flexibility in the estimated tidal levels incorporated into restoration projects. More research is needed in this area so that planning efforts can accurately take these issues into account.
- The identification of sites through mitigation plans provides a potentially important resource. These plans often represent a substantial body of work, identifying a surplus of target sites beyond the scope of the proposed mitigation. Examples of potentially useful project lists driven by mitigation requirements include the Elliott Bay/Duwamish Restoration Panel, the Commencement Bay Natural Resource Damage Assessment Environmental Impact Statement and Restoration Plan, and the Snohomish Estuary Wetland Integration Plan and Salmon Overlay.
- An information clearinghouse that collects baseline information on Puget Sound sites, including aerial photographs, soil maps and project designs. This makes comparisons among sites difficult and thus complicates planning and construction of future restoration projects. It is essential to follow the changes in geomorphology and ecology of restoration sites so that recommendations for future projects can be based on pre-existing projects. Designation of a lead agency to compile these records would be helpful.

Oregon and Washington Coasts and Columbia River Estuary Subregion

Description

Oregon and Washington's coastal estuaries are areas of high biological productivity. They provide critical habitat for many species of cultural, commercial and recreational importance, including several species listed as endangered and threatened under the Endangered Species Act. Since colonization, many of the region's estuaries have been affected by altered hydrology, urbanization, water pollution and the introduction of exotic species. This has had a negative impact on salmon and other finfish and shellfish species, as well as on eelgrass beds, tidal marshes and general biodiversity.

Widespread agricultural and urban development of coastal lowlands in the Pacific Northwest began relatively late in the history of the United States. By the time the coastal areas of Washington and Oregon were settled, our society had developed clear goals for and efficient methods of converting tidal wetlands to other land uses via diking, dredging and filling activities. As a result, thousands of acres of biologically productive estuarine habitat have been lost to development. Although agricultural use of converted lands was dominant early in the last century and remains important in the region, increasing urbanization of coastal communities is resulting in more substantial and permanent alteration of coastal lands and surrounding estuarine waters.

Restoration of these critical estuarine habitats will be essential to recover and maintain the biological productivity of the Pacific Northwest's coastal waters. Restoration efforts are in progress along the Washington and Oregon coasts under the management of federal, state, tribal and local authorities and through the efforts of nongovernmental entities and community groups. Some management plans include sections on restoration that may not have been implemented yet; others already have been completed. There has been considerable effort to re-create habitat rather than simply mitigate damage.

Habitat Issues

Status and Trends

The following statistics reflect significant damage to the Oregon and Washington coasts and Columbia River Estuary.

- More than half the tidal marshland and 70 percent of the tidal wetlands have been destroyed in the Columbia River Estuary since 1870. Only 10 percent of the historic anadromous fish stock remains (Jerrick, 1999).
- South Slough National Research Reserve contains less than 10 percent of the original salt marsh (Donnelley, 1994).
- Tillamook Bay has lost 85 percent of marshlands to diking and draining. Historical tidal wetlands covered 5.52 square miles; 0.3 square mile is native wetland and 1.3 square miles have been restored (NEP and US EPA, 1999).
- Since the 1800s, urbanization converted 90 percent to 98 percent of Washington's coastal wetlands (WDNR, 2000).
- Only 35 percent of Washington's estuaries have good water quality (WDNR, 2000).
- Willapa Bay's infestation of Spartina, an exotic species, is projected to increase from 3,200 acres in 1997 to 30,000 acres in 2030 (WDNR, 2000).
- Yaquina Bay has lost 14 percent of its tidelands to filling (LCEMP, 1982).
- Juveniles of more than 70 species of fish use Oregon's estuaries to forage (Oberrecht, undated).

Threats

Primary threats in this region include modification and loss of habitat through diking, draining, damming*, tide gates, culverts, filling, structures (such as sea walls, jetties and docks), water diversions and altered flow, and dredging; sedimentation problems in the estuary often caused by anthropogenically altered hydrology; loss of biodiversity, especially through invasive or exotic species; degradation of water quality (e.g., elevat-

ed fecal coliform bacterial levels, non-point source pollution); agricultural and forestry practices (e.g., creation of pastureland, erosion, suspended sediments); and Canada geese, a resident species that feed on intertidal plant species, but in some cases can be detrimental to the health and growth of restored wetland plants.

*Dams are a major threat to the migration patterns of Pacific salmon. The physical presence of dams, and the creation of reservoirs, impedes juvenile and adult migrations to and from the ocean. The reservoirs behind the dams slow water velocities, alter river temperatures and increase predation potential. Reduced water velocity increases the time it takes juveniles to migrate downstream. Higher water temperatures may have adverse effects on juvenile and adult behavior, and predators find prey more easily in slower-moving water. Since 1991, the National Marine Fisheries Service (NMFS) has listed 12 "Evolutionarily Significant Units," of Columbia River Basin salmon and steelhead as threatened or endangered under the Endangered Species Act.

Restoration Plans

Although Oregon and Washington do not now have comprehensive estuarine restoration strategies, they have all the elements necessary to develop and implement such strategies. Both states have a statewide framework for land use and estuary or shoreline planning and management; a framework to identify and provide funding for watershed restoration projects; a system of grassroots organizations empowered to identify appropriate restoration sites and projects; and a prototype information system that can assist in the identification of estuarine restoration sites. A national estuarine restoration strategy and federal funding would contribute significantly to the use of these elements in the development and implementation of comprehensive regional estuarine restoration strategies.

Activities in Oregon's estuaries are governed largely by an element in Oregon's Statewide Comprehensive Land Use Program. Oregon law requires all local governments to adopt comprehensive land use plans in compliance with a series of "Statewide Planning Goals." There are 19 such goals; four apply exclusively to coastal resources, one specifically to estuaries. Thus, all of Oregon's major estuaries are governed by "estuary management plans," available on the internet (www.inforain.org/mapsatwork/oregonestuary/). In addition, the Lower Columbia Estuary Program (www.lcrep.org/home.htm) and the Tillamook Bay National Estuary Project (www.co.tillamook.or.us/gov/estuary/tbnep/nephome.html), participants in the U.S. EPA's National Estuary Program, were created to develop partnerships between government agencies that oversee estuarine resources and the people who depend on the estuaries for their livelihood.

Washington has two relevant statewide planning laws. The Growth Management Act requires jurisdictions to locate critical areas such as wetlands, steep slopes, aquifer recharge areas and important fish and wildlife habitat areas, develop ordinances to protect them and incorporate them into county-wide comprehensive land use plans. The Shoreline Management Act requires local jurisdictions to designate appropriate land uses along a 200-foot-wide shoreline zone and develop policies to protect the appropriate land uses for each designation, ranging from shoreline conservancy to shoreline industrial. Both of these planning frameworks receive guidance and programmatic oversight from state agencies and include a public participation and appeals process. The coastal zone of Washington is further managed by the state Department of Ecology through broad, comprehensive coastal management policies. The coastal zone contains three planning regions, the lower Columbia National Estuary Program, the Olympic National Marine Sanctuary and Puget Sound, each with comprehensive management plans.

A full listing of plans and more detailed information can be found on the National Strategy Restoration Plan Database (http://restoration.nos.noaa.gov).

Columbia River Estuary Regional Management Plan

This plan expresses decisions of the Columbia River Estuary Study Taskforce Council on estuarine management issues including restoration, land and water use, dredged material management and mitigation.

Lincoln County Estuary Management Plan

The Lincoln County Estuary Management Plan provides an overall, integrated management scheme for estuarine aquatic areas in Lincoln County and contains comprehensive provisions for guiding estuarine development and conservation activities.

Lower Columbia River Estuary Plan

The Lower Columbia River Estuary Plan was developed by a committed group of citizens participating in the Lower Columbia River Estuary Program. The plan focuses on a unique and critical part of the Columbia River system: the Lower Columbia River. It identifies how to best preserve and enhance this resource.

Padilla Bay National Estuarine Research Reserve

The Padilla Bay National Estuarine Research Reserve was established in Washington in 1980 and currently encompasses

10,700 acres of protected estuarine lands and waters. The reserve management plan was prepared in 1984 and is currently being revised. Important habitats that may be useful for investigation and as reference sites include tidal flats and sloughs, salt marshes and seagrass beds. Restoration priorities include removal of fish migration blockages and salmon recovery by means of restoration of riparian zones and estuarine sloughs. Restoration of salt marshes, mudflats and eelgrasses may include removal of invasive species, woody debris and toxic materials such as creosote logs. Current restoration projects include Spartina alterniflora control that preserves and restores native salt marshes and mudflats.

Salmon Recovery Plan

In May 1997, Washington Governor Gary Locke and thirteen agency heads signed a memorandum of agreement to establish a forum to serve as the "formal and ongoing institutional framework to promote interagency communication, coordination and policy direction on environmental and natural resource issues." This forum is known as the Joint Natural Resources Cabinet (JNRC). To bring together a wider forum to assist with the review and development of a three-part effort to recover salmon, the Government Council on Natural Resources (GCNR) was developed. In order to assist the JNRC and GCNR in accomplishing their mission, the Governor's Salmon Recovery Office was established by the Legislature through the Salmon Recovery Planning Act (Engrossed in Substitute House Bill 2496). The Salmon office's role is to coordinate and produce a statewide salmon strategy, assist in the development of regional salmon recovery plans, and submit the strategy and plans to the federal government. The office also provides the Biennial State of the Salmon report to the state legislature.

South Slough National Estuarine Research Reserve

The South Slough National Estuarine Research Reserve was established in Oregon in 1974 and currently encompasses 4,770 acres of protected estuarine habitats. The reserve management plan was last revised in 1994. South Slough habitats include degraded and relatively undisturbed examples of coastal forests, riparian habitats, freshwater wetlands (including beaver ponds), salt marshes, tidal flats and eelgrass beds. Restoration priorities include anadromous fish rearing habitat, salt marsh vegetation and invertebrate communities, and forest and upland habitat enhancement. Current restoration projects include salt marsh restoration (i.e. dike removal and restoration and creation of tidal creeks), replanting historically harvested upland forests and stream channel restoration and enhancement.

Tillamook Bay Comprehensive Conservation and Management Plan

This Comprehensive Conservation Management Plan (CCMP) addresses four priority problems in the Bay with coordinated goals, objectives and specific actions. Each action details the steps required to complete the action; identifies coordinating entities, other partners and completion dates; estimates costs; acknowledges regulatory issues; and plans for monitoring progress toward the CCMP goals and objectives.

Plan Elements

Goals

Analysis of plans reveals definite similarities among stated goals for habitat protection and restoration. These include: restoration and protection of habitat, including restoration and protection of physical, chemical, hydrological and biological processes; re-creation and protection of wetlands and tidal marshes, no net loss of wetlands, eelgrass beds or tidal marshes, and reversal of historic trends of degradation; maintenance of or increase in biodiversity, including restoration of anadromous and other fish populations, improvement of fish and wildlife health, control and prevention of further introductions of invasive or exotic species; improvement of water quality; increase in acreage of functioning tidal marshes; and conservation of existing habitat function.

Methods

Analysis of restoration plans revealed commonly used methods for restoring and managing habitat.

Restoration Methods:

- Remove or breach dikes and other structures such as jetties, sea walls and dams.
- Remove old tide gates or replace with fish-friendly tide gates.
- Remove fill or dredge material from former wetlands and tidal sloughs.
- Re-create or reconnect sloughs, streams and wetlands; re-establish natural hydrology by excavation or dynamite.
- Revegetate wetlands and upland buffers with native plants.
- Re-create correct ground elevation for natural revegetation of tidal wetlands to take place.
- Suspend maintenance of dikes (passive restoration).
- Control invasive or exotic species through mowing, herbicides, biological controls, uprooting, covering, taking inventory of existing populations and providing information to the public.

Strategies for Managing Habitat:

- Encourage restoration and protection efforts on private land.
- Identify and set priorities for habitat to be restored.
- Acquire land for restoration purposes.
- Establish and enforce shellfish closure criteria.
- Establish and enforce total daily maximum loads.
- Sample water quality regularly.
- Apply land use designations and zoning to direct development away from critical estuarine habitats (e.g., natural, conservation, development).
- Create or implement relevant state laws and county ordinances (e.g., land use, fisheries management).
- Mitigate habitat loss in unavoidable situations.
- Support basic scientific research to inform management decisions.
- Bring a sense of uniformity to restoration efforts.
- Implement a monitoring and adaptive management program after restoration.

Elements of Success

A review of restoration plans revealed some elements of planning and implementation that have proved successful.

Planning:

- Have clear and common goals, design and data.
- Work within a larger-scale restoration plan (based on landscape, watershed or coastal ecosystem) when available.
- Develop cooperation among agencies, stakeholders and interest groups such as watershed councils and "lead entities."
- Build on successful pilot or predecessor restoration programs.
- Work within existing shoreline land use designations.
- Establish a restoration advisory group that includes national science experts who will review plans.
- Use existing mitigation plans to identify candidate restoration sites.

Implementation:

- Monitor before and after alteration needed for restoration.
- Ensure sufficient funds (state, nonprofit sources, grants).
- Create and maintain a large database of relevant information.
- Control elevation when restoring vegetation to ensure that revegetation goals are met.
- Involve representatives from permit-issuing agencies and funding entities in the design process and project implementation through site visits.
- Develop public outreach, education and volunteer opportunities.

Information Needs

Some areas in current restoration efforts could be more successful with further research. The following is a list of factors that have contributed to less successful restoration practices.

- ❖ Lack of agency coordination and lack of a designated single responsible person.
- ❖ The newness of the implementation phase of the programs.
- ❖ Lack of resources for monitoring, public involvement or outreach.
- ❖ Lack of scientific data and tracking of changes in data.
- ❖ Imperfect results (e.g., low salt marsh returns instead of high salt marsh returns).
- ❖ Need for updating older restoration plans.
- ❖ Mapping problems.
- ❖ Use of plugs to direct water flow.
- ❖ Need for research in sedimentation process, fish stranding and ecosystem relationships.
- ❖ Need for a comprehensive look at historical estuarine data (e.g., where, what kind and how to restore).
- ❖ Rate of restoration too slow to meet resource and habitat management goals.
- ❖ Need for research on restoration in brackish water sloughs.
- ❖ Need for cost-effective methods to study the survival of biological populations in habitats or the changes in survival resulting from capacity or other limiting factors, such as available food sources.
- ❖ Need for research on the effects of climate change and rising sea level on estimated tidal levels, so that restoration plans can take these issues into account accurately.

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Regional Analyses of Restoration Planning

PART 2 – CALIFORNIA AND THE PACIFIC ISLANDS

ESTUARIES OF CALIFORNIA AND THE PACIFIC ISLANDS

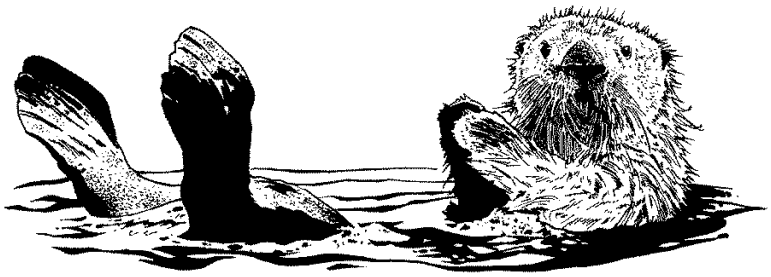
The California and Pacific Islands region is defined here as the northern and southern coasts of California, Hawaii and the Pacific Island/U.S. Pacific Protectorates, including Guam, American Samoa and the Commonwealth of the Northern Marianas (CNMI).

This region:

- Encompasses an area from latitude 15 degrees south to latitude 42 degrees north, and from longitude 117 degrees west to longitude 145 degrees west—a significant portion of the planet.
- Has subregions that are not only distinct from each other ecologically and politically, but as a whole are geologically and ecologically distinct from each other.
- Has lost 9,000 acres (33 percent) of intertidal habitat in the Humboldt Bay estuary (USFWS, 1992).
- Has lost 80 percent of the estuarine area in the Suisun Marsh, Calif. (USFWS, 1981).

SUMMARY

The California and Pacific Islands region covers a large geographic area comprising significant differences in the local extent of coastal and estuarine habitat as well as restoration efforts and planning. In the Pacific Islands, the fact that estuarine habitat is relatively rare makes that habitat uniquely critical to local ecosystem functions. In terms of restoration planning, San Francisco Bay produced the nation's first effort at what has become known as coastal zone management. The Southern California Wetlands Recovery Project is a partnership among 17 federal and state agencies working in concert with a public advisory committee, a science panel and task forces in five coastal counties. The Southern California Wetlands Recovery Project developed a regional restoration strategy that has been evolving over the past four years. In the Pacific Islands, very few plans exist for comprehensive restoration planning for estuarine habitats. This absence of planning is alarming because the populations of these islands are increasing at an extremely high rate and the majority of the populations inhabit the coastal areas. Several government agencies are gathering baseline data that would allow planning efforts to proceed.



INTRODUCTION

Description

For this discussion, the California and Pacific Islands region is defined as the northern and southern coasts of California, Hawaii and the Pacific Island/U.S. Pacific Protectorates.

The Northern California subregion encompasses the coast from the Oregon border to Point Conception, Calif. This subregion covers more than 800 miles of coastline. Because the northern coast is exposed to the Pacific current and cooled from the northern reach, it experiences cooler climates with higher rainfall than the rest of the state. The Southern California subregion includes the area from Point Conception southward to the Mexican border. This part of the coast is subject to a subtropical oceanic gyre that moves northward until it mixes with the cooler Pacific current at Point Conception. This phenomenon creates a warm and semi-arid Mediterranean-like climate unlike that of other parts of the region.

The United States affiliated Pacific islands discussed in this section are the state of Hawaii, the Commonwealth of the Northern Mariana Islands (CNMI) and the territories of Guam and American Samoa. All are tropical oceanic islands; however, they are widely dispersed across the Pacific. Hawaii lies near the edge of the tropics in the north Pacific Ocean and is the most isolated island chain in the world in relation to continental areas. Guam is the southern terminus of the Mariana Islands chain and the remainder are part of the CNMI. These islands lie near the equator in the Western Pacific Ocean. Guam is 3,800 miles west-southwest of Honolulu and 1,500 miles south-southeast of Tokyo. American Samoa is south of the equator in the central Pacific Ocean, approximately 2,500 miles southwest of Hawaii. A triangle formed by these locations encloses an area much larger than the continental United States, and any leg of this triangle is longer than the distance between New York City and Los Angeles.

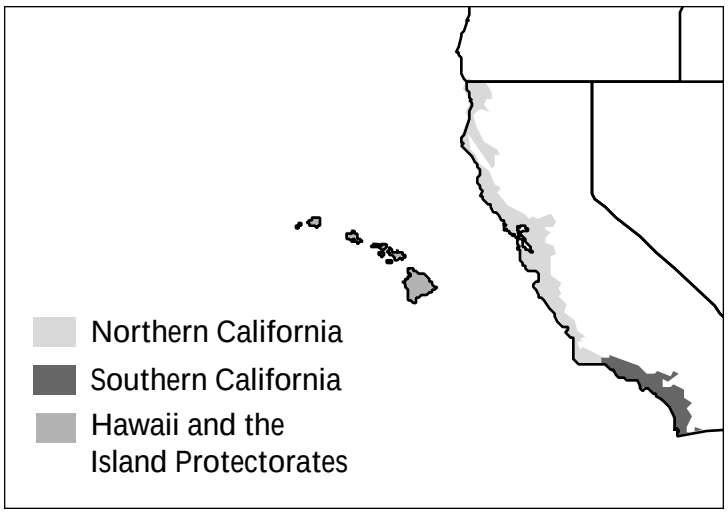


Figure 1. California and the Pacific Islands Region

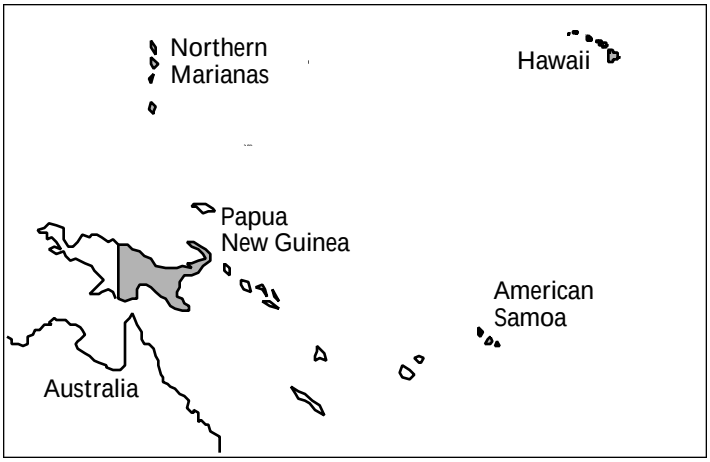


Figure 2. Pacific Protectorates Subregion

Key Habitats and Species

Key habitats within the region include salt, brackish and freshwater marsh; open water lagoon; seasonal wetland; tidal mudflat; beach and dune; upland and riparian habitat; salt ponds; and Hawaiian fishponds. These habitats and their need for restoration are based upon the frequency with which they were mentioned in the restoration plans reviewed. Habitats and the degree of restoration needed vary somewhat between subregions (see Table 1, next page).

Coastal and estuarine habitats within California and the Pacific Islands are designated as essential fish habitat for species managed by the Pacific Fishery Management Council and the Western Pacific Fishery Management Council, indicating that these habitats are necessary to support a sustainable yield from fisheries and to support a healthy ecosystem (NOAA/Pacific Fishery Management Council, 1998; Western Pacific Fishery Management Council, 1998). Many of the estuaries in the region directly support species of fish that are economically important because of their commercial and recreational harvest. These and other estuaries provide habitat for endangered and threatened species of fish and indirectly support important economic species by providing nursery habitat for prey.

The estuaries of California provide important habitat for a host of shore birds and wading birds, fish-eating birds, waterfowl and raptors. Many of these estuarine-dependent species are listed as endangered or threatened; consequently, the limited amounts of healthy estuaries provide critical habitat. Some areas within the region have a high incidence of endemic species, making healthy estuaries essential to

TABLE 1. ESTUARINE HABITATS IN NEED OF RESTORATION IN CALIFORNIA AND THE PACIFIC ISLANDS

Habitat	Northern California	Southern California	Hawaii	U.S. Pacific Protectorates
Tidal salt marsh and freshwater marsh	●	●	●	●
Submerged aquatic vegetation	▲	▲	❍	❍
Diadromous fish corridors	▲	▲	❍	❍
Coastal embayments	▲	▲	▲	▲
Shellfish reefs and coral reefs	▲	▲	●	●
Beaches and dunes	●	●	▲	▲
Intertidal flats	●	●	▲	▲
Salt ponds and salt pannes	❍	❍	❍	❍
Rocky shore and cobble beach	❍	❍	❍	❍
Wetlands	●	●	●	●
Mangroves	❍	❍	❍	●
Estuarine fish corridors	▲	▲	●	●

KEY: ● High need ▲ Moderate need ❍ Low or no need

their survival and regional biodiversity. Across the region, estuaries also play a critical function as resting and feeding areas along the Pacific Flyway (USFWS, 1996).

A number of species in California estuaries are either federally listed by the U.S. Fish and Wildlife Service, or have special state status as determined by the California Department of Fish and Game. Federal endangered species include fish (tidewater goby), mammals (saltmarsh harvest mouse), birds (light-footed clapper rail, California clapper rail, San Clemente loggerhead shrike, California least tern, California brown pelican), and plants (salt marsh bird's beak). Federal threatened species include fish (steelhead trout, chinook salmon, coho salmon, delta smelt, sacramento splittail), mammals (southern sea otter) and birds (marbled murlett, snowy plover). Many other species of estuarine fish, mammals, plants, invertebrates, reptiles and amphibians are listed as threatened or endangered by the state of California.

Invasive species are a serious problem in California estuaries. Invertebrates such as the Asian clam, various non-native algae including *Caulerpa taxifolia*, and plants such as peppergrass and smooth cordgrass are threatening the integrity of native habitats. In many cases, these species alter essential properties of existing habitats, and compete with California's native plants and animals. Many of California's listed species are suffering due to the presence of these invasive exotics.

While limited in extent, estuarine habitats in the Pacific Islands can be quite diverse. In Hawaii, brackish-water marshes, fishponds, anchialine pools and mudflats are the most significant estuarine habitats. In the other island areas, most estuarine habitat is mangrove forest. These habitats support a wide variety of invertebrates such as shrimp, crabs and mollusks. Wetland and coastal habitats also support a range of resident and visiting waterfowl, shore birds and seabirds. In addition, a very important group of organisms rely on estuaries to complete their life cycles—freshwater amphidromous fish (gobies), mollusks and crustaceans. These organisms have evolved from marine forms to inhabit freshwater streams in Hawaii, American Samoa, CNMI and Guam. These species live as adults and spawn in streams, after which the young float to the ocean and drift for weeks or months before returning to the streams as juveniles to continue the cycle (Swenson, personal communication).

California's Anadromous Fish Species

Anadromous fish, such as the coho, chinook salmon, steelhead trout, american shad, striped bass (an introduced species) and white sturgeon, require healthy rivers and associated tributaries for migratory routes, as well as for spawning and nursery grounds. Many of these fish pass through wetland, or shallow nearshore water (which have wetland and estuary influence) for survival during at least a portion of their lives. Most often, these areas are nursery grounds for young fish. The young fish benefit from the high food concentrations, shelter and vegetation that these areas provide. Some salmon and steelhead smolts use streamside wetlands for food and protection and then move to estuaries and fringing marshes for weeks or months as they grow and adapt to the salt water environment before moving out to sea. As adults, salmon and steelhead will

utilize the estuaries again for a brief time to feed before heading upstream to spawn. Other fish species use wetlands and estuaries for years at a time, while still others depend on nearshore environments for their whole lives.

Although salmon and steelhead historically used rivers and streams along the entire coast of California, the strongest remaining populations of anadromous fish typically occur in rivers near or north of San Francisco Bay, where 60 percent of California's annual rainfall occurs. The Klamath River, which drains a 12,000-square-mile watershed, is the second largest river in the state, after the Sacramento River. Other anadromous fish, such as striped bass and white sturgeon, mainly spawn in the Sacramento-San Joaquin Delta.

Many anadromous fish have shown significant population declines in the last decade. In 2000, only 1,352 winter-run chinook salmon migrated upstream in the Sacramento River, compared to an average of 35,000 from 1970 to1974 (see Figure 3). Many of California's salmon and steelhead are either threatened, endangered or candidates for listing under the Endangered Species Act (ESA) (see Table 2).

TABLE 2. STATUS OF SALMON AND STEELHEAD POPULATIONS* IN CALIFORNIA

Species Name	Population	Status
Oncorhyncus kisutch	S. Oregon/Northern California coho	T
	Central California coho	T
Oncorhyncus mykiss	Southern California steelhead	E
	Central CA Coast steelhead	T
	South-Central California Coast steelhead	T
	CA Central Valley steelhead	T
	Northern California steelhead	C
	Klamath Mountain Province steelhead	C
Oncorhyncus tshawytscha	Sacramento River winter chinook	E
	CA Central Valley spring chinook	T
	CA Coastal chinook	T
	CA Central Valley fall chinook	C

** These fish populations are those that are listed under the Endangered Species Act (ESA) as being in danger of extinction (E), threatened with becoming endangered (T), or as a candidate (C) for listing under the ESA. These population groupings, called Evolutionarily Significant Units (ESUs), are broad groupings that contain fish of many different stocks (e.g., fish that are adapted to return to specific rivers, often at a particular time of the year).*

Threats to California's Salmon and Steelhead Fisheries

Hydropower

Hydropower dams have dramatically altered flows and riparian habitat for a large number of rivers and streams. Dams and hydropower operations have modified the level, timing, frequency and duration of stream flows. Dams have blocked the movement of fish both upstream and downstream, de-watered stream segments below dams, caused loss of upstream habitat and increased predation in reservoirs.

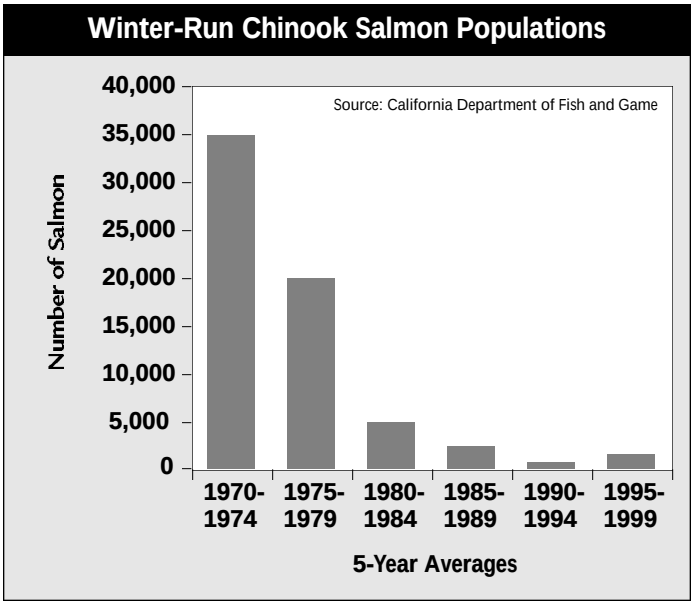


Figure 3. Winter-Run Chinook Salmon Populations

Smolt and juvenile fish migrating downstream through the reservoirs encounter slower moving water. By increasing the time it takes for them to reach the ocean, their chances of dying from predation and diseases increases as well. In addition, the absence or inadequacy of fish ladders or other bypass systems block or limit adult migration upstream, closing off many miles of potential spawning and rearing habitat.

Agricultural Practices

Agricultural practices that may adversely affect salmon include diking, draining, filling, stream channelization, removal of large woody debris, installation of riprap along stream banks, removal of riparian vegetation, road building, diversion of surface and ground water for irrigation and agricultural processing, and pesticide and fertilizer applications. Irrigated agriculture requires diversion of water, which reduces stream flows. In some years, this leaves little or no water for salmon and other aquatic species. Return flows, while perhaps increasing the amount of water in streams, degrade the water quality by rais-

ing its temperature and adding dissolved chemicals. Unscreened or improperly screened diversions can have devastating effects on juvenile fish.

Forest Practices

Forest management activities such as road building, timber harvests near streams or on steep or unstable areas, and the application of chemicals have damaged fish habitat and water quality. The most profound impacts include: increased stream temperature, diminished opportunities for large woody debris recruitment, alteration of groundwater and surface water flows (increased runoff and reduced percolation of rain and snowmelt into the ground), and degradation or loss of riparian habitats. These forest practices also resulted in lost or degraded spawning and rearing habitats, contributing to the ESA listing of some salmon runs.

Urbanization

Urban areas are frequently located in important salmon migration corridors and rearing areas. The areas most significantly affected by urbanization are small streams, riparian corridors and associated wetlands, shorelines and estuaries. Residential, commercial and/or industrial development changes the natural hydrologic cycle by stripping vegetative cover, removing and destroying native soil structure, modifying surface drainage patterns and adding impervious and nearly impervious surfaces, such as roads and other compacted soils. Loss of water in stream channels and riparian areas, due to water withdrawal and consumptive use of water from streams, rivers and aquifers, further reduces groundwater recharge.

Stream Flow Modification

Natural flow conditions have been affected through the diversion of water from streams for irrigation, municipal and industrial uses, water storage operations, and land use changes. Increases in the frequency and duration of both floods and low flows are having considerable detrimental effects on salmon.

Harvest

Harvest rates of adults in many fisheries can reach 50 percent to 80 percent of salmon populations, and though many salmon stocks can sustain this level of harvest, stocks that are challenged by poor productivity or poor ocean conditions cannot. In addition, size-selective gear, coupled with high rates of harvest of larger adults, can result in shifts toward younger, smaller adults with less ability to negotiate the challenges salmon face during their journey (e.g., large barriers) and with lower reproductive potential. Aside from the direct impact of commercial fishing on salmon populations, harvest also reduces the amount of dead salmon that contribute detritus to rivers. This detritus provides nutrients on which new generations of salmon depend.

Climate Change and Ocean Conditions

Climatic changes can affect the numerous physical, biological and chemical processes in the ocean that influence fish population dynamics and survival. Variations in sea surface temperatures, air temperatures, strength of upwelling, salinity, ocean currents, wind speed and ocean productivity have been shown to cause or correspond with fluctuations in abundance and survival of salmonid populations.

Habitat-Dependent Activities

The fisheries economy of California and the Pacific Islands is directly dependent on healthy estuarine habitats. In 1999, California recorded the landing of nearly 295,000 metric tons of fish, worth nearly $145 million. Landings of chinook salmon alone were valued at nearly $7.5 million. Similarly, recorded landings of all species in Hawaii were nearly 17,000 metric tons, worth $65 million (www.nmfs.noaa.gov).

In addition to the important function estuaries play in the coastal and marine ecosystem, they provide all the benefits to humans that terrestrial wetlands provide: water filtration and purification, aquifer recharge (e.g., help protect against salt water intrusion thereby protecting groundwater and drinking water), flood and erosion control, storm surge protection and areas for recreation.

In the Pacific Islands, estuarine habitats, particularly mangrove areas, are important to recreational and semi-subsistence fisheries. Although native to American Samoa, CNMI and Guam, mangroves are actually an alien species in Hawaii. Historically, preferred areas for human settlement and ocean access were at river mouths and semi-enclosed water bodies such as Honolulu Harbor on Oahu; Agana Harbor and the villages along the southern coastline of Guam; and Pala Lagoon on Tutuila, American Samoa.

Status and Trends

Throughout California and the Pacific Islands, introduction of exotic species, discharge of industrial pollutants, oil spills, filling of wetlands, application of fertilizers and pesticides, military administration of remote islands, and major land use modification to promote agriculture and forestry practices and urban growth have altered estuaries and their associated habitats. Table 3 summarizes some of the major past, present and future threats to estuaries in the California and Pacific Islands region. This table is not meant to be comprehensive but simply provides some key examples of threats in this region.

TABLE 3. KEY THREATS TO HABITATS AND SPECIES OF CONCERN IN CALIFORNIA AND THE PACIFIC ISLANDS

Threat	Northern California	Southern California	Hawaii	U.S. Pacific Protectorates
Direct habitat alteration				
Coastal development	●	●	●	●
Dredging	●	●	●	●
Filling	●	●	●	●
Tidal restrictions	●	●	▲	▲
Dams	▲	▲	❍	❍
Mosquito ditching	❍	❍	❍	❍
Nonpoint source pollution				
Urban runoff	●	●	●	●
Agricultural runoff	●	●	●	●
Pathogens	▲	●	▲	●
Aquaculture	▲	▲	❍	❍
Sewage/septic	▲	▲	▲	●
Toxins	●	●	●	●
Resource harvesting and extraction				
Forestry	▲	▲	▲	▲
Mining	▲	▲	▲	▲
Fisheries	▲	▲	●	●
Nuisance, exotic and invasive species				
Pepper grass	●	▲	❍	❍
Pampas grass	●	▲	❍	❍
Cape ivy	●	▲	❍	❍
Smooth cordgrass	●	●	❍	❍
Non-native predators	●	●	●	●
Mangrove	❍	❍	●	❍
Pickleweed	❍	❍	●	●
Pluchea	❍	❍	●	●
Marine algae*	❍	❍	●	●
Tilapia	❍	❍	●	●
Natural disturbance				
Ice scour	▲	▲	❍	❍
Sea level rise	▲	▲	●	●
Predation and grazing	▲	▲	▲	▲
Storms	▲	▲	▲	●
Sea temperature rise off the Calif. coast	●	●	❍	❍

KEY: ● High concern ▲ Medium concern ❍ Low or no concern

**Note that not all species of marine algae are considered a nuisance. Nuisance species include* Caulerpa taxifolia, *a green alga found in coastal lagoons and in the Long Beach harbor in southern California. This alga is fast growing and toxic to invertebrates, fish and other native algae. It is likely it was introduced to southern California by the aquarium trade. Another nuisance alga is* Unidaria sp., *a brown alga, discovered in Monterey Bay in 2001. This alga contributes to loss of biodiversity by taking over habitat utilized by other native alga and the invertebrates that feed on them.*

Habitat loss in California and the Pacific Islands has been extensive and appears to be increasing because of an ever-increasing pressure of development and population growth. Although the population of the metropolitan Los Angeles area grew by only 45 percent between 1970 and 1990, the urbanized area grew by 200 percent, and land use consumption grew by 300 percent (Hartmann, 2001). In San Francisco Bay, there were roughly 190,000 acres of tidal marsh before the mid-1800s. Today, only about 40,000 acres remain (San Francisco Bay Joint Venture, 2001). In southern California, estuarine wetlands have been eliminated by 75 percent to 90 percent as a result of filling or dredging in the last century (Ferren et al., 1995).

In the Pacific Islands, loss of estuarine habitats also has been significant. The state of Hawaii includes 54.8 square miles of estuaries, 43 percent of which fully support their designated uses, 56 percent of which are impaired by some form of pollution or habitat degradation and one percent of which are threatened for one or more uses (CWAP, undated). Filling of wetlands for development has resulted in the loss of 64 percent of Saipan's wetlands and one-quarter of American Samoa's wetlands (NOAA, 1999; USFWS, 1996).

Introduction of alien species is another major concern in the Pacific Islands and is a dominant threat to the islands' endemic species. Hawaii alone has 280 threatened or endangered species, more than any other state in the United States (USFWS, 1996).

Regional Planning Efforts

Within California and the Pacific Islands, restoration plans are primarily being implemented at the state level or subregional level as discussed below. One example of a planning effort with a regional focus is the Essential Fish Habitat Amendments. A description of this planning effort is provided below. A full listing of plans for the California and Pacific Islands region and additional informa-

tion can be found in the National Strategy Restoration Plan Database (http://restoration.nos.noaa.gov).

Essential Fish Habitat Amendments to the Sustainable Fisheries Act

The Essential Fish Habitat (EFH) Amendments were prepared by the Pacific and West Pacific Fisheries Management Councils and identify and describe essential fish habitats for the coastal pelagic and pelagic fisheries of the Pacific and west Pacific. Also included in the amendments is identification of adverse impacts from both fishing and nonfishing activities, and actions required to conserve and enhance EFH.

California and the Pacific Islands Subregions

For this analysis, the region has been divided into four subregions: two in California (northern California and southern California) and two in the Pacific Islands (Hawaii and the U.S. Pacific Protectorates).

The California coast is characterized by extreme geologic uplifting. In the central and northern areas of the state, coastal mountain formations have restricted the area of low-lying coastal plains and rivers that flow toward the sea, resulting in narrow, deep and steep-sided estuaries. The exception to this is San Francisco Bay, which drains the rest of California. Lower-lying areas with more shallow estuaries characterize much of southern California. Southern California also has a distinct climate. This subregion is subject to a warm-water oceanic gyre and a related Mediterranean-like climate, whereas north of Point Conception, the coast is subject to the cooler Pacific current and a relatively cooler and damper climate (NOAA, 1990).

California is divided into two subregions to represent biogeographical distinctions as well as important regional planning efforts. Each subregion has a coastal zone management plan approved by the National Oceanic and Atmospheric Administration (NOAA). This indicates that the state and local land use plans are consistent with the mandates of the federal Coastal Zone Management Act.

The California Coastal Commission administers the state's coastal zone management under the authority granted by the 1976 Coastal Act. The Coastal Act sets state policy for the conservation and development of California's 1,100 miles of coastline, covering such matters as public access, coastal recreation, the marine environment, coastal land resources and coastal development. Under authority of the Act, each local government along the coast is to develop a local coastal program consistent with state policies. These programs consist of land use plans, zoning documents and other implementing actions. When a local coastal program has been approved by the Coastal Commission, regulatory authority reverts to the region; however, the Coastal Commission retains limited permitting authority, hears appeals and may issue orders for restoration of coastal resources and cease and desist orders for actions violating the Coastal Act. Although the overwhelming majority of the state is regulated under the Coastal Act, authority for coastal zone management in the San Francisco Bay area is delegated to the San Francisco Bay Conservation and Development Commission under the McAteer-Petris Act.

Major cities such as San Diego, Los Angeles and San Francisco are located near major estuaries and are either included in EPA's National Estuary Program (NEP) or designated as a National Estuarine Research Reserve (NERR). The Tijuana Estuary, in San Diego County, has been designated as a NERR. The Santa Monica Bay, in Los Angeles County, has been designated as a NEP. Morro Bay and the Elkhorn Slough in Monterey, both in the Northern California subregion, are designated as an NEP and NERR, respectively.

The Pacific islands include Hawaii, American Samoa, Guam and the Commonwealth of the Northern Mariana Islands (CNMI). Because the great distances between these areas are matched by differences in geology and biogeography, these island areas are divided into two subregions: Hawaii—which is ecologically distinct because of its isolated and borderline tropical location—and the remaining three entities. All these island areas feature steep relief both above and below water; there are no wide and shallow coastal shelves, and coastal plain is limited. Beyond fairly narrow fringing reefs, the reef face and basement rock drop off rapidly to considerable depths. As a result, the area suitable for estuarine habitats is very limited, with restricted occurrence at river mouths and along the shores of a few large embayments.

Northern California Subregion

Description

The Northern California subregion encompasses the coast from the Oregon border to Point Conception, Calif. This subregion covers more than 800 miles of coastline. Because the northern coast is exposed to the Pacific current and cooled from the northern reach, it experiences cooler climates with higher rainfall than the rest of the state.

This area has experienced significant geologic uplift and is typically characterized by dramatic topographical relief near the

ocean. This steep relief means that most of the coastal rivers have estuaries that are narrow and deep, with quite short reaches. However, the area also includes significant estuaries, such as San Francisco Bay, Humboldt Bay, Tomales Bay, Drakes Estero, Morro Bay, Eel River and Elkhorn Slough. These estuaries range in size from 452 square miles to one square mile of water surface area and total only 492 square miles (NOAA, 1990). For comparison, this total area is approximately 13 percent the size of the Chesapeake Bay. Nonetheless, these small areas provide critical habitat for numerous species listed as endangered or threatened and often draw large congregations of migratory birds.

Finally, the northern area does not have the overall population density that characterizes the southern area. Except for the San Francisco Bay urban areas, this subregion has relatively sparse populations, and land is typically used for forestry and agricultural purposes.

Among estuaries in this subregion, habitats include salt, brackish and freshwater marsh, mudflats, seasonal wetlands, eelgrass beds, diked baylands (including diked wetlands, agricultural wetlands, managed wetlands and salt ponds), beaches and dunes, open water lagoons, tidal channels, uplands and riparian areas.

Four major habitats make up California's coastal ocean ecosystem:

1. **Inland watershed zone:** Extends from the watersheds of the Sierra Nevada mountains to the California coastline. This zone includes 7,800 miles of rivers, creeks and drainages. Anadromous fish, coastal wetlands and nearshore waters are dependent on these waterways to provide freshwater flows.

2. **Enclosed waters zone:** Includes waters and habitats of bays, estuaries and subtidal areas. Freshwater originating from as far as the Sierra Nevada mountains mixes with saltwater from the Pacific Ocean. The bays and estuaries of northern California are dependent upon nutrient inputs from the inland watershed, nearshore ocean and offshore ocean zones for the maintenance of the organisms that reside, spawn or pass through these water bodies.

3. **Nearshore ocean zone:** Includes nearshore open coastal waters to a depth of 100 meters. This zone comprises over 1,100 miles of coastline, which extends from onshore areas such as sandy beaches, boulder fields and rocky outcroppings to an ocean floor depth of about 100 meters and the associated kelp bed and sandy and muddy bottoms. Waters of this zone are rich in nutrients from freshwater inflows and upwelling events. These waters maintain an abundance and diversity of organisms that support recreational and economic opportunities.

4. **Offshore ocean zone:** Extends from a depth of 100 meters to the edge of the Exclusive Economic Zone (200 miles offshore). Productive oceanographic factors, such as major ocean currents, stimulate biological productivity in both nearshore and offshore ocean waters. The California Current is a cold water current that originates north of California and moves southward along the coast, whereas the Davidson Current is a periodic, nearshore current that flows in a northerly direction, carrying warm waters from semi-tropical seas to southern California. Interactions between the flows of these currents create two distinct marine biological regions along the coast of California. The southern region, extending from the Mexican border to Point Conception near the City of Santa Barbara, is composed of warmer waters and primarily supports temperate- and warm-water fish and invertebrate species. The central and northern coastal region of California, extending from Point Conception to Oregon, contains colder waters and organisms adapted to such conditions. Another oceanographic factor influencing abundance and diversity of biological resources along California's coast is upwelling, the movement of deep ocean waters into shallower, nearshore areas. Upwelling provides essential nutrients needed to support vast populations of microscopic organisms collectively known as plankton. Plankton are a vital component of numerous food webs that support important fish, mammal and bird populations.

Kelp forests

Kelp forests connect the enclosed waters, nearshore, and offshore ocean zones described above. They are among the most productive and diverse ecosystems in the world, and they are a vital source of food for marine animals. Along the northern California coast the major kelp species are the giant kelp (Macrocystis pyrifera) and the bull kelp (Nereocystis luetkeana). Giant kelp forms dense beds in the Monterey Bay area from Cambria to Año Nuevo, except in the area between Monterey and Santa Cruz where the sandy substrate is unsuitable for kelp attachment. North of Santa Cruz, the bull kelp, which occurs from Point Conception northward (Abbott and Hollenberg, 1976; Miller and Estes, 1989), becomes the dominant canopy-forming kelp (Foster, 1982; Foster and Schiel, 1985).

Along the central California coast where the distributions of these two species overlap, giant kelp outcompetes bull kelp for

light. Giant kelp dominates areas of relatively low water motion and is dominant in years with relatively calm sea conditions. The shallow areas inshore of these kelp forests are often characterized by canopies of the feather boa kelp (Egregia menziesii), the intertidal giant kelp *(Macrocystis integrifolia)* and the Fucalean alga *(Cystoseira osmundacea)* (Foster and Schiel, 1985).

Various sea life such as turban snails, kelp crab and isopods, as well as herbivorous fish like the half-moon and the opal eye, graze on the plants directly. Other animals such as sea urchins, bat stars and abalone survive off residues of nutrient-rich drift kelp that sink to the ocean floor. Mature kelp beds contribute up to 30 percent to 40 percent of the net primary production. Filter feeding organisms living in or around the kelp bed derive much of their nourishment from the particulate and dissolved organic matter produced by kelps.

Some species of fish, such as the gopher and black-and-yellow rockfish, rely on the dense canopy for protection and sustenance during warm-water periods. Many juvenile fish (rockfish, senorita, kelp surfperch, blacksmith) spend the early parts of their lives in kelp forests, feeding on plankton concentrated there.

Harbor seals, California sea lions and the federally threatened southern sea otter feed on fish and invertebrates occupying the kelp forests. The sea otter also uses the kelp forest for refuge from predators and as a nursery area for raising pups.

Giant kelp is harvested commercially in both southern and central California, and in the mid-1980s, kelp harvesting supported an industry worth more than $40 million a year (Tarpley, 1992). Kelp was originally harvested as a source of potash for making gunpowder during World War I (Frey, 1971; Tarpley, 1992) but currently the emphasis is on the production of algin, which serves as an emulsifying and binding agent in food and pharmaceutical products (Frey, 1971) and food for use in abalone farms. Currently between 100,000 and 170,000 wet tons of kelp are harvested from California waters each year (Foster and Schiel, 1985; Tarpley, 1992).

In addition to harvesting, kelp forests provide an important source of recreational activities, which range from hook-and-line and spear fishing to sport diving and underwater photography. More is known about kelp forests in southern California and the Monterey Bay area than anywhere else in the world. However, knowledge is lacking on the kelp forests south of Carmel Bay and north of Santa Cruz, and many processes are still poorly understood (e.g., the effects of local fisheries on kelp forest fish populations).

Habitat Issues

Status and Trends

San Francisco Bay is the nation's first effort at what has since come to be known as "coastal zone management." This was spurred by dramatic losses from diking and filling and the recognition that development was slated for every available shallow water area, which would have left only deep-water shipping channels in the Bay.

Since 1850, more than half a million acres of wetlands in the San Francisco Estuary have been modified. In the delta, 97 percent of the original tidal wetlands have been converted to farmland or other uses. In the bay, 82 percent of the original tidal wetlands have been filled or converted to other wetland types (San Francisco Estuary Project, 1992). Approximately 95 percent of the San Francisco Bay's riparian habitat has been damaged or destroyed (San Francisco Bay Joint Venture, 2001).

Sonoma County has the least amount of protected open space: 25,500 hectares (63,013 acres) presently protected out of approximately 409,000 hectares (1,000,000 acres) of land (USFWS: Pacific Coast Joint Venture). In some areas of Morro Bay, 85 percent of the coastal dune scrub community has been converted to suburban or urban development (Morro Bay Estuary Program, 1999).

Threats

Many of the threats that gave rise to past concerns continue today. Among them are direct conversion and loss of habitat from draining, diking and filling. This includes, but is not limited to, conversion of land for agricultural use, urban development, salt ponds and flood control. Remaining areas face many threats, including:

- habitat fragmentation;
- severe sedimentation and erosion;
- point and nonpoint source pollution from adjacent land use (urban and agricultural runoff, storm drains, streams, boating activities);
- reduced tidal influence caused by accumulated sediments or construction of physical barriers;
- dredging and waterway modification;
- intense human activity;
- changes in the volume or timing of freshwater flows because of water storage, diversions and flood control, resulting in increased salinity, poor water circulation or habitat shifts in the estuary;
- invasion of non-native plant species such as pepper grass, pampas grass, cape ivy and smooth cordgrass, which have the potential to alter habitat structure and reduce popula-

tions of native plants and animals;

- invasion of non-native animal species such as the mitten crab, European green crab, New Zealand mud snail, New Zealand sea slug, American bullfrog, Asian clam and the common carp (for a complete list of troublesome species in the San Francisco Estuary, see www.clr.pdx.edn/nis/);
- introduction of non-native predators such as foxes, dogs and cats; and
- potential threats to kelp forests.

Due to its important habitat functions, kelp harvesting in large quantities may have local ecological effects by removing food, shelter, and important nutrients for large numbers of animals. The cutting and removal of kelp in large quantities can upset the balance of resident communities. Kelp also acts as a buffer, absorbing and dissipating wave energy, thus its removal can lead to increased erosion along the shore. Coastal development may cause an increase in the amount of runoff of fine silts and muds. This will increase the turbidity of the water, thereby affecting the amount of light entering the water and restricting the growth of kelp or having a direct smothering effect on the kelp. Dredging activities offshore may have the same effect.

Restoration Plans

Coastal Zone Management Planning

The San Francisco Bay Conservation and Development Commission (BCDC) and the Coastal Commission have responsibility for the comprehensive planning and management of California's land and water areas along the state's coastline. The BCDC developed the San Francisco Bay Plan and has been carrying out a coastal management program based on this plan.

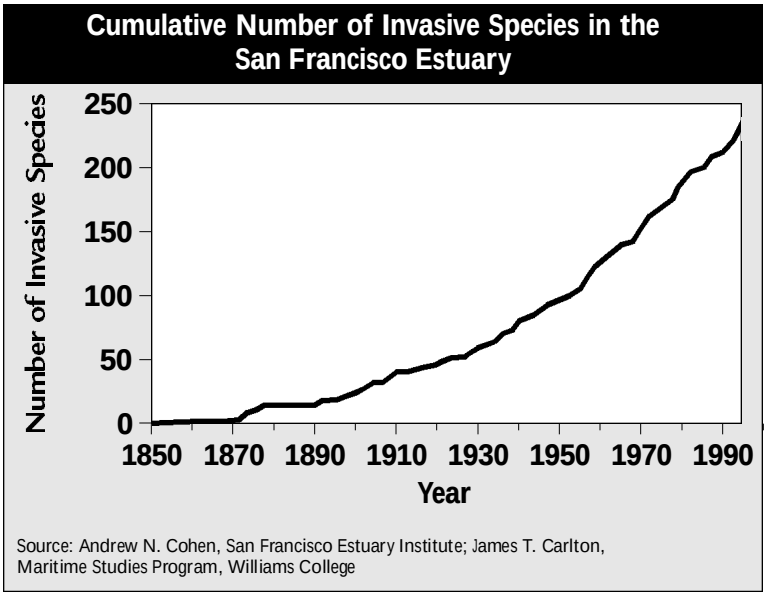


Figure 4. Cumulative Number of Invasive Species in the San Francisco Estuary

The plan was federally approved as a segment of the California coastal management program in 1977. San Francisco Bay and its shoreline continue to be managed under the plan as administered by the BCDC and other state agencies.

San Francisco Bay National Estuarine Research Reserve

The proposed San Francisco Bay National Estuarine Research Reserve encompasses 4,200 acres of California's protected estuarine lands and waters. The reserve management plan was prepared in 2001, and it is expected that the reserve will be designated in late 2001 or early 2002. Important habitats in the proposed reserve that may be useful for investigation and as reference sites include historic saline and brackish tidal marsh, live oak woodlands, coastal scrub and seasonal palustrine wetlands. Restoration priorities include exotic species control, hydrological restoration, prescribed burning and erosion control. Current restoration projects include native species reintroduction, erosion control and prescribed burning.

Morro Bay Comprehensive Conservation Management Plan

The watershed communities of Morro Bay, Los Osos, Baywood, Cuesta-by-the-Sea and Chorro Valley worked together to develop the Morro Bay Comprehensive Conservation Management Plan (CCMP), which is administered under the Morro Bay National Estuary Program. The CCMP addresses seven priority problems causing harmful impacts to the Morro Bay Estuary. Through the development of 61 action plans based on information from scientific studies, the CCMP aims to sustain existing wildlife resources and environmental quality.

Comprehensive Conservation Management Plan for the San Francisco Estuary

The San Francisco Estuary Project, jointly sponsored by the EPA and the state of California, is a public-private partnership that developed the Comprehensive Conservation Management Plan for the San Francisco Estuary. This plan presents a blueprint to restore and maintain the chemical, physical and biological integrity of the bay and delta.

Elkhorn Slough Watershed Conservation Plan

The Elkhorn Slough Watershed Conservation Plan is administered by the Elkhorn Slough Foundation and The Nature Conservancy and was developed to identify and address threats to Elkhorn Slough and to maintain its long-term viability as a significant coastal system. This plan recommends continuation of other federal programs, such as the Natural Resource Conservation Service's Elkhorn Slough Watershed Project.

Elkhorn Slough National Estuarine Research Reserve

The Elkhorn Slough National Estuarine Research Reserve was established in 1980 and currently encompasses 1,385 acres of California's protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1985 and is currently being revised. Important habitats that may be useful for investigation and as reference sites include coastal prairie, oak woodland, coastal scrub, freshwater wetlands and ponds, salt marshes and mud flats. Restoration priorities include monitoring for new invasive species, exotic weed control, aquatic habitat restoration, and replanting grasslands, oak understories and marsh-to-upland transition zones with native species. Current restoration projects include the development of a comprehensive vegetation restoration and management plan, coastal prairie and oak woodland restoration, invasion detection and exotic species control.

Baylands Ecosystem Habitat Goals

Baylands Ecosystem Habitat Goals was developed by a group of representatives from a number of federal and state agencies in support of the San Francisco CCMP. This report identifies types, amounts, and distribution of wetlands and related habitats needed to sustain diverse and healthy communities of fish and wildlife and provides a guide to the regional wetlands planning process.

Restoring the Estuary: Implementation Strategy of the San Francisco Bay Joint Venture

Restoring the Estuary: Implementation Strategy of the San Francisco Bay Joint Venture was developed and adopted to help the San Francisco Bay Joint Venture (SFBJV) partners reach their shared habitat objectives by working from what has already been accomplished and planning for the future. The SFBJV is based on both the San Francisco Bay CCMP and the Baylands Ecosystem Habitat Goals. The CCMP calls for the formation of a joint venture to increase the acreage of wetlands permanently protected in the estuary, and the goals outlined in the strategy are based on the findings and recommendations of the Baylands Ecosystem Habitat Goals.

Plan Elements

Goals

An overriding goal is to approach restoration on an ecosystem basis. Some of the specific goals outlined in restoration documents focus on increasing and preserving the quality and diversity of habitat and living resources within the estuaries; removing invasive non-native plant species, and protecting habitat from the invasion of non-native predators and other exotic species competing for the remaining habitat. Non-native plant removal and control is often followed by efforts to replant areas with native species such as pickleweed, eelgrass, arrowgrass and native cordgrass. Enhancement of water quality involves reducing point and nonpoint source pollution and debris, restoring tidal influence and limiting the discharge of harmful sedimentation.

An example of a crosscutting issue in the San Francisco and Humboldt Bays is the removal of invasive eastern cordgrass, which pushes out native cordgrass and, over time, fills deep-water channels with sediment. Eastern cordgrass has the potential to spread coast-wide, and its eradication is taking on regional and local implications. Finally, plans speak to the need for regional planning and ongoing monitoring and maintenance. Critical to monitoring, maintenance and future restoration planning is the need for developing a widely accepted, standard method for measuring the success of restoration projects.

Methods

The Northern California subregion's plans most commonly recommend implementing best management practices to reduce pollution, erosion and sedimentation from adjacent land use, and offering incentives and assistance to private landowners to do the same. Maintenance of water quality and habitat also is specifically addressed by repairing gullies to reduce erosion in adjacent areas (techniques include constructing checkdams and installing headcut and nickpoint protection), as well as seeding and planting annual and perennial grasses and riparian vegetation to help stabilize soil and prevent erosion. Also, removing debris and eradicating invasive plants that contribute to harmful sedimentation are methods for unblocking channels and streams. In agricultural areas, plans call for preventing livestock grazing by installing fencing in sensitive erosion sites. Where appropriate, plans specify eradicating invasive exotic plants and replanting native wetland vegetation. Public involvement is recommended through public outreach and education activities (e.g., workshops, meetings, reports, brochures and interpretive signs), as well as efforts to design public access that is compatible with and sensitive to environmental needs.

Elements of Success

Many of the plans address the need for good coordination and cooperation between agencies and private landowners. The Baylands Ecosystem Habitat Goals highlight the importance of complete site information and rigorous evaluation of each site's suitability for its proposed project. Careful consideration of such factors as the site's water and sediment supplies, historical drainage patterns and current and future uses of adjacent lands is an important element of regional and site-specific success.

Site plans also emphasized the need for adequate funding to complete projects and provide for long-term monitoring and maintenance.

Information Needs

Information needs cited in several plans highlight the importance of a comprehensive, watershed-wide, ecosystem approach to restoration and future maintenance. Information needed on a global scale is further research on the potential effects of sea level rise. On a regional scale, examples include a better understanding of the estuarine habitat needs of anadromous fish, the migration patterns of waterfowl and shore birds, the interaction between agricultural and forestry practices and waterfowl use in coastal lowland pastures, and listing the species of fish and wildlife most affected by ecosystem fragmentation. Regional planning also would benefit from a better understanding of water quality issues that would come from studying circulation and dispersion of pollutants in bay ecosystems.

An example of a habitat-specific need is to gain better understanding of tidal marshes. For instance:

- What are the effects of tidal marsh on the sediment budget and tidal prism?
- How does the form of tidal marsh channels vary with salinity?
- What factors affect the evolution of mudflats and tidal marsh features?
- What is the effect of tidal marsh on nutrient supplies to the bay?
- What species comprise the tidal marsh fish community?

Effective planning also requires a better understanding of several controversial topics, including potential uses and availability of dredge material for wetlands restoration, potential reuse of wastewater in creating or improving habitats, disposal of concentrated waste products from salt ponds, and the potential use of created wetlands to treat stormwater runoff. Plans also discuss the pros and cons of public access and balancing public access with natural resource protection.

Finally, more work is needed to develop a widely accepted standard method for measuring the success of restoration projects. An example would be determining the appropriate scale to measure shoreline loss or gain.

Southern California Subregion

Description

The physical features, climate and hydrology of coastal southern California have produced a diversity of plants and animals and a set of unusual conditions that sharply distinguish the region from any other in North America. Unlike the broad, gradually sloping coastal plains of the Atlantic and Gulf coasts, southern California has steep, rugged coastal mountains that descend sharply to the ocean where the underwater topography mirrors that of the craggy, exposed land. Warmer waters from the south meet chillier waters from the north. Summers are hot and dry in this semi-arid, Mediterranean-like climate, while the winters are cool with torrential downpours. The San Gabriel and San Bernardino Mountains can experience more rain in a twelve-hour period than anywhere else in the continental United States. The rains cut numerous short, steep river channels, which, especially in years of fire, can carry large sediment loads to the region's lagoons and estuaries (Potter, personal communication).

A more arid climate and less elevated topography in direct proximity to the shore also create conditions for estuaries that differ significantly from other subregions. Most estuarine areas here are more heavily influenced by marine water than larger estuaries such as the San Francisco Bay. However, irregular, heavy rains can inundate coastal wetlands, and the species associated with these areas are uniquely adapted to rare but heavy freshwater flows (Fancher, personal communication).

Habitats in the Southern California subregion include salt marsh, open water lagoon and tidal channel, seasonal wetland, tidal mudflat, brackish and freshwater marsh, upland and riparian, beach and dune. Estuarine-dependent species in this region are too numerous to list here. However, there are more species listed as threatened or endangered in southern California than in any other region of the state. Listed species include fish (e.g., steelhead trout, tidewater goby, California halibut), birds (e.g., Belding Savannah sparrow, California least tern, clapper rail, snowy plover), plants (salt marsh bird's beak, southern tarplant), insects (salt marsh wandering skipper, Dorothy's El Segundo sand dune weevil), mammals (Pacific little pocket mouse and salt marsh shrew), reptiles (southwestern pond turtle) and amphibians (silvery legless lizard).

In short, the dramatic historical loss of healthy habitat and the associated loss of species make restoration efforts vitally important. However, given the projected rate of coastal population growth, restoration may prove more challenging in the future.

Habitat Issues

Status and Trends

Estuaries in coastal southern California are comparatively small and precious, given the region's narrow coastal shelf and semi-arid climate. But with 8.7 percent of the state's landmass and almost 50 percent of the state's population, coastal southern California has experienced an even greater loss of wetlands than the entire state, which has lost a greater percentage of its wetlands than any other state (National Research Council, 1992). The five counties of coastal Southern California are home to 16 million people; more people than all but two states (New York and Texas) and more people than the 15 least populous states combined. A full 25 percent of the nation's coastal population (those within 50 miles of the coast) lives in southern California (NOAA, 1990).

This ever-increasing population requires housing, flood control, transportation infrastructure, and economic development, all of which have encroached upon and degraded wetlands and streams. The region has a radically altered hydrology, with more flood control dams (227), more debris basins (193), and more concrete channels than any other region in the country. It is the only major region where storm drains carry runoff directly to the ocean rather than through sewage treatment plants, which accounts in large part for the 150 beach closures that occurred in southern California during the summer of 2000, undermining a tourism and recreation industry worth over $7 billion annually to the region. Its network of highways and freeways is unparalleled and the Los Angeles/Long Beach port complex is three times larger than the next largest in the country and the third largest port facility in the world. With a gross regional product of $500 billion, the region has the 12th largest economy in the world. All of these factors have led to the loss and degradation of the region's coastal wetlands (Potter, personal communication).

To quantify the loss of wetlands in the subregion, researchers have compared historical geological surveys to present-day surveys. However, because the historical surveys did not differentiate by specific subhabitat types (e.g., mudflats, salt pannes, low salt marsh), the loss of habitats of concern is not reliably quantifiable. Moreover, radically changed conditions sometimes make restoration of historical habitat types impossible. In this sense, the dramatic decline of every habitat complicates regional priority setting. Restoration efforts are further complicated by the broad array of endangered and threatened species. For instance, restoration of habitat for threatened shore birds may inadvertently attract threatened falcons, which feed on shore birds (Fancher, personal communication).

The following statistics provide some indication of the extent of lost habitat in the southern California subregion.

- Southern California's coastal wetlands have declined from approximately 53,000 acres to 13,000 acres (Hartmann, 2001).
- Southern California's estuarine wetlands have been eliminated by 75 percent to 90 percent as a result of filling or dredging in the last century (Ferren et al., 1995).
- An estimated 95 percent of the historical wetlands acreage of the Santa Monica Bay watershed has been destroyed (Santa Monica Bay Restoration Project, 1994).
- An estimated 55 percent of the animals and 25 percent of the plants designated as threatened or endangered depend on wetland habitats for survival (Hartmann, 2001).

Threats

In addition to the dramatic losses listed above, there is the threat of additional habitat loss associated with urban expansion and direct conversion (e.g., dredging and filling, constructing dikes). Reduced tidal influence, changes in the volume and timing of freshwater flows, habitat fragmentation, invasion by non-native vegetation and predator animals (e.g., domestic dogs and cats), disturbed patterns of erosion and sedimentation, subsidence from oil extraction, and disturbances from human traffic are all significant threats. Remaining estuarine systems and the associated habitat also are degraded due to point and nonpoint source pollution from adjacent land use. Pollutants include, but are not limited to, pesticides and other toxins, bacteria, heavy metals, excess sediments and nutrients, and pathogens.

Restoration Plans

California Coastal Management Program

The California Coastal Management Program was developed to provide effective resource management by protecting, maintaining, restoring and enhancing the resources of the coastal zone. California coastal zone management (excluding the San Francisco Bay area) is administered by the California Coastal Commission under the authority granted by the 1976 Coastal Act. The California Coastal Management Program is a combination of federal, state and local planning and regulatory authorities for controlling the uses of land, air and water resources along the coast.

Southern California Wetlands Recovery Project

The Southern California Wetlands Recovery Project (SCWRP) is a partnership among 17 federal and state agencies working in concert with a public advisory committee, a science panel and task forces in five coastal counties. Southern California has a

draft regional restoration strategy that has been evolving over the past four years and will be formally adopted by the governing board of the SCWRP on November of 2001. The regional restoration strategy establishes a framework for preserving and restoring coastal wetlands; preserving and restoring stream corridors and wetlands in coastal watersheds; recovering habitat and species diversity; advancing the science of wetland restoration in southern California; promoting education and compatible access related to coastal wetlands and watersheds; and integrating wetland recovery with other public objectives.

Santa Monica Bay Restoration Plan

The Santa Monica Bay Restoration Plan was produced by the Santa Monica Bay Restoration Project as a result of being nominated and accepted as a National Estuary Program. The plan serves as a comprehensive blueprint for the bay's recovery and as a guide to dealing with management issues such as interagency coordination, resolution of conflicting or redundant resource management approaches and resolution of conflicting policies among jurisdictions. This plan is composed of six sections that deal with major issues affecting the bay, including restoring, protecting and managing habitats and resources.

Tijuana River National Estuarine Research Reserve

The Tijuana River National Estuarine Research Reserve was established in California in 1982 and currently encompasses 2,513 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1999. Important habitats that may be useful for investigation and as reference sites include uplands, coastal sage, saltwater marsh, mud flats, dunes and beaches. Restoration priorities include sediment and flood control of upstream areas and salt marsh restoration designed to increase endangered species habitat. Current restoration projects include completed and planned large-scale salt marsh restoration as well as upland, dune and riparian restoration projects.

Plan Elements

Goals

Site restoration plans in the Southern California subregion uniformly focus on increasing habitat values for fish and wildlife and restoring or enhancing native vegetation such as pickleweed and native cordgrass. Under these general principles, specific goals include maintaining water quality through better pollution control, improving the volume and timing of freshwater flows, and restoring tidal influence. Plans also call for long-term maintenance and monitoring of sites to help assess and ensure effectiveness, as well as adaptive management to account for changes in natural dynamics and scientific knowledge. Several plans also mention restricting human intrusion and providing buffer zones to limit human disturbances.

Methods

To meet the restoration goals of site plans, planning documents specify restoration methods. For instance, mechanical breaching or dredging is planned to improve or create tidal influence; grading or filling is recommended to recontour the area for improved water circulation and created habitat. Occasionally, improved water circulation and tidal influence demands rerouting existing infrastructure, such as roads and bridges. Also, ensuring stable bottom contours and shore areas requires control of sediments; for example, constructing sediment basins and stabilizing upstream banks through planting or embankment structures.

Often plans identify the need for removal of invasive plant species followed by replanting with native species. Water quality also is addressed to reroute or treat stormwater drainage and runoff. Some plans call for enhancement or creation of specific habitat for threatened or endangered species.

Elements of Success

Site plans rarely discuss elements of success. The Science Panel of the Southern California Wetlands Recovery Program, however, is developing monitoring protocols to better assess the success of individual projects and of the wetland recovery program region-wide. Public involvement through education and cooperative planning also is emphasized. Ultimately, success is dependent on ongoing regional planning, which is emphasized by the collaborative efforts of the Southern California Wetlands Recovery Project. The plans also focus on a watershed-wide approach to restoration and ecosystem management. Finally, managers often point to the need for a long-term monitoring strategy to ensure implementation and effectiveness, as well as a maintenance strategy that involves adaptive management.

Information Needs

Information needed might be characterized as global, regional or local. For instance, on a global scale, more information is needed regarding impacts associated with global warming and sea level rise. On a regional scale, further research is needed on the chemical and biological processes that control the transfer, fate and toxicity of toxic chemicals; effective means to identify the sources of chemical and bacteriological pollution; and beneficial uses for flood control and dredge spoil sediments. Regional policy needs to address the underlying causes of urban sprawl, standardized methods for measuring the success of restoration projects, and the role of mitigation banks in

helping to accomplish restoration goals. Finally, local research needs to be done on the role tidal creek networks play in the development of wetland habitats in the Tijuana estuary. Considering the overwhelming and urgent need to preserve and restore the limited resources of the Southern California subregion, an overriding question is whether to focus on "quality or quantity." Large sites may offer the best opportunity for overall biodiversity, but small sites may serve the critical function of "stepping stones" for migratory birds or may be unique and critical to the survival of certain species.

Hawaii Subregion

Description

The island chain of Hawaii was formed as the Pacific tectonic plate moved northwest over a "hot spot" where, during many millennia, volcanic activity produced a series of high islands. The eight principal islands of the Hawaiian Archipelago are progressive in age, with active volcanoes at the southeastern end on the Big Island and older, inactive and highly eroded volcanoes on Kauai Island to the northwest. The island chain continues with a series of pinnacles, atolls, banks and seamounts representing progressively older and more weathered products of the hot spot. Rugged topography and an impressive range in elevation (from sea level to 4,180 meters [13,794 feet]) interact with a climate regime, resulting in significant spatial variation in rainfall. This produces diverse terrestrial environments (Scott, 1993; Maragos, 1998).

Hawaii's topography results in relatively limited, although biologically important, estuarine habitat. Coastal wetlands of Hawaii provide important wintering habitat for migratory waterfowl and shorebirds. Since the Hawaiian Islands are so isolated, another important characteristic is the high level of endemism. About 10,000 Hawaiian species have been identified as endemics, including 85 percent of birds, 89 percent of flowering plants and 99 percent of snail and insects (USFWS, 1996).

The Hawaiian Islands generally exhibit extremely steep relief and narrow coastal plains. Steep relief continues underwater so that shallow coastal areas are limited; depths can reach more than one thousand feet just a few hundred yards offshore. Rainfall, and consequently stream flow, is low and often intermittent on leeward sides of the islands. As a result, these islands do not have developed river deltas, sheltered embayments are few and shallow coastal habitat is limited.

Limited estuarine habitats are found along the shore of large embayments such as Pearl Harbor and Kaneohe Bay on Oahu, and Hilo Bay on the east coast of the island of Hawaii. Small estuaries also occur at river mouths on all islands and areas of offshore groundwater discharge, primarily on the island of Hawaii, where porous lava rock limits surface flow. Fishponds built by native Hawaiians in the pre-contact period (most common along the south coast of Molokai) are largely abandoned today and may also be considered estuarine (Kirch, 1998).

Anchialine pools, which occur mostly on the south coast of Maui and the west coast of Hawaii, are unique habitats where porous rock allows a subsurface connection to the sea. Salinity is generally marine except for a brackish surface layer. Coastal ponds may be brackish and are important waterfowl habitat. Although considered estuarine in other regions, seagrass beds are largely marine and found on inner reef flats. Mangroves (*Rhizophera mangle* and *Bruguiera gymnorhiza*) were intentionally introduced on Oahu and Molokai in the early 1900s and subsequently spread into estuarine areas. They have colonized estuarine habitats where introduced, taking over brackish mudflats and coastlines in Hawaii and displacing native plants, shore birds and wading birds that would otherwise occupy these areas (Scott, 1993; Maragos, 1998).

Habitat Issues

Status and Trends

Historic losses of native habitats are associated with mining of guano, introduction of alien species, military administration of remote islands, and major land use modifications to promote agriculture, forestry practices and urban growth. The U.S. Fish and Wildlife Service estimate of coastal plain wetlands around 1980 in this subregion is 15,474 acres—a decrease of 31 percent over a 200-year period (USFWS, 1996). Relatively large estuarine areas have been lost to development. The tourist center of Waikiki, for example, was developed by draining and filling coastal wetlands and estuaries. Oahu, which supports approximately 80 percent of the state's population, has more significant wetland loss than the other islands; however, rapid growth and expansion of the tourist industry are a constant threat to the coastal resources of all the main islands (USFWS, 1996). Harbor development, for both military and civil uses, has destroyed or degraded estuarine areas, as exemplified by coastal development in Pearl Harbor. Channel dredging also has eliminated estuarine habitats in some areas. Diversion of stream water for agriculture historically changed coastal salinity regimes in some areas, notably Kaneohe Bay on Oahu, reducing estuarine habitats.

Threats

Introduction of alien species has especially severe impact on Hawaiian ecosystems because of the islands' unique, largely endemic biota. Alien plants—notably mangrove and pickleweed—and alien fish (e.g., mosquito fish) have displaced native species. Introduced mongoose, rats, pigs, dogs and feral cats prey on waterbird eggs. Water quality at the watershed level is a second major concern. For example, Manoa Stream, which flows into the now severely degraded Ala Wai Canal estuary bordering Waikiki, is heavily contaminated by lead and certain organic chemicals. More generally, sedimentation and nutrient loading caused by some land uses can harm coastal ecosystems, including estuaries. The cessation of sugar cane production in central Oahu led to calls (and eventually litigation) by environmentalists to return diverted water to streams on the windward (northeast) side of the island, many of which flow into Kaneohe Bay. These efforts were partly successful, with a return of some of the diverted water to windward streams.

Restoration Plans

Hawaii Coastal Management Program

The Hawaii Coastal Management Program guides government activities related to the protection, preservation and development of Hawaii's natural, cultural and economic coastal resources. A network of seven agencies implements the program, led by the Hawaii Department of Planning and Economic Development. The Hawaii State Plan coordinates the state's planning process through functional plans, agencies and departments, boards, commissions, and county general and development plans. A number of government agencies implement the state and functional plans.

Environmental and Enhancement Plan for Pouhala Marsh, Oahu, Hawaii

The Environmental and Enhancement Plan for Pouhala Marsh, Oahu, Hawaii was a cooperative effort of the Hawaii Division of Forestry and Wildlife, the USFWS, the City and County of Honolulu and Ducks Unlimited. This plan addresses the need to secure and restore nearly 70 acres of wetlands in Pearl Harbor's West Loch.

Aside from the Hawaii Coastal Management Program, there has not been a concerted effort to coordinate with federal activities in restoration planning on a state-wide level. In fact, there has been limited state wetland management, planning and coordination, as well as a lack of state-wide wetlands policies to guide restoration efforts.

The state of Hawaii has very little comprehensive conservation and management planning for estuarine habitats. Very few plans have been developed for restoration of estuarine habitats at a regional or watershed level; those that have been developed usually respond to a specific request or problem. Many relate to mitigation projects, such as the Final Restoration Plan and Environmental Assessment for the May 14, 1996 Chevron Pipeline Oil Spill into Waiau Stream and Pearl Harbor, Oahu, Hawaii.

Plan Elements

Goals

Restoration goals outlined in the few documents available focus on protecting and enhancing the limited estuarine habitat that exists in this region. In particular, restoration activities are pursued to restore essential habitat for a number of endangered or threatened species. Restoration goals also focus on the use of the natural, cultural and economic resources that estuarine habitats provide.

Methods

In the few plans reviewed, several methods have been outlined for reaching the state's restoration goals. These methods consist of three components: economic, cultural and ecological. The methods include designation of habitat as sanctuaries and refuges and intensification of management and development of those areas; acquisition of habitat by fee or long-term lease to prevent alteration or conversion to other uses; removal of excess vegetation and landfill; and discontinuation of sewage discharge.

Elements of Success

The plans that have been developed rarely discuss elements of success but do acknowledge a need for coordination and cooperation among public and private organizations and agencies. Most plans also mention the need for monitoring and assessment of baseline conditions.

Information Needs

Data and information on the status of wetlands and estuarine habitats in Hawaii are needed. There is a significant shortage of baseline data, sustainable capacity data and resource value data for many resources and geographic areas of the state. Basic data on the location and various functions of wetlands are lacking, as are maps showing all regulated wetlands in Hawaii. However, the U.S. Fish and Wildlife Service's National Wetland Inventory group is planning to update the wetland maps for Hawaii.

Pacific Protectorate Subregion

Description

Guam and the Commonwealth of the Northern Marianas (CNMI) are part of the same island arc, which was formed by volcanism and uplifting along the converging edges of the Pacific and Philippine tectonic plates. For this reason, although they are politically distinct, they are treated together in this discussion. Population is concentrated on the southern islands of Guam, Rota, Tinian and Saipan. The islands north of Saipan are isolated, small and essentially uninhabited. Several are volcanically active. Their geology is a mix of upraised limestone features and material derived from volcanism. Raised limestone is highly porous. Streams in these areas are either nonexistent or ephemeral. As a result, most estuarine habitats occur on the southern part of Guam, which is mountainous and volcanically derived. The main habitats are mangroves and lower river channels. The largest mangrove stand in the Mariana Islands (approximately 85 acres) occurs at Sasa Bay in inner Apra Harbor. Smaller stands occur elsewhere in Apra Harbor, along the southern coast of Guam, and the west coast of Saipan. Mudflat or reef flat on the seaward mangrove margin may be included as estuarine habitat. Aside from mangrove areas in Apra Harbor, additional estuarine habitat can be found in the island's largest watershed in lower Talafofo River valley on Guam's southeast coast. Brackish water extends about one mile upstream from the river mouth. Other estuarine habitats include limited marshland located on the interior to mangroves and river mouths. Saipan has an extensive lagoon, which is influenced by the freshwater drainage along the western side of the island. It contains the largest area of seagrass habitat in the CNMI and probably in all of the Marinas (Scott, 1993; Maragos, 1998).

American Samoa consists of five high islands, the largest of which is Tutuila, where most of the population is concentrated. Aunu'u is less than a mile from Tutuila. The Manu'a group, consisting of Ofu, Olosenga, and Ta'u, lies 60 miles to the east. These islands are volcanic in origin and generally very rugged. Rose Atoll, a national wildlife refuge, and privately owned Swains Island (a raised atoll) are smaller and relatively isolated, lying to the southeast and north respectively. There are extremely limited estuarine habitats in American Samoa, and these are primarily located on Tutuila, with mangrove forest being the predominant habitat type. (The enclosed lagoon at Swains Island contains some brackish water marsh.) Mangroves reach their eastern limit in Samoa, and no mangroves occur in the Manu'a group. Streams are relatively abundant on Tutuila but tend to be small and short (generally less than two miles). There are sheltered bays on Tutuila but, as with Pago Pago Harbor, they may be quite deep, limiting estuarine habitats. The most significant river-associated estuarine habitats occur at Leone Bay, where two streams discharge into a sheltered embayment. In addition to mangroves, estuarine habitats in this bay include tidal mudflat and salt marsh. The other major estuarine area in American Samoa is Pala Lagoon, located on the southwest coast of Tutuila on the margin of a relatively large coastal plain. Estuarine habitats in the bay include mangroves and shallow muddy or sandy bay floor (Scott, 1993; Maragos, 1998).

Habitat Issues

Status and Trends

Large expanses of estuarine habitats have been lost as a result of filling in all island areas. Guam has experienced a large historic loss because of military construction in Apra Harbor in the years immediately after World War II. More recently, an oil spill killed mangrove trees in Sasa Bay. Because it is difficult to estimate the size, location and type of wetlands that existed before European contact, estimates of loss are usually calculated from more recent years as wetlands have begun to be mapped and measured. It is estimated that filling has resulted in the loss of 64 percent of Saipan's wetlands (USFWS, 1996). In American Samoa, it is estimated that wetland loss has averaged 4.5 acres per year with accelerated decline over the past 10 years. To date, it is likely that American Samoa has lost approximately 60 percent to 70 percent of its original wetlands (American Samoa EPA, 2000). Pala Lagoon, for example, has been partially filled and its entrance narrowed to build an airport runway.

Threats

Threats to the wetlands of the U.S. Pacific Protectorates can be split into two separate categories: agriculture before World War II and urbanization and infrastructure development after World War II. A major concern of the U.S. Pacific Protectorates is the clearing and filling of wetlands for development. In addition, oil spills, effluent from sugar cane mills, heavy metals and other contaminated runoff from military bases are all concerns that threaten estuarine health (USFWS, 1996). The CNMI is currently concerned with the impacts of nonpoint source pollution, especially in the Saipan Lagoon. Although nonpoint source pollution results from a number of sources, infrastructure shortfalls are probably the largest contributor and are starting to be addressed by a number of local and federal government agencies.

Restoration Plans

Very few plans exist with comprehensive restoration planning for estuarine habitats in the Pacific Protectorate subregion. Although the amount of estuarine habitat is small, this absence of planning is alarming because the populations of these islands are increasing at an extremely high rate and the majority of the populations inhabit the coastal areas. Several government agencies are gathering baseline data that would allow such a plan to be created. The Division of Environmental Quality is looking at restoring or creating estuarine habitat to reduce the effects of nonpoint source pollution.

CNMI Coastal Resources Management Program

The CNMI Coastal Resources Management Program guides governmental activities related to the protection, preservation and development of the coastal resources of the CNMI. This program was developed by the Commonwealth's Planning and Budget Affairs Office. With the installation of a new constitutional government in 1978, it was recognized that there was a need to establish a policy base sensitive to the needs of both economic development and resource protection and the authorities and government organization required to implement the policies.

American Samoa Coastal Management Program

The American Samoa Coastal Management Program was developed to provide effective resource management by protecting, maintaining, restoring and enhancing the resources of the coastal zone. Responsibility for development of the program was given to the Development Planning Office (which has subsequently become the Department of Commerce). This program is designed to accommodate and complement other planning efforts (e.g., Economic Development Plan and Quality of Life Plan) that will guide the socioeconomic development of American Samoa.

Guam Coastal Management Program

The Guam Coastal Management Program guides the use, protection and development of land and ocean resources within Guam's coastal zone. The program was developed by the Guam Coastal Management Bureau of Planning, and its policies can be divided into three categories: resource protection, coastal development and simplification of government process.

Wetlands Conservation Plan

Guam's Wetlands Conservation Plan was developed by the U.S. EPA and a steering committee of representatives from a number of federal and state agencies. This plan was prepared to review existing Guam and federal regulations and to determine how to update, simplify and improve their application in Guam. It was prepared as a guide to assist the government of Guam with future wetland resource conservation and management.

A Comprehensive Wetlands Management Plan for the Islands of Tutuila and Aunu'u, American Samoa

This plan is administered by the Department of Commerce as a means for the American Samoan government to anticipate, rather than merely react to, wetland problems and conflicts. The plan provides a policy framework to manage the wetland resources of American Samoa.

The above-mentioned plans were developed with the coordination of local and federal government agencies. However, it has been noted that there is a significant lack of coordination among agencies, particularly in CNMI, which affects the adherence to and enforcement of regulations and agreements.

Plan Elements

Goals

Goals identified in the plans reviewed for the U.S. Pacific Protectorates focus on restoration and protection of wetland resources to ensure “no net loss” of those resources. Developing policy guidance for wetlands management may help local governments mitigate potential conflicts in this subregion.

Methods

For many of these plans, the first step toward restoration is compiling information on the wetland resources in the area. The extent of wetland areas in many of the islands has not been documented. Public participation in and coordination of restoration efforts also are acknowledged as crucial components in the restoration process. Specific restoration activities include excavating formerly filled wetlands and revegetating the sites.

Elements of Success

The plans that have been developed rarely discuss elements of success but do acknowledge the need for coordination amount federal and state agencies. Monitoring and public involvement are also acknowledged as important components of successful restoration.

Information Needs

Basic information on the extent and condition of wetland and estuarine habitats in the islands is needed. Up-to-date and precise wetland maps are needed for this subregion. In American Samoa, more hydrological assessments of wetlands are needed, as well as a technical mapping system to assist with a more

accurate delineation and survey process. The U.S. Fish and Wildlife Service is trying to gather support for obtaining aerial photos and mapping of American Samoa's wetlands for the first time. A need to address the management of cumulative and secondary impacts to wetlands in CNMI also has been identified.

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Regional Analyses of Restoration Planning

PART 3 – GULF OF MEXICO

ESTUARIES OF THE GULF OF MEXICO

The Gulf of Mexico region is defined here as the Gulf coasts of Texas, Louisiana, Mississippi, Alabama and Florida, excluding the Everglades, the Florida Keys, and Florida Bay, which are included in the Southeast Atlantic Regional Summary.

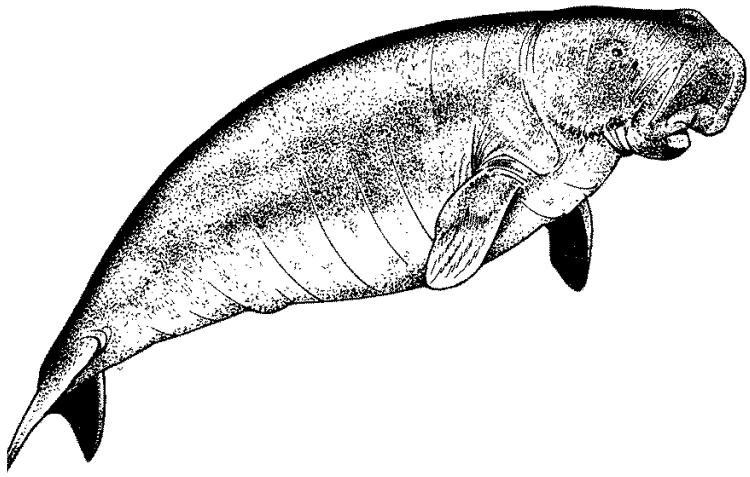
This region:

- Contains the greatest amount of coastal wetlands of any region (NOAA, 1990).
- Drains an area approximately 1.6 million square miles wide, which is equivalent to about 60 percent of the land area of the continental U.S. (Beck et al., 2000).
- Accounts for more than 96,000 square miles of estuarine drainage along the Gulf Coast (NOAA 1990).

These estuaries support more than half the nation's wetlands, as well as communities such as Corpus Christi, Houston, New Orleans, Mobile and Tampa (NOAA, 1990).

SUMMARY

In terms of population, the Gulf Coast is one of the fastest growing regions in the country. This region also supports one of the most productive fisheries in the world. Several excellent programs and plans have been developed for restoration of the Gulf Coast. The Gulf of Mexico Program provides an example of the effective use of partnerships in restoration efforts. This program is the result of a partnership of 18 federal agencies, state agencies from the five Gulf states, and diverse public and private organizations. The Coast 2050 plan is a strategic plan for the survival of Louisiana's coast and coastal communities and promotes restoration and protection on a coast-wide basis. The plan involves federal, state and local entities as well as landowners, environmentalists and scientists. This plan builds on previous restoration planning efforts including the Louisiana Coastal Wetlands Restoration Plan and the Coastal Wetlands Conservation and Restoration Plan. Information needs for the Gulf pertain to gaining a more complete understanding of habitat functions and links between habitats. Nonstructural or "soft" shoreline stabilization is being successfully used in restoration projects throughout the Gulf Coast to battle subsidence and erosion. These methods include coastal dune revegetation or beach nourishment, brush fences and breakwaters, rebuilding of coastal ridges, marsh terracing, dredged material use, and large scale freshwater and sediment diversion.



Introduction to the Gulf of Mexico

Description

For this discussion, the Gulf of Mexico region is defined as the Gulf coasts of Texas, Louisiana, Mississippi, Alabama and Florida, excluding the Everglades, the Florida Keys and Florida Bay.

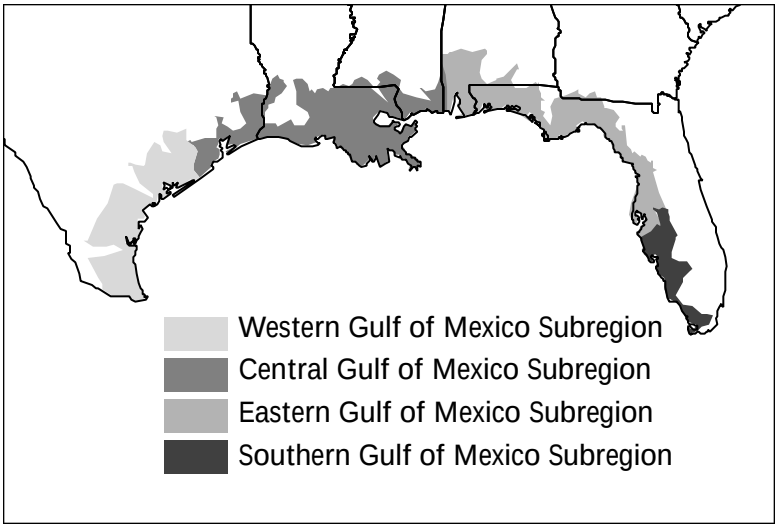


Figure 1: Gulf of Mexico Region and Subregions

The 31 estuarine systems within the Gulf of Mexico region cover approximately 12,000 square miles—accounting for more water surface area than any other region of the United States (NOAA, 1990). The drainage basin for the Gulf of Mexico, which includes the area drained by the Mississippi River, is approximately 1.6 million square miles or 60 percent of the land area of the continental United States (Beck et al., 2000).

Key Habitats and Species

The physical and hydrological conditions within Gulf estuaries are ideal for the formation and growth of wetlands. In fact, the Gulf region contains approximately five million acres of emergent salt marsh and mangrove vegetation, accounting for more than half of the nationwide total (USEPA, 1999). Gulf Coast estuaries also support oyster reefs, submerged aquatic vegetation, tidal flats, open water habitat, barrier islands, swamps, bogs, prairies and forests.

All estuarine habitats within the Gulf of Mexico are designated as essential fish habitat for species managed by the Gulf of Mexico Fishery Management Council, including shrimp, red drum, reef fish, mackerel, stone crab, spiny lobster and coral. The Council defines estuarine habitat as all waters and substrates within estuarine boundaries, including subtidal vegetation. Estuarine boundaries are set landward at the limit of permanent freshwater bottom, and seaward at the coastal barrier islands or other lines of demarcation (NOAA, 1998).

Estuaries and their associated habitats are highly productive and contribute significantly to the ecology of the Gulf of Mexico region. Marshes, mangroves, and seagrass beds provide food and shelter to resident and transient species and function as vital nursery habitats. Gulf Coastal wetlands and barrier islands provide habitat for waterfowl, neotropical migrant birds, shore birds, wading birds, and raptors, as well as a variety of reptiles and mammals. The estuaries of the Gulf Coast also are home to a diversity of protected species, including Kemp's ridley sea turtles, piping plover, brown pelican, West Indian manatee, diamondback terrapin, Texas pipefish and bald eagle.

Habitat-Dependent Activities

Gulf Coast estuaries are centers of residential, recreational, commercial, agricultural and industrial activity. Indeed, estuaries have historically been preferred as centers of human settlement because of the abundance of fish and shellfish, proximity to freshwater and the ocean, and access to inland areas. Today, the estuaries of the Gulf Coast support cities such as Corpus Christi and Houston, Texas; New Orleans, La.; Mobile, Ala.; and Tampa, Fla. The Gulf Coast has one of the fastest growing populations in the country. In 1990 it was estimated that the population of the Gulf region would increase approximately 26 percent by 2010 (NOAA, 1990). Tourism in the Gulf states is valued at $20 billion each year, as beachgoers, boaters, anglers, bird watchers and hunters participate in diverse habitat-dependent activities (USEPA, 1999).

The Gulf Coast supports one of the most productive fishery areas in the world (NOAA, 1990). Commercial finfish and shellfish landings rank first in the nation in both quantity and value, contributing approximately 69 percent of the U.S. shrimp harvest and 57 percent of U.S. oyster production (USEPA, 1999). Commercial and recreational fisheries, which play such a large role in Gulf economies, rely on the health of estuarine habitats. Approximately 95 percent of Gulf Coast landings depend on estuaries during some stage of their life cycle (USEPA, 1999), and studies have demonstrated a quantitative link between wetlands loss and fisheries production (Turner and Boesch, 1988; Turner, 1977).

In addition to recreational uses and commercial fishing, the economies of the Gulf Coast are linked to estuaries in a number of other ways. Estuarine habitats serve as buffers for human communities by improving water quality, protecting shorelines from erosion, and reducing the effects of flooding. The shipping access provided by estuaries of the Gulf supports a great deal of maritime commerce. In terms of total tonnage, seven of

the 10 busiest ports in the United States are in the Gulf region (USEPA, 1999). Of the ships using these ports, approximately 98 percent use the Gulf Intracoastal Waterway (USEPA, 1999). Oil, gas and chemical production and development are prevalent along the Gulf Coast. Approximately 31 percent of the land in the Gulf region is used for agriculture. Silviculture and aquaculture also are significant activities in this region (USEPA, 1999).

These diverse activities affect both the structure and function of the estuarine resources on which they depend. Estuaries have been described as the most anthropogenically degraded habitat type on earth (Edgar et al., 1999). Throughout the Gulf region, estuaries have been altered by many of the factors that affect estuaries worldwide. As Gulf Coast populations increase, the demand for, and impacts on, estuarine resources can be expected to increase as well.

Habitat Status and Trends

Throughout the Gulf region, estuaries and their associated habitats have been altered due to discharge of industrial pollutants and urban waste; alteration of freshwater inflows; dredging of ship channels and oil and gas canals; filling of wetlands; armoring of shorelines; introduction of exotic species; deforestation; application of fertilizers and pesticides; and severing of migratory pathways.

Efforts have been made to assess the current extent of various estuarine habitats and the need for restoration. A 1990 study conducted by the National Oceanic and Atmospheric Administration (NOAA) examined the extent and distribution of marshes (fresh, brackish and salt), estuary scrub-shrub (mangroves) and freshwater forested scrub-shrub wetlands through the use of photos and U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory maps from 1972 and 1984. The total acreage was reported at approximately 3.3 million acres. National trends, however, suggest that wetland coverage has continued to decline since those photos and maps were produced (Freyer et al., 1983). No current studies summarize coastal wetland loss rates for the Gulf as a whole. Information is available from key Gulf Coast estuaries, however, and is discussed for each of the Gulf subregions.

Seagrasses have declined markedly since the 1950s, with most estuaries losing between 20 percent to 100 percent of their seagrass habitat (Handley, 1995). This is mostly the result of water quality degradation from increasing human impacts (Neckles, 1993). Six species of seagrass occur in the Gulf region, accounting for a total of approximately 2.5 million acres (Duke and Kruczynski, 1992).

Water quality within Gulf estuaries is a key issue. More than half of the oyster-producing areas in the region are closed, either permanently or conditionally. There also have been significant changes in both the quantity and timing of freshwater entering the estuaries.

Regional Planning Efforts

The regional nature of the issues faced by Gulf estuaries, coupled with the importance of the resources to the nation, has made the restoration of Gulf habitats a key objective noted in federal and regional plans reviewed. Regional efforts include the Gulf of Mexico Program, The Nature Conservancy's *Ecoregional Plan for the Northern Gulf of Mexico,* and the *Essential Fish Habitat Amendments* prepared by the Gulf of Mexico Fishery Management Council.

The Gulf of Mexico Program is a partnership of 18 federal agencies, state agencies from the five Gulf states, and diverse public and private organizations. The program implements research, demonstration projects, restoration activities and public information activities that focus on restoring seagrass and wetland habitat, enhancing water quality, controlling invasive species, monitoring habitats and educating the public. In the five Gulf states, 12 priority coastal areas have been identified: Corpus Christi Bay, Galveston Bay, Barataria-Terrebonne, Lake Ponchartrain, Mississippi Sound, Mississippi's coastal basins, Mobile Bay, Pensacola Bay, Suwanee River, Tampa Bay, Sarasota Bay and Charlotte Harbor.

The Nature Conservancy's *Ecoregional Plan for the Northern Gulf of Mexico* identifies a collection of sites that, if conserved, managed or restored, could represent the biodiversity of the region, including its nearshore waters. The ecoregional planning process used a reserve selection algorithm, expert interviews and a workshop to select a set of priority sites. Habitats targeted included seagrasses, oyster reefs, sponge and soft coral, salt marshes, tidal fresh marshes and tidal flats. Sites are considered on a landscape scale, with entire bays and estuaries included in the plan (Beck et al., 2000).

The Essential Fish Habitat Amendments prepared by the Gulf of Mexico Fishery Management Council identify and describe Gulf habitats that are “required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem” (NOAA, 1998). The document provides information for the identification and description of essential fish habitat for 26 representative species under federal management in the Gulf of Mexico. It also considers threats to essential fish habitat, identifies options for the conservation and enhancement of essential fish habitat and needed research to better identify and

describe essential fish habitat.

Gulf of Mexico Subregions

Although Gulf estuaries share many similar geographical features, habitat types, and habitat-dependent activities, the region has ecological differences. The Gulf of Mexico encompasses portions of both the Louisianan Province (Rio Grande, Texas, to Anclote Key, Fla.) and the West Indian Province (west coast of Florida from Tampa Bay to the Keys) and is greatly influenced by the Mississippi River. Gulf estuaries also vary geomorphologically, from complex networks of deltaic channels to shallow, bar-built systems. On the basis of these ecological and geographical distinctions, the region has been divided into four subregions.

The western, central and eastern Gulf subregions have been adopted based on The Nature Conservancy's ecoregional plan for the northern Gulf of Mexico (Beck et al., 2000). A southern subregion also has been added. For the purposes of this discussion, the Everglades, the Florida Keys and Florida Bay are excluded from the Gulf analysis and are discussed as part of the Southeast Atlantic regional analysis.

The following sections summarize the habitat issues and highlight certain restoration planning efforts for each of the four Gulf of Mexico subregions. Detailed information and additional plans are available through the National Strategy Restoration Plan Database (http://restoration.nos.noaa.gov).

Western Gulf of Mexico Subregion

Description

Extending from the southernmost coast of Texas to just south of Galveston Bay, the western subregion is characterized by low levels of freshwater inflow, sandy sediments, clear water and extensive growth of seagrasses. Estuaries in this subregion also support salt marshes, tidal flats, oyster reef, serpulid worm reefs, freshwater marshes, open bay, barrier islands and riparian woodlands.

Habitat Issues

Status and Trends

Within the subregion, direct loss of habitat has been attributed to erosion, damage by invasive species and other anthropogenic factors such as dredging and filling, hydrologic alteration and shoreline modification. Habitat also is being degraded as factors such as water and sediment quality affect the function of estuarine systems. For example, in the Coastal Bend, freshwater inflow has decreased by approximately 19 percent since 1940 (Coastal Bend Bays and Estuaries Program, 1998).

Threats

Degraded water and sediment quality as a result of point and nonpoint source pollution, and alteration of freshwater inflow have been identified as major concerns for the subregion. There also is concern that continued growth and changing land use within the subregion will have additional adverse effects, including fragmentation of habitat. Other threats to fishery species include increased fishing pressure, trawling and by-catch, and entrainment of organisms by industrial cooling systems.

Restoration Plans

Texas Coastal Management Plan (TCMP)

This plan was designed to meet the requirements for participation in the federal Coastal Zone Management Program and has been approved by NOAA. The TCMP coordinates state, local and federal programs for the management of Texas coastal resources. The plan is administered by the Coastal Coordination Council, which is charged with adopting uniform goals and policies to guide decision-making by all entities that regulate or manage natural resource use within the coastal area of Texas. Current areas of high priority are protecting wetlands, improving shoreline access, and addressing impacts of nonpoint sources of pollution.

To address priority issues, the Coastal Coordination Council oversees a TCMP grants program and a small business and individual permitting assistance program. Also under the TCMP, the Texas General Land Office leases coastal lands to the Texas Parks and Wildlife Department to manage as preserves. This Coastal Preserve program is designed to protect unique coastal areas and fragile biological communities. Two of the four currently designated preserves are in the western Gulf subregion: Welder Flats in San Antonio Bay and South Bay in the lower Laguna Madre.

Coastal Bend Bays Plan

The Coastal Bend Bays Estuary Program is implementing the Coastal Bend Bays Plan for the Aransas, Corpus Christi and upper Laguna Madre estuaries. The document outlines action plans for human uses, maritime commerce and dredging, habitat and living resources, water and sediment quality, freshwater resources and public education and outreach. Priority issues for the study area include freshwater inflow, condition of living resources, public health, loss of wetlands and other estuarine

habitats, degradation of water quality, altered circulation and debris.

Seagrass Conservation Plan for Texas
The Seagrass Conservation Plan for Texas is a cooperative effort of the Texas Parks and Wildlife Department, Texas General Land Office, Texas Natural Resource Conservation Commission, Galveston Bay Estuary Program, and Coastal Bend Bays Estuary Program. The document addresses the assessment, restoration and management of seagrasses in Texas waters.

The Clean Rivers Program
The Clean Rivers Program is administered by the Texas Natural Resource Conservation Commission, which works with river authorities and other stakeholders to address issues related to monitoring and assessment of water quality. The Texas General Land Office and the Texas Parks and Wildlife Department cooperate on the State-owned Wetlands Conservation Plan. The Texas Parks and Wildlife Department also implements the Texas Wetlands Plan.

Mission/Aransas Watershed Conservation Plan
The Texas General Land Office, in cooperation with EPA, has developed the Mission/Aransas Watershed Conservation Plan, which outlines habitat assessment, enhancement and education goals for portions of Aransas, Refugio and San Patricio counties. This local wetlands plan was designed as a model for other coastal communities interested in bringing stakeholders together to evaluate wetland issues and to develop a plan for conserving wetlands while allowing for economic growth.

Plan Elements

Goals
Restoration goals outlined in these documents focus on increasing and preserving the quality and diversity of habitats and living resources within the estuaries, enhancing water quality, and reducing debris. Reductions of point and nonpoint sources of pollution, creation of seagrass and marsh habitat, and maintenance of freshwater inflow have been identified as top priorities.

Methods
Several methods have been applied or recommended for achieving the subregion's restoration goals. Among these are creation of wetlands through the beneficial use of dredged material or by ponding, and enhancement of habitat and water quality via promotion of best management practices, participation in landowner initiatives, and development of a comprehensive regional water management plan.

Elements of Success
Common principles of successful estuarine restoration are apparent in the planning efforts for the western Gulf. Plans emphasize the need for cooperation of diverse entities, planning and restoration on an ecosystem level, and a high degree of public education and involvement in both the planning and implementation phases.

Information Needs
The understanding of habitat functions and the understanding of total loadings and transport pathways, as well as their biological effects, were identified as areas in need of further research. Long-term monitoring was suggested as an important tool for gathering this information.

Central Gulf of Mexico Subregion

Description
The central subregion includes Galveston Bay and spans the coasts of Louisiana, Mississippi and Alabama. The subregion is characterized by high, and sometimes variable, levels of freshwater inflow and by high levels of sediment input. The nutrient-rich waters and muddy sediments support extensive marsh and oyster reef habitat. Other key habitats within the subregion are freshwater marsh, oyster reef, seagrass, swamp, tidal flats, open bay, barrier islands, nesting islands, bayous, pitcher plant bogs, dune swales, forested wetlands, coastal prairie and long-leaf pine savannah.

Habitat Issues

Status and Trends
The marsh-dominated estuaries of the central Gulf have experienced tremendous habitat losses in recent decades. In Louisiana, more than 960,000 acres of marsh have been lost since 1930. Currently, an area of marsh the size of a football field is disappearing every 30 minutes (LCWCRT, 1998). In Galveston Bay, more than 30,000 acres of marsh and approximately 90 percent of the seagrass beds have been lost since the 1950s (Galveston Bay NEP, 1994). Alabama's fresh and salt marshes declined by 69 percent and 29 percent , respectively, between 1955 and 1979 (Alabama Department and Community Affairs, Science, Technology, and Energy Division, Coastal Programs Office, 1999). For these reasons, much of the restoration planning focuses on creating and enhancing marshes.

Threats
Habitat, residences, property and business opportunities are

being lost to subsidence and subsequent erosion. In addition to loss of habitat structure, most plans express concern about lost function caused by degraded water quality as a result of runoff and point sources of pollution, and changes in freshwater inflows. Habitat fragmentation has also been identified as a concern.

A variety of factors have been identified as contributing to habitat loss in the Central Gulf of Mexico subregion. Among these are subsidence, erosion and direct alterations, such as dredging and filling, changes to hydrology, shoreline modification, sand extraction, prop scarring, shoreline alteration and disturbance from trawling. Key among these is the loss of sediment and nutrients to Louisiana marshes, resulting in the levelling of the Mississippi River. Invasive species, particularly herbivores such as nutria, also are responsible for loss of habitat.

General habitat types including submerged aquatic vegetation, emergent vegetated wetlands, oyster reefs, shellfish beds and certain intertidal zones have been identified as areas of particular concern. Fisheries species most affected include brown shrimp, white shrimp, blue crab, oysters, red drum, black drum, speckled sea trout, gulf menhaden, southern flounder, largemouth bass and channel catfish. These habitats also support a variety of migratory neotropical birds, waterfowl, shore birds, wading birds and raptors, as well as threatened and endangered species such as the Florida yellow bat, American alligator, piping plover, Alabama red-bellied turtle, eastern indigo snake, black bear and gopher tortoise.

Restoration Plans

Texas Coastal Management Plan (TCMP)

The TCMP was designed to meet the requirements for participation in the federal Coastal Zone Management Program. The TCMP coordinates state, local, and federal programs for the management of Texas coastal resources. The plan is administered by the Coastal Coordination Council, which is charged with adopting uniform goals and policies to guide decision-making by all entities regulating or managing natural resource use within the Texas coastal area. Current areas of high priority are protecting wetlands, improving shoreline access and addressing impacts of nonpoint sources of pollution.

Weeks Bay National Estuarine Research Reserve

The Weeks Bay National Estuarine Research Reserve was established in Alabama in 1986 and currently encompasses 3,028 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1998. Important habitats that may be useful for investigation and as reference sites include upland forests, fresh and saltwater marshes, forested swamps, pitcher plant bogs and tidal flats. Restoration priorities include restoring riparian buffers, shorelines, wetlands and bottom lands. Restoration projects currently underway include prior-converted wetland and riparian buffer restoration, pitcher plant bog restoration, salt marsh restoration and prescribed burning.

Galveston Bay Plan

The Galveston Bay Plan is undergoing its five-year review process. A five-year work plan is being generated that will include action items in the areas of habitat protection, species population protection, public health, freshwater inflow and bay circulation, spills and dumping, shoreline management, water and sediment quality, point and nonpoint sources of pollution, research, monitoring, and public participation and education. Restoration, creation and protection of wetlands are identified as top priorities for Galveston Bay.

The Galveston Bay Plan is administered by the Galveston Bay Estuary Program, a program of the Texas Natural Resource Conservation Commission, in conjunction with the Galveston Bay Council. The Council consists of representatives of state, federal and local natural resource agencies, the research community, local governments, citizens and other Galveston Bay stakeholders.

The Texas Coastal Management Plan and the Galveston Bay Plan are augmented by several state plans and programs. To address priority issues, the Coastal Coordination Council oversees a TCMP grants program and a small business and individual permitting assistance program. Also under the TCMP, the Texas General Land Office leases coastal lands to the Texas Parks and Wildlife Department to manage as preserves. This Coastal Preserve program is designed to protect unique coastal areas and fragile biological communities. Two of the four state-designated coastal preserves are in the Galveston Bay system: Armand Bayou and Christmas Bay.

Louisiana Coastal Resources Program

The Louisiana Coastal Resources Program is administered by the Louisiana Department of Natural Resources. The program works with local parishes to design programs that resolve conflicting local uses of the coast. Programs include the Coastal Use Permit Program and management of the Marsh Island Refuge and the Louisiana Offshore Oil Port.

Mississippi Coastal Program

The Mississippi Coastal Program is administered by the state Department of Marine Resources. An advisory council of citi-

zen and industry representatives makes recommendations to the program, and a commission of citizen and industry representatives creates the program's policies. The program manages port and beach special management areas based on separate management plans for those areas.

Grand Bay National Estuarine Research Reserve

The Grand Bay National Estuarine Research Reserve was established in Mississippi in 1999 and currently encompasses 18,000 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1998. Important habitats that may be useful for investigation and as reference sites include wet pine savannah, coastal swamp habitats, estuarine tidal marsh and shallow water open bay. Restoration priorities include exotic species control, shoal and salt marsh restoration, oyster reef restoration, reestablishment of flood water flow and hydrological restoration, and prescribed burning in wet pine savannah and pine flatwoods. Current restoration projects include prescribed burning.

Alabama Coastal Area Management Plan

The Alabama Coastal Area Management Plan consists of comprehensive management policies and guidance for the protection and enhancement of the quality, quantity and viability of coastal resources and the management and uses of those resources. The plan was developed in response to the Coastal Zone Management Act and is used by the Alabama Coastal Area Management Program to balance preservation, conservation, enhancement and development of coastal resources while promoting a sustainable economy. The Alabama Coastal Area Management Program is a joint effort of the Alabama Department of Economic and Community Affairs, which has primary responsibility for planning and policy development, and the Alabama Department of Environmental Management, which has primary responsibility for regulation and implementation of policies and goals.

Barataria-Terrebonne Estuary Plan

The study area for the Barataria-Terrebone National Estuary Program includes the Barataria and Terrebonne basins and portions of the Mississippi and Atchafalaya rivers. The Barataria-Terrebonne Estuary Plan was developed in conjunction with the state of Louisiana, and is being implemented by the Barataria-Terrebone National Estuary Program and the Barataria-Terrebonne Management Council, which consists of state, federal and local resource agencies, as well as universities and diverse stakeholders. The plan identifies seven priority issues: hydrologic modifications, sediment reduction, habitat loss, eutrophication, pathogen contamination, toxic substances, and changes in living resources. The plan also contains action items in the areas of coordinated planning and implementation, ecological management, sustained recognition and citizen involvement, and economic growth.

Mobile Bay and Delta Comprehensive Conservation and Management Plan (Draft)

A draft Comprehensive Conservation and Management Plan is being finalized for Mobile Bay and Delta. The Mobile Bay National Estuary Program has outlined the issues and action items, which the plan will address in a document titled Our Water Our Future. The document was developed in coordination with a management conference, six community-based issue workgroups and a variety of research entities. Priority issues include water quality, physical and hydrologic modifications, habitat loss, living resources, human uses, and public education and involvement.

Habitat Conservation Blueprint

The Galveston Bay Foundation's Habitat Conservation Blueprint was developed with federal, state and local partners to facilitate the habitat restoration and protection goals of the Galveston Bay Plan. The Blueprint is an inventory of potential restoration sites within the Galveston Bay system, and includes information regarding potential strategies and resources. The Blueprint will be implemented by the Galveston Bay Foundation and other environmental organizations, resource agencies, universities, local governments, private landowners, industry representatives, and other stakeholders.

Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico

Another example of an interagency water quality improvement effort that can be used to forward restoration activities is the Action Plan for Reducing, Mitigating and Controlling Hypoxia in the Northern Gulf of Mexico. Federal agencies have joined together in response to a serious threat that has been linked to nutrient over-enrichment. Each summer in the Gulf of Mexico, the oxygen levels near the bottom become too low to allow most fish and crustaceans to live, resulting in an 8,000 square mile “dead zone.” Concern about the dead zone is both environmental and economic as approximately 40 percent of U.S. fisheries landings come from this area. Research indicates that the dead zone is caused by a combination of natural and human influences, with the main driver being excess nutrients. Nitrogen loads in the Mississippi Basin come from a variety of sources, but over half can be attributed to agriculture, primarily runoff of nitrate from fertilizers.

To address this issue, federal agencies along with other stakeholders have crafted an Action Plan for Reducing, Mitigating,

and Controlling Hypoxia in the Northern Gulf of Mexico. The Action Plan describes a national strategy to reduce the frequency, duration, size and degree of oxygen depletion of the hypoxic zone of the northern Gulf of Mexico. The plan is the result of several years of study and discussion by the members of the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force and many concerned officials and citizens who participated in their deliberations. The primary approaches to reduce hypoxia in the Gulf of Mexico outlined are to reduce nitrogen loads from watersheds to streams and rivers in the basin and restore and enhance denitrification and nitrogen retention within the basin. While the primary focus of this strategy is reducing nitrogen loads to the northern Gulf, many of the actions proposed in this plan also will achieve basin-wide improvements in surface-water quality by reducing phosphorous. Likewise, actions taken to address local water quality problems in the basin often contribute to reductions in nitrogen loadings to the Gulf.

Coast 2050: Toward a Sustainable Coastal Louisiana

Perhaps the most all-encompassing restoration plan within the Gulf region is Louisiana's Coast 2050: Toward a Sustainable Coastal Louisiana. This strategic plan for the survival of Louisiana's coast and communities promotes restoration and protection on a coast-wide basis, and recommends strategies that work with natural forces such as the river, climate, and tidal influences. The strategies included in the plan are expected to prevent the loss of 1,000 square miles of coastal habitat.

Coast 2050, which has been approved by all 20 of Louisiana's coastal parishes, involved federal, state and local entities, landowners, environmentalists, scientists and other stakeholders. Partners include the Louisiana Coastal Wetlands Conservation and Restoration Task Force (U.S. Army Corps of Engineers, National Marine Fisheries Service [NMFS], USFWS, Natural Resources Conservation Service [NRCS], EPA, and the Office of the Governor of Louisiana) and the Louisiana State Wetlands Conservation and Restoration Authority (Office of the Governor of Louisiana; the Louisiana Departments of Natural Resources, Transportation and Development, Environmental Quality, and Wildlife and Fisheries; Louisiana Division of Administration; and State Soil and Water Conservation Committee.)

Louisiana Coastal Wetlands Restoration Plan and the Coastal Wetlands Conservation and Restoration Plan

Coast 2050 builds on previous restoration planning efforts for the Louisiana coast, including the Louisiana Coastal Wetlands Restoration Plan and the Coastal Wetlands Conservation and Restoration Plan. Coast 2050 also builds on the projects and partnerships developed under the Coastal Wetlands Planning, Protection and Restoration Act of 1990 (CWPPRA). CWPPRA established a multi-agency task force that is responsible for program management and project selection based on recommendations of the technical committee. The task force is comprised of NOAA Fisheries, Army Corps of Engineers, the U.S. Fish and Wildlife Service, the Environmental Protection Agency, the Natural Resources Conservation Service and the Louisiana Governor's Office.

Since 1991, 99 CWPPRA projects have been authorized in Louisiana's nine coastal basins. The projects are expected to create, protect and restore 75,000 acres of wetlands over the next 20 years. Demonstration projects and feasibility studies are also part of CWPPRA. CWPPRA funds enabled a comprehensive approach to restoration by funding restoration, coordinated planning and monitoring.

Citizens' groups such as the Coalition to Restore Coastal Louisiana, the Lake Pontchartrain Basin Foundation, the Acadiana Bay Association and the Vermillion Rice Growers Association have played a significant role in habitat restoration planning for Louisiana.

Plan Elements

Goals

Habitat goals for the central Gulf focus on the restoration of productivity and diversity through the enhancement of habitat structure and function. Examples of restoration goals for the area include Galveston Bay's target of restoring and/or conserving 24,000 acres of habitat by 2010, and Coast 2050's overarching goal to “sustain a coastal ecosystem that supports and protects the environment, economy and culture of southern Louisiana, and that contributes greatly to the economy and well-being of the nation.”

Many closely linked goals call for the protection, enhancement or creation of lost habitats such as marshes, seagrasses, coastal prairies, swamps, bay and lake shorelines, barrier islands and critical land forms. Other goals address the causes of habitat loss and degradation. These goals are designed to control invasive species, ensure freshwater and sediment inflows, improve water quality and restore riparian buffer zones and barrier islands. Still other goals focus on the restoration of goods and services provided by estuarine habitats. In order to achieve one set of goals—the restoration of goods and services provided by estuarine habitats—actions aim to preserve and enhance fisheries resources, such as maintenance of temporal and spatial biodiversity; maintenance of exchange and interface to achieve

system linkages; and reduction of water and sediment toxicity. Restoration of colonial bird nesting habitat, elimination of dumping and debris, and control of shoreline erosion also are examples of goals based on the recovery of habitat services.

Methods

Within the central Gulf subregion, a variety of restoration methods have been suggested, developed and applied. Although specific strategies are linked to particular habitats and threats, most habitats can benefit from landowner initiatives, removal of debris, establishment of habitat corridors and land use planning.

Erosion control and compensation methods include nonstructural shoreline stabilization, brush fences and breakwaters, artificial reefs, shoreline scraping and grading, and rebuilding coastal ridges. Where subsidence has occurred or sedimentation patterns have been altered, techniques such as terracing, the beneficial use of dredged material, dedicated dredging for wetland creation, induced deposition of sediment, and sediment diversion are recommended.

The innovative marsh terracing project at Sabine National Wildlife Refuge has served as a model for smaller projects in Galveston Bay. Louisiana also is pioneering the large-scale use of freshwater diversion as part of the Caernarvan and Davis Pond restoration projects. As part of its plan to deepen and widen the Houston Ship Channel, the Port of Houston Authority has consulted with resource agencies to create marsh, nesting areas and oyster reef habitats.

Seagrasses have been transplanted using a variety of methods, and there is interest in developing nursery capability. Methods for revegetation include the use of either nursery or transplant stock. Techniques for enhancing oyster reefs also are being developed, mostly with use of supplemental culch or artificial substrate. Coastal prairie is often managed through the use of prescribed burns and the removal of invasive species.

Restoration of hydrologic conditions is often necessary and can encompass, the diversion of freshwater, management of pump outfalls and removal of pipelines. To address water quality issues, many plans suggest the creation of buffer zones, reduction of septic tank and sewer overflows, implementation of best management practices and improvement of unpaved roads.

Elements of Success

Several common themes have been identified among the central Gulf plans. Of the documents reviewed, nearly all recommended the development of strong partnerships, involvement of diverse stakeholders, and facilitation of coast-wide cooperation. The integration of research and the acquisition, interpretation and application of information were also emphasized, along with the use of predictive modeling. There seems to be a consensus that restoration should be planned and implemented at the watershed or ecosystem level. Also recommended is an increase in public support within the context of communities and a tenfold increase in current funding levels.

Information Needs

Interdisciplinary research is recommended to:

- Identify rare and threatened habitats;
- Improve understanding of structure and function of coastal habitats;
- Improve understanding of human impacts on habitat;
- Improve understanding of water and sediment processes and interactions;
- Develop innovative, practical techniques for habitat enhancement, especially the design of structures and methods for managing hydrology, and the development of techniques and materials for marsh creation;
- Employ hydrologic studies to determine restoration needs and strategies;
- Develop a regional monitoring program; and
- Assess current status and trends.

Eastern Gulf of Mexico Subregion

Description

The upper Gulf Coast of Florida, south to Anclote Key, defines the eastern subregion. Moderate freshwater inflow, coarser sediments and clearer water than is found in the central subregion supports extensive seagrass habitat. Where the limestone bottom is exposed, sponge and soft coral communities exist. In addition, the subregion also supports salt marsh, freshwater marsh, oyster reef, open water, barrier islands, bayous, dune lakes, forested wetlands, sand pine, pine flatwoods, scrub hammock and hardwood hammock.

Habitat Issues

Status and Trends

There is some indication that fisheries have been declining in Pensacola Bay (Northwest Florida Water Management District, 1997). Throughout the subregion, fishery species such as blue crab, shrimp, oysters and bay scallops, as well as finfish such as redfish, flounder, mullet, menhaden, speckled sea trout and largemouth bass, are identified as key beneficiaries of habitat restoration. Protected species of particular concern in the East-

ern Gulf region include pelicans, plovers, oyster catchers, skimmers, terns, raptors, alligators and river otters.

Threats

Within the eastern Gulf, habitat is being lost, degraded, fragmented and threatened. Hydrologic alterations, invasive species, dredging and filling have caused much of the habitat loss within this subregion. Changing land uses, an increase in the amount of polluted runoff, point and nonpoint sources of pollution, changes in freshwater inflow, and withdrawal of groundwater threaten estuarine habitats in the subregion.

Restoration Plans

Florida Coastal Management Program

The Florida Coastal Management Program activities relate to the protection, preservation and development of Florida's natural, cultural and economic coastal resources. A network of 10 agencies implements the program, led by the Florida Department of Community Affairs. A 15-member Governor's Coastal Advisory Committee advises the governor and the legislature on coastal management issues and program implementation. The Coastal Management Program implements 23 state statutes related to coastal resources.

Management Plan for the Apalachicola National Estuarine Research Reserve

The Apalachicola National Estuarine Research Reserve was established in Florida in 1979 and currently encompasses 246,766 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1998. Important habitats that may be useful for investigation and as reference sites include forested flood plains, fresh- and saltwater marshes, oyster bars and barrier islands. Restoration priorities include restoring historic hydrology, historic biological communities and fire regimes. Current restoration projects include shoreline stabilization, Phragmites removal, marsh restoration and prescribed burning.

Surface Water Improvement and Management Plans

The Northwest Florida Water Management District has prepared Surface Water Improvement and Management Plans for Pensacola Bay, St. Marks River and the Choctawatchee River and Bay systems. These plans for comprehensive coordinated watershed management describe the resources and issues of the watershed, as well as the resource management activities of various resource agencies. The plans also describe proposed projects to address issues related to watershed management, biological concerns, water quality and public awareness.

Plan Elements

Goals

Restoration goals focus on the protection and restoration of seagrasses, marshes and forests, and on the reduction of runoff and point source pollution. Maintenance of historic freshwater inflow and the protection of listed species also are priorities for the eastern Gulf.

Methods

Shellfish restoration methods have involved enhancement of oyster reefs, construction of artificial reefs and the transplanting of scallop. Improvements to stormwater and wastewater management and treatment, landowner initiatives and implementation of best management practices for urban and agricultural areas have been identified as techniques for improving water quality. Seagrass planting and sediment detention have been recommended for restoration of vegetated habitat.

Elements of Success

Consistent with other Gulf subregions, key elements for successful restoration are: system-wide coordination, public education and involvement, and incorporation of research.

Information Needs

Two research priorities—mapping of existing natural resources and long-term monitoring of existing and restored habitat—have been developed for the subregion.

Southern Gulf of Mexico Subregion

Description

The southern subregion encompasses the Gulf Coast of Florida from south of Anclote Key to Cape Romano. The region is characteristic of the West Indian ecological province. In addition to salt marsh and seagrass, the clear, shallow estuaries of the southern Gulf also support extensive mangrove habitat. Other key habitats are oyster reef, freshwater marsh, barrier islands, swamp, salt pans, dry-zone scrub, pine flatwoods, oak scrub, scrub flatwoods and hammocks.

Habitat Issues

Status and Trends

Direct loss of habitat has occurred as a result of erosion, degraded water quality, and physical disturbance. Since 1870, approximately 80 percent of the seagrasses and 50 percent of the salt marsh and mangrove habitat in Tampa Bay have been lost (Tampa BayWatch, 1998). Erosion and degraded water

quality affect estuaries as a whole, as do changes to freshwater inflow and changing land use. Invasive species and hydrologic alteration are particularly damaging to marshes, and prop scarring is a large problem in seagrass beds. In some cases, public overuse and misuse of natural areas also are leading to degradation.

Threats

Plans emphasize the effects of habitat loss on fisheries species such as mullet, blue crab, and stone crab. Several protected species inhabit the southern Gulf subregion, including: West Indian manatee, Atlantic loggerhead turtle, gopher tortoise, indigo snake, Florida panther and 16 species of threatened or endangered birds. These species are threatened by a variety of habitat alterations. There also is a concern that habitat is becoming fragmented and migration corridors are being severed.

Restoration Plans

Florida Coastal Management Program (see Restoration Plans for the Eastern Gulf of Mexico Subregion).

Charlotte Harbor Comprehensive Conservation and Management Plan (Draft)

The Charlotte Harbor National Estuary Program has completed a draft Comprehensive Conservation and Management Plan for the greater Charlotte Harbor watershed, including the Caloosahatchee River and Estero Bay watersheds, Lower Peace and Myakka River watersheds, and the Upper Peace and Myakka River watersheds. The plan identifies hydrologic alterations, water quality degradation, and fish and wildlife habitat loss as priority issues.

Charting the Course, the Comprehensive Conservation and Management Plan for Tampa Bay

Charting the Course was produced by the Tampa Bay National Estuary Program in cooperation with local government and agency partners. The document addresses seven priority issues: degradation of water quality; impacts to living resources and habitats; impacts associated with human uses of the estuary; agency coordination and response; community awareness; bay circulation and flushing; and spills and contamination. Restoration and protection of seagrasses is a key goal. The goal is to restore 12,350 acres and protect the Tampa Bay's existing 25,600 acres of grass beds based on restoring the vital underwater seagrass meadows to 1950s levels. This will largely be achieved by controlling the bay's nitrogen loading, although other factors such as turbidity and water color, also influence seagrass regrowth. The goal includes restoring at least 100 acres of low-salinity tidal stream habitat every five years for a total increase over time of 1,800 acres, while preserving existing salt marshes and mangroves.

Management Plan for the Rookery Bay National Estuarine Research Reserve

The Rookery Bay National Estuarine Research Reserve was established in Florida in 1978 and currently encompasses 9,400 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1998 and is currently being revised. Important habitats that may be useful for investigation and as reference sites include tropical hardwood hammocks, xeric scrub, pine flatwoods, saltwater marsh, mangroves, shallow bay waters and barrier islands. Restoration priorities include hydrologic restoration and native community restoration. Current restoration projects include hydrological restoration through roadbed removal and GeoWeb installation, invasive plant control, mangrove restoration and prescribed burning.

Southwest Florida Conservation Corridor Tampa Bay Watershed

This framework document is designed to provide a partnership vehicle to synchronize comprehensive planning efforts by a host of independent partners. Designed to be a "living document," it will provide a template for developing strategies and priorities through time and allow for new opportunities for federal, state and regional governments to work together with local governments and the private sector to explore and develop innovative conservation, restoration and preservation programs. Further, it will allow funding requests to be streamlined as monies become available for acquisition and restoration at the local, state and federal levels. Under the guidance of the Agency on Bay Management (ABM), this document is the result of a unified planning effort with state and federal agencies, local governments, private landowners, and nongovernmental organizations and businesses (Southwest Florida Conservation Corridor planning document, 2001).

Land Management Plan for the Estero Bay State Buffer Preserve

The Land Management Plan for the Estero Bay State Buffer Preserve has been prepared by the Bureau of Coastal and Aquatic Managed Areas in the Florida Department of Environmental Protection's Division of Marine Resources. The document describes the resources associated with the preserve, as well as proposed management activities and the roles of managing agencies, the public and local government in management of the area. The plan identifies the following restoration goals: assess natural resources and restoration needs, establish

and post presence boundaries, manage invasive plant species, manage ecosystems with prescribed burns, and control damage by feral hogs.

Tampa BayWatch and other citizens' groups have been very active in the implementation of community-based restoration projects. Tampa BayWatch has published the results of several workshops that identify restoration sites and resources, as well as proposed project selection criteria. The Tampa Surface Water Improvement and Management Department has also prepared a five-year plan that includes potential restoration sites.

Plan Elements

Goals

Restoration goals focus on enhancing hydrology, water quality, and habitats such as seagrass, salt marsh, oyster reefs, freshwater marsh, native uplands and mud flats. Ecological function will be restored through establishment of buffer zones around sensitive areas and restoration of freshwater inflow. Also planned are activities that will control invasive species populations and assist with the recovery of protected species populations.

Methods

For preserve areas, techniques as simple as posting boundaries have been identified. Prescribed burns and removal of trash and invasive species have been recommended for marshes and uplands. The conservation of flyways has also been identified as essential.

Elements of Success

Restoration planners in the southern Gulf subregion have shown strong support for public education and involvement; cooperation of federal, state and local agencies with other organizations; science-based adaptive management; coordination of regional maps and databases; and partnerships among universities, resource agencies and research institutions. Also noted as an essential element of successful restoration was the ability to balance human use and sensitive areas.

Information Needs

Several types of information were determined to be necessary for successful restoration in the subregion, including:

- assessment of management strategies for listed species;
- effectiveness of control techniques for invasive species;
- freshwater inflow needs;
- existing resources (inventory and status of existing resources);
- the carrying capacity of sensitive habitats relative to public use and mosquito control methods; and
- GIS-based information about habitat distribution, topography, hydrology, and biological and cultural resources.

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Regional Analyses of Restoration Planning

PART 4 – SOUTHEAST ATLANTIC

ESTUARIES OF THE SOUTHEAST ATLANTIC

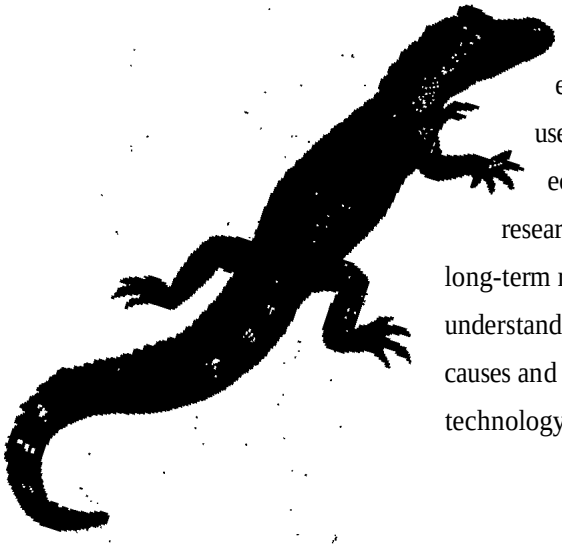
The Southeast Atlantic region is defined here as the coastal and estuarine zones of the states of North Carolina, South Carolina, Georgia, the Atlantic coast of Florida (including South Florida, the Everglades, the Florida Keys and Florida Bay), the U.S. Virgin Islands and Puerto Rico.

The Southeast Atlantic region:

- Contains about 17.2 million acres of marsh and other estuarine habitat and 5.1 million acres of intertidal areas (http://caldera.sero.nmfs.gov/habitat/sp.htm).
- Includes the only emergent reefs off the continental U.S. (Causey et al., 2000).
- Contains the largest seagrass bed yet documented (5,791 square miles), which occurs off south Florida (www.fiu.edu/~seagrass/).
- Includes 3.9 million acres (18 percent of national total) of shellfish beds, ranking third in the total acreage of classified waters (NOAA, 1990).

SUMMARY

The Southeast Atlantic region is characterized by broad scale climatic patterns, which produce a diversity of ecosystems. In this region, restoration programs and plans are primarily implemented as regional or state level strategies. A review of restoration plans and programs determined that there is significant duplication of effort within and among federal and state initiatives. Several successful restoration methods were identified in this region. While mangrove restoration is still in need of further development, there are some examples of effective restoration methods that have been applied in the field such as the use of PVC pipes to stabilize mangrove propagules in order to protect them from washing away (this method is known as the Riley Encased Methodology). Another more recent technique being tested is the use of burlap, whereby four or five propagules may be placed on a section of burlap so that the roots of the propagules intertwine and protect one another from washout. Innovative approaches and new techniques also are being tested for coral and artificial reef enhancement. Until the 1980s, bundled automobile tires were most often used, but this practice was discontinued due to stability problems. Materials most often used include boating vessels, large diameter concrete pipe, train cars, bridge railing and rubble. A document entitled Guidelines for Marine Artificial Reef Materials, published by the Gulf States Marine Fisheries Commission, provides details and drawbacks of past uses of materials used for restoration and enhancement projects. Regional habitat restoration plans identify several research and information needs that are necessary to achieve long-term restoration success. Some of the information needs include understanding ecosystem structure and function; understanding the causes and effects of habitat alterations; and using the best available technology and methodology for effective habitat restoration.



INTRODUCTION

Description

For the purposes of this discussion, the Southeast Atlantic region includes North Carolina, South Carolina, Georgia, the Atlantic coast of Florida (including South Florida, the Florida Keys, the Everglades and Florida Bay), the U.S. Virgin Islands and Puerto Rico. The Southeast Atlantic estuarine region is one of the largest, most diverse and most productive coastal areas in the United States. Eighteen estuaries and two sub-estuaries, totaling almost 56,000 square miles of total drainage area, characterize the region. It represents the second highest U.S. region in wetlands and coral reef coverage area (NOAA, 1990).

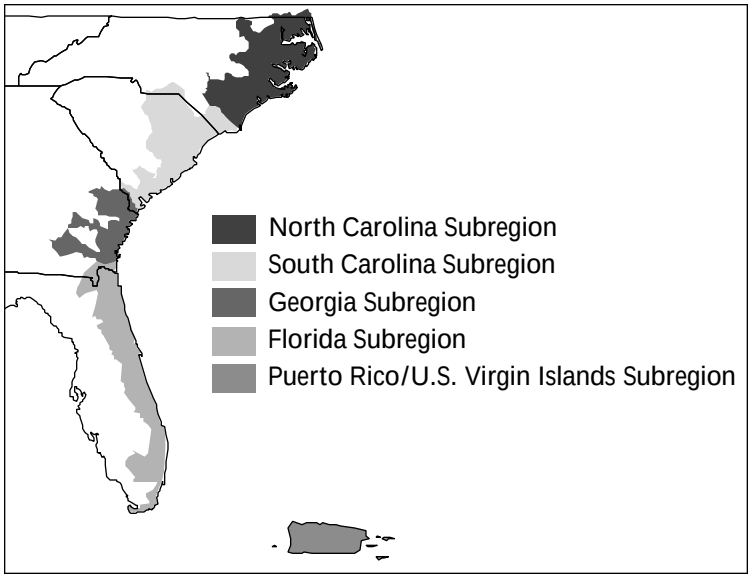


Figure 1: Southeast Region and Subregions

There is a great deal of diversity among land types and habitats within the Southeast region. River drainage areas range in size from 500 square miles (New River) to over 11,600 square miles (Albemarle-Pamlico Estuary) (NOAA, 1990). For the purposes of this discussion, the regional estuary systems are classified into three broad types: low-lying marshes within South Carolina and Georgia; lagoons and barrier islands along the coasts of North Carolina and Florida; and coral reefs and salt ponds within Puerto Rico and the U.S. Virgin Islands (White et al., 1995). Wetlands cover over 9,000 square miles of the region, and forested wetlands constitute three-quarters of southeast wetlands (NOAA, 1990). Total salt and brackish marsh acreage in this region is 894,000 acres, or 16 percent of the nation's total coastal wetlands (White et al., 1995).

Key Habitats and Species

Broad-scale climatic patterns explain much of this diversity, and the Southeast region's most distinctive characteristic is diversity at small scales. Due to these diverse environments and a long evolutionary isolation, a number of groups have reached continental high points of species richness in the Southeast Atlantic region, making it one of the most species-rich areas in the temperate zone, surpassed only by eastern Asia (White et al., 1995).

Historically, longleaf pine savanna was widely dominant on the Coastal Plain. Open habitats, including fens, bogs, glades, barrens and prairies; freshwater and saline marshes; sand dunes; and salt flats and rock outcrops, form island-like habitats within the matrix of closed forest. Over thirty plant and animal species associated with the longleaf pine habitat are listed as threatened or endangered, including red-cockaded woodpecker, fox squirrel and gopher tortoise (White et al., 1995).

It has been estimated that non-alluvial wetlands support more than one-third of the rare plants that occur in the Southeast Atlantic region and 23 species of rare, threatened or otherwise noteworthy plants have been identified in bays in South Carolina. Animals that depend on bay habitat include amphibians, the American alligator, freshwater turtles, snakes, and birds. Several animal species are endemic to particular bays; Lake Waccamaw, for example, supports at least two and possibly four endemic fish species, and three endemic mollusk species (White et al., 1995). Recreationally important fish species in the region include tarpon, American shad, and striped bass (Iliff, personal communication).

Pocosins are freshwater wetlands dominated by a dense cover of broad-leaved evergreen shrubs or low-growing trees with highly organic soils developed in areas of poor drainage. Several plant species depend on pocosin habitat, including whitewicky, arrowleaf shieldwort, spring-flowering goldenrod and roughleaf yellow loosestrife (White et al., 1995).

The coastal physiography of the northern and southern part of the South Atlantic Bight (North Carolina and Florida) is dominated by shallow water lagoons behind sand coastal barrier shorelines, while the central portion (South Carolina and Georgia) contains depositional marsh-filled lagoons. Estuarine marshes constitute a complex ecosystem that is vital to fish and wildlife including threatened and endangered species, furbearers and other mammals, waterfowl, wading birds, shore birds, reptiles and amphibians, shellfish and invertebrates.

Within this region, barrier islands and maritime forests are complex and dynamic ecosystems. Large numbers of migratory and nesting bird species are found on barrier islands. Coastal marshes are critical to overwintering populations of many

waterbirds. Southeastern barrier islands are included in the migration routes of many raptor species. Neotropical migrants use the islands as a resting stop when traveling to and from their winter habitats in the tropics. Nine endangered species of birds have been listed as wholly or partially dependent on southeastern barrier island habitats. These species use the barrier islands for nesting, migration, wintering, feeding, resting and roosting (Stalter and Odum, 1993).

Dunes and beaches provide essential nesting habitat for sea turtles. There are five species of sea turtles found in the open ocean and coastal waters of the Southeast Atlantic. All of these species nest on open beaches and include: the green sea turtle (endangered/threatened), the hawksbill (endangered), Kemp's ridley (endangered), the leatherback (endangered) and the loggerhead (threatened) (White et al., 1995).

In the Southeast Atlantic region, well-developed mangrove forests occur in South Florida, the U.S. Virgin Islands and Puerto Rico in areas where tidal waters produce saline conditions for all or part of the year. The red mangrove *(Rhizophora mangle),* black mangrove (*Avincennia germinans)* and white mangrove *(Laguncularia racemosa)* are the three true mangrove species found in the Southeast Atlantic. Mangrove habitats provide shelter for fish and invertebrates, contribute detritus to estuarine food webs, trap sediment and nutrients before they reach the sea, and protect coastal shorelines from the full effects of storms.

Seagrass beds in North Carolina and Florida are preferred habitat areas of many managed species such as shrimp, red drum, and estuarine-dependent snapper and grouper. In addition, many key species of birds (e.g., black brant), green turtles and manatees feed directly upon coastal and estuarine seagrasses (NOAA, 1998a; 1998b). Seagrass species found in the region include turtle grass (*Thalassia testudinum),* manatee grass *(Syringodium filiforme)* and shoal grass *(Halodule wrightii).*

The Southeast Atlantic region contains the only emergent coral reefs off the continental U.S. (Causey et al. 2000). Coral reefs help to build landmass in tropical environments, provide beach sand and offer protection to coastlines from hurricanes, storm erosion and flooding by reducing wave action. The number and density of species using coral reefs is extremely high and many reef taxa have yet to be described or inventoried (Bruckner, personal communication). Recent estimates of the extent of coral reefs in Puerto Rico by the Department of Natural and Environmental Resources have placed Puerto Rico's reef acreage second only to Hawaii's.

Florida Bay is a unique, relatively young subtropical lagoon with localized estuarine characteristics. Some scientists believe that the cumulative lack of freshwater inflow to Florida Bay, due to man-made water diversions coupled with other anthropogenic and possibly natural causes, led to a major seagrass die-off in the bay in 1987, followed by subsequent die-offs in the 1990s. The declining health of Florida Bay was a major catalyst for passage of the Comprehensive Everglades Restoration Plan, which in part proposes to restore freshwater inflow from the Everglades into Florida Bay (Porter and Porter 2001). The bay is inextricably linked to the Everglades and the Florida Keys reef tract. A decline in water quality associated with rapid population growth in the South Florida area and the subsequent increase in polluted runoff have a synergistic impact on the downstream coral reefs of the Florida Keys. Degraded water quality is a major concern for coastal managers in South Florida and the Florida Keys.

Oyster reefs and shell banks in the South Atlantic are composed of oyster shell, live oysters and other organisms that are discrete, contiguous and clearly distinguishable from scattered oysters in marshes and mudflats. The American oyster *(Crassostrea virginica)* extends over a wide latitude. The ecological role of the oyster reef is to provide structure, food and protection, and to filter impurities from the water column. This role is the reason intertidal oysters are described as “keystone” species, defined as species that are critical to a healthy coastal ecosystem (NOAA, 1998a; 1998b).

Oysters form living intertidal reef structures that support a host of other associated organisms including but not limited to birds, shellfish, mammals and invertebrates. Oysters also filter water by depositing suspended sediments on the estuarine bottom and removing excess nutrients. Improved water clarity has many benefits, one of which is allowing recolonization and growth of submerged aquatic vegetation. Oysters and their reefs buffer wave action, thereby reducing erosion to salt marshes and adjacent uplands.

Intertidal flats are diverse along the South Atlantic coast. Considerable regional variability in tidal ranges causes the diversity in distribution and character of the estimated one million acres of tidal flat habitat. The constantly changing systems provide nursery grounds for early development of benthic species, refuges and feeding grounds for forage species of fish, and feeding grounds for specialized predators (NOAA, 1998a; 1998b).

Free flowing riverine systems are the historic preferred habitat of anadromous fish populations. However, through the

damming of most significant riverine systems, the historic ranges of anadromous fish populations have been greatly reduced. Pollution and the construction of dams have resulted in substantial loss and degradation of suitable spawning habitat. South Atlantic coastal stream habitat from North Carolina to Florida is estimated to have been reduced by 77 percent due to the construction of 6,944 dams. The riverine habitat historically utilized by anadromous fishes has been reduced from approximately 152,862 miles of unobstructed stream access to 30,168 miles of optimal stream habitat (Busch et al., 1998). In addition, habitat alterations from discharges, dredging or disposal of material into rivers, and related development activities directly affecting riverine and estuarine mudflats and marshes, remain constant threats.

Mainstream spawning and juvenile rearing habitat for anadromous fishes has specific physical and biological characteristics for the successful reproduction and survival of anadromous fish populations. Streambed hydraulics and substrate composition are the primary factors for successful spawning of anadromous fish species. Optimal anadromous fish habitat is found in areas with cobble and gravel substrate and appropriate water velocities to maintain high levels of oxygenated waters for spawning and to prevent the excessive buildup of fine sediments throughout the incubation stage of larval anadromous species. Substantial groundwater upwelling contributes to specific spawning and essential temperature requirements.

Water level fluctuations within a riverine system can have an adverse effect on developing embryos depending upon the developmental stage and duration of the water level changes. The river flushing rate affects aquatic productivity, which is typically high in free-flowing sections of mainstream rivers. Submerged aquatic plant species allow for increased diversity of food sources, which includes macroinvertebrates and zooplankton, and provides protective cover for developing juvenile fishes. Organism diversity decreases in reservoirs created through the damming of free-flowing rivers. Thermal regime is another important habitat requirement that is altered through the stratification of dammed reservoir waters and releases of altered water temperatures downstream from permanent structures.

Southeast Atlantic anadromous fish management efforts should take a holistic ecosystem approach. Habitat restoration efforts within primary watersheds of the southeastern Atlantic should specifically address the cumulative impacts from habitat loss due to damming and expand present-day population ranges back to historic ranges. Habitat restoration measures include dam removal, breeching of dam structures, installation of fish ladders, or constructing natural dam bypasses to ensure that optimal habitat is available for future populations of anadromous fishes.

Anadromous fish species commonly found in southeastern Atlantic waters include American shad *(Alosa sapidissima)*, hickory shad *(Alosa mediocris)*, blueback herring *(Alosa aestivalis)*, alewife *(Alosa pseudoharengus)*, Atlantic sturgeon* *(Acipenser oxyrinchus)*, Shortnose sturgeon** *(Acipenser brevirostrum)*, and the striped bass *(Morone saxatilis)*. A catadromous fish species (one that spends its adult life in freshwater and spawns in the ocean) found in southeastern Atlantic waters is the American eel *(Anguilla rostrata)*.

**The Atlantic sturgeon is a candidate species of federal concern.*
***The Shortnose sturgeon was federally listed as endangered in 1967 and is still endangered today*.

Habitat-Dependent Activities

Traditionally, forests have been the dominant land cover within the estuarine and coastal regimes of the southeastern U.S., accounting for about 33 percent of all land within the estuarine drainage areas. Agriculture accounts for 22 percent of the lands within estuarine drainage areas. Winyah Bay, Ossabaw Sound, Broad River and Indian River each have over 30 percent of their lands classified as agricultural (NOAA, 1990).

Although urban centers represent only about four percent of its estuarine drainage areas, Florida has a rapidly urbanizing coast extending north from Miami to Jacksonville at the mouth of the St. Johns River. The population in 126 counties of this region is projected to increase by more than 24 percent between 1988 and 2010 (NOAA, 1990). The southeastern U.S. coastal region continues to attract visitors and residents in increasing numbers, with consequent stress to and loss of the natural resources and habitats within these coastal and estuarine zones.

There are nearly 2,700 public outdoor recreation sites comprising about 5,200 square miles of land in this coastal region. Over 60 percent of these lands are managed for hunting, while about 32 percent are set aside for conservation, preservation and aesthetic value. Of the almost 900 public sites which provide access to the water, 61 percent are adjacent to estuarine waters and 36 percent provide access to the Atlantic Ocean. Florida has the largest concentration of private sites in the region (70 percent of the region's total) (NOAA, 1990).

Coral reefs are the major marine tourist attraction in the southeast. In the Florida Keys alone, coral reefs are credited with

generating $1.2 billion in tourism revenue each year from four million visitors (English et al., 1996). Economically and culturally important fisheries of the U.S. Virgin Islands and Puerto Rico (specifically reef fish, conch, lobster and aquarium species in trade) are completely dependent on reef habitats (Bruckner, personal communication).

Habitat Status and Trends

Based on an analysis of plans within the Southeast region, findings indicate that the major factors contributing to estuarine and coastal habitat loss and degradation include: logging, conversion to agriculture and development, hydrological alteration, and anthropogenic and natural threats. Table 1 summarizes some of the key past, present and future threats for all subregions of the Southeast.

Within private or public land, pristine areas and rare habitats in the Southeast Atlantic region have suffered significant losses, and human effects have permeated the region, rather than encroaching into the region along one or even several fronts (White et al., 1995).

Data from 1987 show that although 55 percent of the southeast region's land was forested, there was a downward trend and a decline of five percent since 1960 (U.S. Forest Service, 1988; Martin and Boyce, 1993). The rest of the land was used for crop and pasture (31 percent) and miscellaneous purposes (roads, towns, cities, airports: 14 percent). Urban areas were growing at the fastest rate (White et al., 1995).

Predictions of trends in land use include a decline in forest land by 15 percent over the next 50 years (with additional forest land converted from natural to plantation forests); a slight decline in agricultural land (with a continued shift from small to large farming operations); and an increase in urban areas. These predictions suggest that further habitat loss and fragmentation will occur near human population centers (Boyce and Martin, 1993).

In Georgia, the Savannah River has experienced the greatest human impact. Large dams, dredging and channelization have removed the vegetated flood plains in the freshwater tidal zone. It has been estimated that 78 percent of southeastern wetlands were lost between settlement and 1980 (Noss et al., 1995). Southern floodplain forests may constitute the largest remaining riparian habitat type in the United States. Estimates of extent vary from 25,482 square miles to 50,193 square miles. This areal extent is decreasing (0.51 percent per year from 1954 to 1974), with a total loss of about 63 percent. These forests have been converted to farmland, industrial parks and urban areas while levee construction, channelization, agricultural runoff, cattle grazing, timber extraction and invasions of non-indigenous species influence surviving stands (White et al., 1995).

Within the Southeast region, human activities have had a major effect on barrier island habitats over the past 50 years. Development has meant the construction of jetties and sea walls, filling and draining of marshes, and extensive dune stabilization and beach nourishment programs, all of which obstruct the natural fluctuations of the barrier island communities. Although there remain isolated stretches of protected barrier island beaches and dunes and intact salt- and freshwater marshes, nearly half of the area of these communities is estimated to have been lost (White et al., 1995).

Many birds have been negatively affected by development and human encroachment. Species that nest in bare sand can be disturbed by pedestrian and off-road vehicle traffic, and by the construction of artificial dunes. Loss of habitat due to coastal development also can have a detrimental effect on seabird and shorebird populations that may use mangroves, coastal and riparian forests, or dune vegetation to nest and roost.

Historically, the Florida Everglades system extended from Lake Okeechobee to Florida Bay. However, 50 percent of the original wetland area (3,861 square miles) has been drained and used for agriculture and development. The remaining area lies within impoundments of the South Florida Water Management District (White et al., 1995).

An exemplary study of landscape change in the historical Everglades (Davis et al, 1994) showed three of seven physiographic landscapes had been entirely eliminated (swamp or custard-apple forest, peripheral wet prairie, and bald cypress stand), and other landscape types had been reduced by 74 percent (sawgrass plains), 47 percent (sawgrass-dominated mosaic), 24 percent (southern marl-forming marshes) and 13 percent (wet prairie/slough-tree island-sawgrass mosaic). On the local scale, wet prairie and slough decreased by 25 percent, and sawgrass marsh increased by 33 percent, a change attributed to lower water levels. The study concluded that the factors responsible for the historical configuration of habitats were extended hydroperiods and slow water flow caused by the presence of extensive sawgrass marshes, punctuated by drought years with severe fires. However, due to man-made alterations in the natural hydrological flow, historic estuaries such as Florida Bay have been starved of freshwater, resulting in significant shifts in the natural ecosystem and subsequent seagrass die-offs.

Table 1. Key Threats in the Southeast Atlantic region

Threats	Description	Subregions
Agriculture	Conversion of wetlands to agricultural lands; direct and indirect nonpoint source discharges of fill, nutrients and chemicals; hydrologic modifications to create ditches, dikes and farm ponds; damage to wetlands and submerged lands by livestock; and cumulative and synergistic effects of these impacts.	N.C., S.C., Fla., Ga., Puerto Rico and U.S.V.I.*
Aquaculture	Dredging and filling of wetlands and other coastal habitats through the introduction of pens; nets and other containment devices; and introduction of waste products and toxic chemicals.	N.C., S.C., Fla., Ga., Puerto Rico and U.S.V.I.
Silviculture	Conversion of wetlands to production sites with related impacts similar to those listed for agriculture.	N.C., S.C., Fla., Ga., Puerto Rico and U.S.V.I.
Urban, suburban and coastal development	Conversion of wetlands and coastal habitats to sites for residential or commercial uses with some of the following associated impacts: direct and indirect nonpoint source discharges of fill, nutrients and chemicals; hydrologic modifications; damage to coastal dunes, wetlands and other sensitive habitats; and cumulative and synergistic effects caused by these impacts.	N.C., S.C., Fla., Ga., Puerto Rico and U.S.V.I.
Industrial and commercial activities	Impacts similar to those listed for agriculture and urban and suburban development.	N.C., S.C., Fla., Ga., Puerto Rico and U.S.V.I.
Navigation	Port construction and operation; channel dredging and stabilization projects; discharge of fuels or other chemicals; turbidity; ship groundings/prop damage/sinking in sensitive areas; and transfer of exotic species through ballast water discharge.	N.C., S.C., Fla., Ga., Puerto Rico and U.S.V.I.
Land subsidence and erosion		N.C., S.C., Fla., Ga., Puerto Rico and U.S.V.I.
Vessel operation	Impacts similar to those listed for navigation and gear-related impacts such as damage to coral reefs caused by the improper setting of anchors; mono-filament line and ghost nets (threatens marine and coastal species); propeller scarring (causes irreparable damage to seagrass habitat); and shrimp trawling (damages important benthic habitats).	N.C.**, S.C., Fla., Ga., Puerto Rico and U.S.V.I.
Inshore mining	Phosphate and marl mining.	N.C., S.C., Fla., Ga., Puerto Rico and U.S.V.I.
Hydrologic modifications	Mosquito control, agriculture, flood control projects, urban and suburban development, deprivation of freshwater from upland watersheds and saltwater intrusion.	N.C., S.C., Fla., Ga., Puerto Rico and U.S.V.I.
Dams, impoundments, barriers to fish passage		N.C., S.C., Fla., Ga., Puerto Rico and U.S.V.I.
Point and nonpoint source pollution	Pollutants, including chemical, sediment, stormwater source runoff, nutrients and bacteria.	N.C., S.C., Fla., Ga., Puerto Rico and U.S.V.I.
Natural events	Coastal storms, hurricanes, global warming and sea level rise.***	N.C., S.C., Fla., Ga., Puerto Rico and U.S.V.I.
Dumping	Burial of habitats with fill or debris; introduction of toxics and contaminants; and associated turbidity.	N.C., S.C., Fla., Ga., Puerto Rico and U.S.V.I.
Illegal cutting or removal of key species		N.C., S.C., Fla., Ga., Puerto Rico and U.S.V.I.
Adverse impacts associated with over-harvesting of resources		N.C., S.C., Fla., Ga., Puerto Rico and U.S.V.I.

**For Puerto Rico and the U.S. Virgin Islands, agricultural threats also include impacts associated with cattle grazing, such as degradation of wetlands and deforestation.*

***For N.C., vessel operation threats include impacts similar to those listed for navigation and gear-related impacts with the addition of impacts associated with damage from clam kicking and clam dredging.*

****Note that global warming and sea level rise are topics of extensive scientific debate regarding whether these phenomena are caused by natural climatic fluctuations, anthropogenic factors, or whether it may be a combination of the two.*

In addition to historic freshwater flow alterations, the Everglades are facing a number of threats: nonindigenous plant invasions and sea-level rise (sea level rise is occurring at a rate 6 to 10 times higher than in the past 3,200 years, possibly affected by global warming (Light and Dineen, 1994). Light and Dineen (1994) reviewed the role of agriculture in causing peat subsidence through increased oxidation of organic matter and suggested that the late 1900s may well have been the high point of agricultural production in the area because of the eventual loss of peat soils.

Upland outcroppings of limestone in south Florida support pine rockland and tropical hardwood hammocks that are unique in the continental United States (Snyder et al., 1990). The extent of these ecosystems has been greatly reduced by development and conversion to agriculture. Although wetlands have decreased by 40 percent to 50 percent since 1900, the more restricted upland pine forests have decreased by 80 percent (Robertson and Frederick, 1994). Most of the remaining stands of pine rockland and tropical hardwood hammocks in peninsular Florida are protected in Everglades National Park or by state or local governments. In contrast, most of the remaining undeveloped land in the Florida Keys is privately owned and likely to be developed, with the exception of that in the lower Keys lying within national wildlife refuges. Even where upland vegetation is protected, species survival is not guaranteed. Fire is essential to the management of pine rockland vegetation, and pine and tropical hardwood hammocks are severely threatened by invasions of nonindigenous animal and plant species (Snyder et al., 1990).

There are about 780 square miles of mangrove forests in Florida (Gilmore and Snedaker, 1993). Odum and McIvor (1990) reviewed data that indicated a loss of about 2.5 percent of the mangrove habitat between 1943 and 1970 in the three counties with the highest original total. Overall areal extent of this habitat has been reduced by coastal development (draining and filling for urban areas and mosquito control); reductions in freshwater flow because of diversion of runoff from inland areas; invasion of nonindigenous species; port development; and natural causes such as tropical storms and hurricanes.

There were nine square miles of mangrove in the U.S. Virgin Islands and Puerto Rico in 1995, an increase of 61.2 percent since 1936. Marsh areas in 1995 were three square miles, a decrease of 42.2 percent since 1936. Combined, there was a gain of 1.5 square miles or about 20.6 percent. The apparent gain of mangrove forest could be the result of a successional change from one type of habitat to another due to natural and/or human influences. By 1936, significant impacts to the wetlands of the area had occurred due to sugar cane plantations. The increase in wetland area corresponds to the natural regeneration process following abandonment of agricultural activities.

Coral reefs in the Southeast Atlantic region are subjected to greater stress than anywhere else in the United States. Human impacts tend to be significant because of large, concentrated coastal populations located in sensitive areas. Land runoff and coastal pollution problems introduce sediments, pesticides, sewage, fertilizers and heavy metals into coral habitats, particularly where large populations are centered close to reefs. Vessel groundings, anchor damage and tourism impacts are more prevalent throughout the southeastern U.S. and the Caribbean islands because of high levels of recreational activity by residents and visitors (Bruckner, personal communication).

Regional Planning Efforts

Within the region, some programs and plans encourage a regional approach to restoration planning. Some examples are described below. A list of plans can be found in the National Strategy Restoration Plan Database (http://restoration.nos.noaa.gov).

Habitat Plan for the South Atlantic Region: Essential Fish Habitat Requirements for Fishery Management Plans of the South Atlantic Fishery Management Council

In order to address the new essential fish habitats mandates in the Magnuson-Stevens Act, the South Atlantic Fisheries Management Council began development of a habitat plan that will serve as a source document describing essential fish habitat; a comprehensive amendment to each of the existing fishery management plans; and a monitoring program for each fishery management plan to determine new impacts from fishing gear and practices that will have an adverse affect on essential fish habitat. The description of essential fish habitat in the Habitat Plan includes estuarine inshore habitats, mainly focusing on North Carolina, South Carolina, Georgia and Florida (east coast), as well as adjacent offshore marine habitats (coral reefs, coral, live and hard bottom habitat, artificial reefs, Sargassum habitat and the water column).

Partners In Flight

Partners In Flight (PIF) is a consortium of public and private organizations and individuals working to conserve land birds throughout the Western Hemisphere. PIF's guiding principles are to restore populations of the most imperiled species and to prevent other birds from becoming endangered. A comprehensive set of regional Bird Conservation Plans for land birds in the continental U.S. was completed by the PIF partnerships in

2000. Bird Conservation plans which cover the southeast include the South Atlantic Coastal Plain Plan; the Peninsular Florida Plan; and the Subtropical Florida Plan.

North American Waterfowl Management Plan

In 1986, the United States and Canada signed the North American Waterfowl Management Plan (joined by Mexico in 1994). This international agreement challenged conservationists in North America to restore waterfowl populations to 1970s levels. Most importantly, it directed that this be accomplished by creating sustainable landscapes for waterfowl using unprecedented partnerships among the federal, state and private sectors. This constituency facilitated the passage of the 1989 North American Wetlands Conservation Act, the primary funding tool for habitat conservation under the plan. Within the Southeast Atlantic region, the Atlantic Coast Joint Venture includes the states of Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia and Florida.

Plan Elements

Goals

The review of restoration plans identified similar goals among restoration efforts. These goals include: formation of partnerships and cooperative efforts; development of (or identification of the need for a strong scientific basis for restoration efforts; setting priorities within the geographic zone or range; defining the appropriate geographic scale for given restoration goals; planning with an ecological approach; and developing a clear understanding of the possible causes and effects of habitat loss and degradation.

Methods

Several restoration plans with a regional focus provide some information on methods that have been used or recommended for achieving the region's restoration goals. The methods are categorized by key habitats and briefly outlined below:

1. **Estuary intertidal.** Restoration or creation most often involves designing the project site with appropriate hydrology, tidal exchange and sediment properties to support continued growth of marsh species. Physical modification of a site is followed by planting, most often Spartina alterniflora or Spartina patens. Restoration of intertidal marsh also is accomplished by removal of the impediment to tidal exchange (e.g., removal of shoreline hardening structures such as bulkheads, dikes or fill).

2. **Mangrove ecosystems.** Mangrove habitat restoration techniques have evolved over time. Shortfalls in early restoration attempts have been identified and can be avoided by proper restoration planning. The single most important factor in designing a successful mangrove restoration project is determining the hydrology (frequency and duration of tidal flooding) typical of existing mangrove plant communities near the restoration site (Lewis and Streever, 2000). Although mangrove restoration techniques still require further development, there are some examples of effective restoration methods that have been applied in the field. One method involves the use of PVC pipes to stabilize mangrove propagules and protect them from washing away (this is known as the Riley Encased Methodology). Another more recent technique that is being tested is the use of burlap, whereby four or five propagules may be placed on a section of burlap so that the roots of the propagules intertwine and protect one another from washing out.

3. **Seagrass (submerged aquatic vegetation).** Most effective techniques involve transplantation of species (e.g., from nursery-grown shoots or existing seagrass beds). Most effective restoration occurs within protected coastal lagoons, behind protection of barrier islands. An innovative approach to seagrass restoration in South Florida entails the use of temporary bird-roosting stakes for fertilizer-enhanced seagrass recolonization (http://shrimp.bea.nmfs.gov/~mfonseca/lvfinalreport.pdf – report by Kenworthy et al.). Restoration of propeller scars and "blowholes" from vessel groundings are accomplished by replacing lost sediment coupled with seagrass transplanting. Efforts are increasing to protect seagrass habitats by proactive management (avoid impacts and/or losses). Research continues to evaluate current techniques and develop new approaches (e.g., clonal development).

4. **Oyster reefs and shellbanks.** Restoration efforts most often involve the eastern oyster, Crassostrea virginica. Restoration or enhancement involves both the distribution of clean shell material as settlement substrate for juvenile shellfish larvae and "seeding" with sub-adult stage oysters. If oysters are naturally occurring in an area, oyster spat will colonize cultched area; however more intensive restoration of all life phases of oysters may be needed in areas devoid of active oyster population. Widespread presence of pathogens such as Dermo and MSX may present problems with transplantation of oysters.

5. **Tidal flats.** While tidal flats have some legal protection as vegetated intertidal areas, permits have been relatively easy to obtain for dredging and/or filling of these habitats. Restoration involves removal of fill (if filled) or restoration

of appropriate grades by filling (if dredged).

6. **Coral, man-made reefs and live/hard bottom.** Most restoration efforts focus on artificial reef enhancement or construction. North Carolina, South Carolina, Georgia and Florida have or are developing artificial reef management plans. Until the 1980s, bundled automobile tires were most often used, but this practice was discontinued due to stability problems. Materials most often used to construct artificial reefs include boating vessels, large diameter concrete pipe, train cars, bridge railing and rubble. Guidelines for Marine Artificial Reef Materials, published by the Gulf States Marine Fisheries Commission, provides details on experiences and drawbacks of past uses of materials used for restoration and enhancement projects. Habitat enhancement through the construction of man-made reefs can be achieved by conversion of mud, sand, shell or other soft bottom habitats into hard bottom communities by the addition of hard structure with low or high relief.

   Coral reef restoration projects also focus on repairing corals damaged by ship groundings. An example is the NOAA Fisheries Mona Island coral reef restoration project in Puerto Rico. After a merchant vessel known as the M/V Fortuna Reefer ran aground on a shallow-water fringing reef dominated by elkhorn coral (*Acropora palmata*) off Mona Island, scientists used an innovative method of reattaching and stabilizing broken pieces of coral. Loose branches of coral were secured to the reef buttress and to existent relic Acropora framework using stainless steel wire and nails, permitting timely removal of injured coral from sand areas where they were being smothered. It also minimized abrasion damage to broken coral pieces from swell and wave motion. A number of stabilization techniques were tested, and it was determined that the best method consisted of drilling holes into the reef, driving nails into the holes, and wiring corals to the reef. At the conclusion of the restoration effort, 1,857 coral fragments had been stabilized, and monitoring stations to track the success of the restoration effort had been established.

7. **Anadromous fish passage corridors.** Most common techniques involve the removal of a dam (e.g., Quaker Neck Dam in North Carolina) or other obstruction to fish migration. Other methods include the installation of fish passage structures (dam notches, fish ladders, elevators, baffles, appropriately-sized culverts, step pools) to facilitate fish passage where obstructions cannot be removed. Restoration of formal hydrologic conditions may be accompanied by active stream or shoreline restoration which includes replanting and/or reestablishment of natural in-stream morphology.

8. **Beach and dune ecosystems.** Restoration of beaches most often involves placement of sand or nourishment by various methods, such as offshore dredging and disposal with hopper or mechanical dredges, or hauling of material to site and spreading by bulldozer. The use of bulldozers to redistribute sand in post-storm periods is a very common practice in the hurricane-prone southeast region. Beach bulldozing, or "scraping," most often is designed to move overwash materials back onto a beach or to move sand eroded into the intertidal zone during a storm to re-establish a dune line. Dune planting most often accompanies beach scraping, and involves planting dune flora such as Ammophila breviligulata and/or Uniola paniculata. The practices of beach nourishment and beach scraping are not universally accepted as viable habitat restoration practices. It is generally agreed that new technologies need to be explored. The benefits versus the adverse impacts to beach and dune species as a result of beach nourishment is currently a topic of research and debate within this region.

9. **Bird corridor and ecosystems restoration.** Restoration efforts included within the various conservation plans and programs (outlined under the North American Bird Conservation Initiative in the U.S.) involve a suite of restoration methods and options including both habitat preservation principles (through purchase of lands or conservation easements) and active restoration techniques designed to restore and/or enhance bird habitats (e.g., improving impoundment construction and management, establishing forested "greenways" or planting riparian buffers, removal of impediments to habitat access such as shoreline hardening structures, or contaminants.).

Elements of Success

Of the documents reviewed with a regional planning focus, most efforts emphasize the need for partnerships, education and outreach efforts (depicting the benefits derived and importance of habitat restoration), and having adequate and sustained funding for restoration efforts that go beyond a project-level approach. The use of best available technology, both for the planning and implementation phases of restoration efforts, was mentioned as key to successful efforts. Plans also emphasized the need for incorporation of restoration into larger, watershed or basin level efforts, together with meaningful prioritization of key habitats and species, and well-defined pre- and post-construction monitoring, to guide needed research and adaptive management efforts.

Information Needs

Regional habitat restoration plans cite the following information needs as significant to achieving long-term restoration goals:

- **Ecosystem structure and function:** More research is needed to understand the structure and function of natural ecosystems, their linkages to one another, and the role they play in supporting and sustaining living resources, their abundance, distribution and health. Knowing when and how systems are affected, assessing the cause and degree of impact, and providing the basis for restoring and maintaining these systems are integral to this research area.

- **Effects of habitat alterations:** Quantification of the causes of damage to ecosystems is critical to restoration and prevention of future losses. There also is a need to quantify the response of habitats and living resources to natural and anthropogenic alterations.

- **Habitat restoration methods:** Many methods for restoration have not been rigorously tested under experimental conditions throughout wide geographic ranges and at different scales (e.g., salt marsh restoration). For other habitats (e.g., coral reefs, riparian habitat, intertidal substrates) only limited methodology exists; little emphasis has been placed on rapidly restoring biodiversity and monitoring for success and persistence. Research areas and areas of concern include analyses of the successes of contaminant sequestration, assessment of bioremediation techniques, development and evaluation of new restoration techniques, experiments on transplant species culture techniques, and evaluation of the role and size of buffers and the importance of habitat heterogeneity in the restoration process.

- **Indicators of habitat and living resources impacts and recovery:** There is a need to develop indicators to determine whether an ecosystem, habitat or living resource is healthy, degraded or recovering. The development of indicators must be based on information derived from comparative research on the structure and function of disturbed, natural and/or restored habitats of different ages and geographical locations for a suite of biological, chemical and physical parameters; time-dependent biotic populations analyses; and contaminant level follow-up evaluations for sediment, biota and water.

- **Synthesis and information transfer:** Synthesis and timely transfer of information derived from research findings and the existing literature is a key element of the essential fish habitat research and monitoring program. Decisions on permitting, regulations, enforcement, redirection of research efforts and development and implementation of restoration plans must be made with best available data.

- **Implementation:** The elements listed above must be interlinked to provide a framework for effective research and management. Research on ecosystem structure and function must be known in order to effectively determine the effects of habitat alteration, develop restoration methods and develop indicators of impact and/or recovery.

- **Better science and information:** In order to maximize the biological diversity that exists in the southeast, a better understanding of the following issues is required.
  - Sensitivity of species to habitat fragmentation and the persistence of species in agricultural landscapes of various types.
  - Roles of hydrological regimes and fires of various intensities and in different seasons.
  - Ways to avoid future nonindigenous species problems and to control the problems that already exist.
  - Sustainable methods and levels of harvest, both for target species and for non-target species that are affected by harvest.
  - Ways to propagate species taken directly from the wild to avoid damage to surviving natural areas.
  - Ways to develop off-site gene and species banks as last resorts for the rarest and most threatened species.
  - Ways to restore natural processes and whole systems on the ubiquitous degraded lands in the southeast.
  - Ways to predict the varying sensitivities of ecosystems and species to sea level rise and climatic change.

Southeastern Atlantic Subregions

From a primarily ecological standpoint, the Southeast region can be divided into several bioregions: the South Atlantic coastal plain, Peninsular Florida, Atlantic Coastal Florida and the U.S. Virgin Islands and Puerto Rico.

Although these areas may be grouped by biological and geological similarities, *A National Strategy* adopts state-by-state subregions to identify and characterize the estuarine drainage areas and coastal subregions in the Southeast Atlantic region. The analysis of the region's status and trends, threats, and ongoing restoration efforts are best understood within a state-by-state framework.

The following sections summarize the habitat issues and highlight certain restoration planning efforts for each of the South-

east Atlantic subregions. Detailed information and additional plans are available in the National Strategy Restoration Plan Database (http://restoration.nos.noaa.gov).

North Carolina Subregion

Description

North Carolina encompasses 2.2 million acres of sounds, creeks and marshes, and nearly 4,400 miles of estuarine shoreline. The state includes eight coastal river basins, which provide spawning habitat for a number of anadromous species of fish. Approximately 50 percent of the fish caught on the east coast of the United States depend upon North Carolina's estuarine system at some point in their life cycles. Of the nearly five million acres of wetlands located in North Carolina, over 95 percent are found in the 41 counties that make up the Coastal Plain (Holman and Childres, 1995).

Within North Carolina, the Albemarle-Pamlico Estuary (APES) is a huge complex of shallow sounds, rivers and wetlands. With a total water area that exceeds 2,900 square miles, it is the second largest estuary system in the country. APES is composed of seven sounds (Albemarle, Currituck, Croatan, Pamlico, Bogue, Core and Roanoke) and is drained by several major river basins. The entire APES region consists of 1.8 million acres of brackish estuarine waters (Albermarle-Pamlico Estuarine Study, 1990).

The sounds of North Carolina are uniquely characterized by wind-driven tides that affect circulation patterns within the sounds and saltwater concentrations in their tributaries.

Habitat Issues

Status and Trends

Within North Carolina estuaries, fish landings, seagrass beds and catches of clams, oysters and bay scallops have all experienced declining trends due in part to overfishing, eutrophication, sediment loadings and other pollution. Throughout North Carolina, the areas closed to shellfishing as a result of long-term pollutant monitoring increased by nearly 40,000 acres over a thirteen-year period (NCDENR, 1999). This increase can be attributed to increased nonpoint source pollution loads in rapidly growing regions. Pressure on sensitive ecosystems has resulted from increased coastal development. Currituck, Dare, Hyde, Carteret, Onslow, Pender, New Hanover and Brunswick counties experienced a population increase of 32 percent between 1977 and 1997.

Threats

Key threats for this subregion are listed in Table 1. Urbanization and population growth have led to greatly increased nonpoint source pollution of coastal waters. Point source discharges are increasing as well. In the Cape Fear Basin alone, there are 641 licensed point source discharges (NCDENR, 1999). Eighteen of North Carolina's 26 commercially important fish species are exhibiting signs of stress from overfishing or environmental degradation (Center for Watershed Protection and Land Ethics, Inc., undated).

Within North Carolina, pollution from stormwater and marinas has resulted in the permanent closure of 56,000 acres of shellfish waters. Since 1990 more than 1,000 acres of Outstanding Resource Waters, so designated because of their superior quality, have been closed to shellfishing. State reporting indicates that nonpoint source pollution is thought to account for 85 percent of the total impaired acreage (NCDENR, 1999).

Restoration Plans

Albemarle-Pamlico Comprehensive Conservation Management Plan (CCMP)

As part of the National Estuary Program, the Albemarle-Pamlico Estuary (APES) was identified as a significant estuary threatened by pollution and development. The Albemarle-Pamlico CCMP is a comprehensive plan for conservation and management of the estuary. The plan promotes regional planning to protect and restore the natural heritage of the APES region. It has been partially implemented through the development of new programs and eight coastal basin-wide plans.

North Carolina Wetlands Restoration Program (NCWRP) and Associated Plans

The NCWRP was created as a nonregulatory program for the acquisition, maintenance, restoration, enhancement and creation of wetland and riparian resources. Its purpose is to restore degraded wetlands and riparian areas throughout all of North Carolina's river basins to compensate for the loss of vital functions and values that have occurred through wetlands conversion. The NCWRP developed restoration plans for all eight coastal river basins in North Carolina, and is pursuing restoration projects in accordance with those plans.

North Carolina Estuarine Research Reserve Management Plan

The North Carolina Estuarine Research Reserve was established in 1985 and currently encompasses 10,000 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1998. Important habitats at

the four reserve components that may be useful for investigation and as reference sites include maritime forests, shrub thickets, freshwater, brackish, and saltwater marshes; mud and salt flats, sandy beaches, oyster bars and subtidal vegetation. Restoration priorities include serving as a reference site and assessing invasive species control, especially for Phragmites.

Watershed Restoration Action Strategy (WRAS) by the Environmental Protection Agency

The WRAS process is intended to integrate existing state, local and federal programs in a coordinated way with local and regional group activities to speed up response and treatment of impaired waters. North Carolina has used this program to heighten the visibility of watershed issues and to funnel grant funds to watersheds such as the Bogue and Core Sounds that are high priorities for restoration.

Coastal Habitat Protection Plans

A key provision of the 1997 Fisheries Reform Act of North Carolina was to create protection plans for key fisheries habitats such as ocean waters and estuaries. The plans are being prepared through an interagency agreement between the Coastal Resources Commission, Marine Fisheries Commission and the Environmental Management Commission. Once complete, the goal of the plans is long-term enhancement of coastal fisheries associated with each coastal habitat. Plans must be prepared by 2003 for the Chowan River, Coastal Ocean, Southern Estuaries, Tar-Pamlico River, Roanoke River, New and White Oak Rivers, Albemarle Sound, Core and Bogue Sounds, Neuse River, Pamlico River and the Cape Fear River.

Plan Elements

Goals

Goals of North Carolina restoration plans include fish and wildlife habitat protection and restoration, as well as restoration and protection of water quality. Both degraded and non-degraded areas are targeted.

Methods

Implementation methods include marsh plantings, wetlands construction, shellfish bed plantings and acquisition of key areas. Many of the efforts are locally driven with support from state and federal agencies. Other efforts include attempts to simplify or modify the regulatory process primarily for shoreline setbacks, bulkheading, buffers and impervious surfaces. In addition, watershed-based planning for pollution prevention is recommended. Public-private partnerships also are common.

Elements of Success

In North Carolina, common elements of success include shoreline grading and marsh planting, sometimes including the use of stone sills in addition to the plantings; wetland creation; and oyster bed plantings. These efforts have been successful in part because of public/private cooperation and partnerships in project planning and implementation. Public participation and education is key for successful implementation.

Information Needs

Key information needs in North Carolina include continued project monitoring and testing of techniques. The greatest challenge ahead in coastal habitat restoration is grappling with global warming and consequent sea level rise.

South Carolina Subregion

Description

The coastal zone of South Carolina encompasses approximately 8,116 square miles and ranks fourth nationally in its acreage of salt marsh estuaries. There are 187 miles of ocean beaches, with 2,876 miles of shoreline around its estuaries, bays, rivers and creeks.

South Carolina estuaries account for almost one-sixth of all salt marshes on the east coast of the United States. These wetlands are dominated by salt marsh cordgrass *(Spartina alterniflora)*. It is estimated that South Carolina's wetlands include 540,445 acres of total coastal marsh, 344,500 acres of salt marsh, and approximately 4.5 million acres of total freshwater wetlands (NOAA, 1979).

Included among South Carolina's freshwater wetlands are approximately 79 coastal impoundments totaling 70,000 acres of impounded coastal marshes. Unique rice field impoundments, dating back to when rice culture was common, attract waterfowl. These former rice fields have been identified for protection under the *North American Waterfowl Management Plan.* Within the Ashepoo-Combahee-Edisto Basin, these rice fields also have been identified for protection under the Nature Conservancy's Last Great Places Program. This system is the largest of its type in the state, with over 3,300 acres of managed impoundments.

North Inlet/Winyah Bay is unique in that it has one undisturbed estuary (North Inlet) and one influenced by human activity (Winyah Bay). Of the 17 estuaries in the state, Winyah Bay is the most important in terms of freshwater marshes, containing nearly 35 percent of South Carolina's freshwater marshes.

Habitat Issues

Status and Trends

The coastal region of South Carolina has experienced a 40 percent population increase in the past 20 years. The population of urban areas has increased 250 percent within this same period (South Carolina Coastal Conservation League, www.scccl.org/programs/programs.htm). This rise in population, along with increased tourism, has altered habitats and water quality.

Significant trends within the coastal zone of South Carolina include hydrologic modifications and conversion of habitats for human uses. Urban expansion has led to conversion of wetlands in various locations, most notably in the areas around Hilton Head, Charleston, North Charleston and in the vicinity of Myrtle Beach and Columbia. Hydrologic modifications include multiple rice field impoundments covering 70,451 acres of land (NOAA, 1979).

Diversion of the Santee River into the Cooper River occurred in 1941 when the Works Progress Administration completed the Santee-Cooper Hydroelectric Project. This effectively increased the drainage area of the Charleston Harbor Estuary by eleven times the original area. The Cooper River was transformed from a tidal slough to a riverine system, and massive shoaling resulted from the project. To alleviate this problem, the Cooper River Rediversion Project diverted approximately 70 percent of the Santee drainage water back into the Santee River through the canal (South Carolina Department of Health and Environment Control, 2000).

Wetlands are being altered or destroyed due to increasing residential, commercial and industrial development, as well as changing forestry practices. South Carolina has been relatively successful in protecting its tidal wetland resources, and has retained approximately 73 percent of its historic acreage. Although tidal wetlands have been relatively well protected, significant losses have occurred in freshwater nontidal areas. Within South Carolina's estuaries, nearly one-third of the shellfish areas are permanently closed (USES, 2000).

Threats

Key threats for this subregion are listed in Table 1.

Restoration Plans

Ashepoo-Combahee-Edisto (ACE) Basin National Estuarine Research Reserve Program

The ACE Basin National Estuarine Research Reserve was established in 1992 and currently encompasses 140,000 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1992. Important habitats that may be useful for investigation and as reference sites include forested flood plains; fresh, brackish and saltwater marshes; oyster reefs; bird keys and banks; and maritime forests. Restoration priorities include restoring flow to a salt marsh bisected by a road, restoring native terrestrial plants and shellfish habitat, and controlling invasive species. Current restoration projects include shellfish habitat restoration and prescribed burning.

Charleston Harbor Plan

The Charleston Harbor Plan calls for establishment of: vegetated buffers with a minimum average width of 50 feet for all development bordering tidal creeks and rivers; wetland master planning to protect wetlands smaller than one acre; and wetland land banks that would include isolated wetlands. The plan is to be implemented at the local level. It encourages governments to develop mechanisms to allow collection of funds to acquire areas for public recreation and resource conservation. The plan also examines the utilization of oyster shells for erosion control to benefit shoreline and marsh protection; the capacity for the growth of a complex, three-dimensional intertidal habitat; and propagating shellfish restoration.

North Inlet/Winyah Bay National Estuarine Research Reserve

The North Inlet/Winyah Bay National Estuarine Research Reserve was established in 1992 and currently encompasses 12,327 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1992. Important habitats that may be useful for investigation, especially as reference sites, include abandoned rice fields and canals, tidal creeks, brackish and saltwater marshes, mud flats, sand bars, intertidal oyster reefs and shallow sounds. Restoration priorities lie mainly in invasive species control, especially crustaceans and *Phragmites.* No restoration projects are currently underway, as the North Inlet system remains in a relatively natural, pristine state. Reserve staff members have participated in oyster reef restoration efforts that have taken place outside reserve boundaries.

Wetland Restoration Project

As part of the recent Coastal Program Improvement Project, NOAA's Office of Coastal Resource Management (OCRM) identified areas for potential restoration along the New, Waccamaw and Ashley Rivers. To accomplish this, OCRM has developed the South Carolina Coastal Stream Corridor Restoration Initiative. The initiative focuses on stormwater

management and channelization, and impacts on riparian habitat. Assistance from NOAA and EPA will help to develop an ongoing program of technical assistance and guidance for local governments in the identification and restoration of impaired stream corridors and associated wetlands.

Oyster Habitat Restoration/Enhancement Plan
This restoration plan will help reduce shoreline erosion, improve water quality, and provide additional refuge, spawning areas and habitat for prey species. The community-based Oyster Habitat Restoration and Enhancement Plan is a cooperative effort between the South Carolina Department of Natural Resources (SCDNR) and local and state partners to involve citizens, schools and community organizations in oyster habitat restoration projects. Funding for this effort came from NOAA's Community-Based Restoration Program, Five Star Challenge Grant, the Hilton Head Island Foundation, and South Carolina Sea Grant. Partners include Charleston Math and Science Hub, South Carolina Aquarium, South Carolina Coastal Conservation League, SCDNR, Sea Grant, and the University of South Carolina. Components include building oyster habitats, shell recycling, educational activities and related research.

The Wetlands Reserve Program
The Wetlands Reserve Program is a voluntary program to restore and protect wetlands on private property. It is an opportunity for landowners to receive financial incentives to enhance wetlands in exchange for retiring marginal agricultural land.

Santee-Cooper Basin Diadromous Fish Passage Restoration Plan
This management plan provides a framework for rebuilding populations of the basin's diadromous fish. Some of the target species include American shad, hickory shad, Atlantic sturgeon, shortnose sturgeon and striped bass. These species historically ascended the Santee River and its tributaries to locations above the fall line. Some species even traveled into North Carolina. In the eastern U.S., the Santee-Cooper Basin is second only to the Susquehanna River Basin in terms of drainage area and volume of flow. The basin's diadromous fish stocks are significantly depressed relative to historic levels. This plan seeks to restore diadromous fish populations by eliminating or reducing migration blockages and habitat alterations caused by dams. The USFWS, NOAA's National Marine Fisheries Service, and the SCDNR have developed this plan. To implement the plan, development of partnerships is envisioned. Prospective partners include state and federal resources agencies, the U.S. Army Corps of Engineers, Santee-Cooper Public Service Authority, South Carolina Electric and Gas Company, Duke Power Company, local governments, the private sector, and others who manage, use, or enjoy the publicly-owned water resources of the Santee-Cooper Basin.

Plan Elements

Goals
Goals of South Carolina restoration plans include stormwater management, erosion reduction, natural vegetated buffer maintenance and oyster bed habitat restoration for the protection of the ecological and consumptive values of the resource. In addition, South Carolina is conducting research to use as a scientific basis for habitat restoration.

Methods
Implementation methods for restoration in South Carolina include oyster bed plantings, acquisition of stream banks, wetland creation and financial incentives for private wetlands protection.

Elements of Success
Oyster reef plantings and restoration of mosquito impoundments have been successful in South Carolina. Partnerships are key to the success of these projects.

Information Needs
In South Carolina, there is a need to study the impact of the restoration of impoundments on seagrasses due to changes in hydrology. Oyster reefs are treated as a fishery resource rather than a habitat. Mudflats and beaches are often neglected in restoration planning despite the important ecosystem functions they serve.

Georgia Subregion

Description
Georgia is comprised of five estuaries: the Savannah, Ogeechee, Altamaha, Satilla and St. Marys Rivers. The Altamaha is the largest river of the Georgia coast and the second largest basin in the eastern United States (Georgia Rivers LMER, http://wiegert.marsci.uga.edu). It is a relatively undisturbed analogue of the Savannah River, with no major channelization, dredging or reservoirs.

The Georgia coastline is approximately 100 miles long. The coastline consists of a chain of barrier islands separated from the mainland by a four- to six-mile wide band of coastal marsh.

Habitat Issues

Status and Trends

The Georgia coastline is relatively unaffected by the heavy development that has been seen in other areas of the south Atlantic coast in recent years, and Georgia's barrier islands and marshes have been less altered by human activity than in most other coastal areas. Development has largely been of a residential or recreational nature and has usually had a minimal effect on salt marshes. In earlier days, considerable alteration of many marshes near the barrier island uplands was due to cultivation of sea-island cotton. Even though U.S. Highway 17 was paved through coastal Georgia in 1926, only four barrier islands have road access from the mainland. Seven of the 14 barrier islands are in federal ownership, and thus protected from heavy development and loss of habitat areas.

Threats

Key threats for this subregion are listed in Table 1.

Restoration Plans

Sapelo Island National Estuarine Research Reserve Management Plan

The Sapelo National Estuarine Research Reserve was established in 1976 and currently encompasses 6,111 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1999. Important habitats that may be useful for investigation and as reference sites include maritime forests, freshwater ponds, sloughs, salt marshes, and barrier island beaches and dunes. Restoration priorities include maritime forest and ephemeral wetlands restoration, rare endemic habitat restoration (e.g., longleaf pine, pond pine habitats); hydrologic, terrestrial and associated freshwater habitat; wetland reclamation by restoration of natural hydrology; dune stabilization and restoration; invasive plant control and invasive species control (e.g., popcorn trees, feral hogs). Current restoration projects include rare and endemic habitat restoration, selective timber harvest, maritime forest restoration and prescribed burning. Comprehensive mapping and monitoring of oyster reef habitat and biology, and high marsh plant community interaction have been conducted to identify restoration needs in these areas.

Basinwide Plans

To date, draft basin-wide plans for coastal river basins do not specifically address coastal habitat restoration except to mention the Department of Natural Resources and Wildlife Resources Division's land acquisition program that began in 1987 to acquire 60,000 acres of additional land for Wildlife Management Areas and Public Fishing Areas. This initiative was funded by $30 million of 20-year obligation bonds to be paid off by hunting and fishing license increases and Wildlife Management Area permit fees.

Preservation 2000 and River Care 2000 Programs

The Land, Water, Wildlife and Recreation Heritage Fund will derive funding from an increase in the real estate transfer tax to $2 per $1000, generating more than $30 million each year. 1998 legislation authorizes the fund to be used to purchase land to protect and preserve natural wildlife habitat, river corridors and wetlands along major rivers.

Altamaha Buffers

The state of Georgia, along with International Paper and Georgia-Pacific, will protect nearly 300 feet of buffers along the Altamaha River at a cost of $1.4 million in state funds. The state purchased timber rights from the companies. In addition, the paper companies will fund The Nature Conservancy of Georgia over a five-year period to direct research projects on the river.

Georgia Wetlands Trust Fund (GWTF)

Created in 1997 in an agreement between the U.S. Army Corps of Engineers and the Georgia Land Trust Service Center, the GWTF provides alternatives to wetland mitigation requirements by allowing an alternative to provide money to the GWTF to purchase wetlands. The GWTF currently focuses on preservation with some limited restoration.

Plan Elements

Goals

Goals of Georgia restoration plans primarily include reinstatement of natural processes that have been significantly disrupted. There are very limited restoration goals for the Georgia coast.

Methods

Current methods primarily include the use of existing regulatory programs. In addition, acquisition programs as a form of habitat protection are being adopted and implemented.

Elements of Success

In Georgia, shorelines are primarily managed by the Coastal Marshlands Protection Act. Conservation easements are a successful technique for ecosystem protection but for the most part there is very little restoration occurring in Georgia.

Information Needs

Of the plans reviewed for this subregion, no information needs were identified.

Florida Subregion

Description

This coastal subregion includes peninsular Florida extending from the northern edge of Lake Okeechobee north to the transitional zone around the Suwanee River in northern Florida, and from the northern edge of Lake Okeechobee south through the Florida Keys, including the Everglades and Florida Bay. The region has very little topographic relief, but slight changes in elevation have important consequences for vegetation and the diversity of habitat types. The South Florida and Florida Keys region contains one of North America's most diverse assemblages of terrestrial, estuarine and marine fauna and flora and represents one of the most complex ecosystems on earth.

Within Florida, the Indian River Lagoon (IRL) is located in the zone where tropical and temperate climates meet. Flora and fauna include tropical and subtropical species that cannot survive in colder climates in addition to species that thrive in cooler weather. This has resulted in more species and a wider range of species than in any other American estuary. The IRL covers 40 percent of the east coast of Florida. Since 1916, human activities have resulted in the enlargement of the lagoon's watershed from 572,000 acres to more than 1.4 million acres—an increase of 146 percent. The IRL is located along the Atlantic Flyway, a route used by millions of birds that migrate between eastern North America, South America and the Caribbean.

The South Florida and Florida Keys region includes mangrove-fringed shorelines, mangrove islands, sea grass meadows, hard bottom habitats, thousands of patch reefs, and one of the world's largest coral reef tracts. The Keys are made up of over 1,700 islands encompassing approximately 103 square miles. They have a shoreline length of 1,857 miles and are permanently inhabited from Soldier Key to Key West.

The largest seagrass bed yet documented (5,792 square miles) occurs off the south Florida coast (www.fiu.edu/~seagrass/). Seagrasses in Florida Bay have been adversely impacted by a decrease in freshwater inflow due to upstream hydrological alterations resulting in a massive seagrass die-off in 1987. The Comprehensive Everglades Restoration Plan proposes in part to restore freshwater inflow from the Everglades into Florida Bay.

Habitat Issues

Status and Trends

Rapid urbanization and associated coastal development in southeastern Florida over the last 100 years have virtually eliminated the low coastal wetlands along approximately 21 miles of mainland shoreline and approximately 12 miles of barrier island shoreline bordering Biscayne Bay. These estuarine ecosystems have been replaced by eroding, altered shorelines or hardened shorelines with numerous bulkheads (Milano, 1999).

In southeastern Florida, development of reclaimed swamp lands, uplands and newly created lands produced by dredging and filling practices essentially began with the completion of the Florida East Coast Railroad in 1896. This, and networks of draining, caused serious environmental degradation to southeastern Florida's coastal wetlands and estuaries.

Dredging and filling in the early 1900s to create navigation channels and harbors in Biscayne Bay resulted in over 20 human-made spoil islands and two partially filled natural mangrove islands. Dredging, draining and diking of the river systems leading into and out of Lake Okeechobee occurred in the 1950s with the implementation of the Central and Southern Florida (CS&F) Project under the Flood Control Act of 1948. The first phase of the CS&F Project was undertaken for flood control, water level control, water conservation, prevention of salt water intrusion, and preservation of fish and wildlife (www.evergladesplan.org/the_plan/csf_devel.htm). Over the years, the waters of the Everglades also have been drained and diverted to create agricultural and residential lands, which has inevitably altered the natural hydrologic flow. The Comprehensive Everglades Restoration Plan (CERP) seeks to mitigate changes to South Florida ecosystems by restoring freshwater flow to the Everglades and Florida Bay, though the plan does not attempt to restore the hydrologic flow to what it once was 100 years ago (www.evergladesplan.org).

During the summer of 1987, a massive seagrass die-off began in the Florida Bay that resulted in 15 square miles of seagrass loss. This was just the beginning of a series of major ecological events that culminated in grave concern that the bay's ecosystem was near an unprecedented collapse (Fourqurean and Robblee, 1999). These events include plankton blooms and sponge die-offs in the 1990s as well as mangrove die-backs and reduced catches in some fisheries (www.aoml.noaa.gov/flbay/). As a result, South Florida received national attention and the CERP was authorized under Section 601 of the Water

Resources Development Act of 2000 to restore the quantity, quality, timing and distribution of freshwater flows into Florida Bay with downstream effects on the Florida Keys National Marine Sanctuary (www.evergladesplan.org).

Threats

Key threats for this subregion are listed in Table 1.

Restoration Plans

Florida Keys National Marine Sanctuary Plan

Within this plan, the designation of special-use areas includes "restoration areas" to provide for restoration of degraded or otherwise injured sanctuary resources. No person may enter, disturb or interfere with "such areas designated as a recovery area or a restoration area," or engage in "habitat manipulation related to restoration of degraded or otherwise injured sanctuary resources, or activities reasonably necessary to monitor recovery of degraded or otherwise injured sanctuary resources."

The Surface Water Improvement Management (SWIM) Program

The SWIM Program was created by the Florida Legislature in the late 1980s to address concerns over nonpoint sources of pollution. SWIM addresses the needs of a waterbody as a system of connected resources, rather than as isolated wetlands or water bodies. While the state's five water management districts and the Department of Environmental Protection are directly responsible for the SWIM program, they work in concert with federal, state and local governments and the private sector.

SWIM develops carefully crafted plans for at-risk water bodies, and directs the work needed to restore damaged ecosystems, prevent pollution from runoff and other sources, and educate the public. SWIM plans are used by other state programs, such as Save Our Rivers, to help make land-buying decisions, and by local governments to help make land-use management decisions. Today, 29 water bodies are on the SWIM waterbody priority list.

Indian River Lagoon Comprehensive Conservation and Management Plan

The Indian River Lagoon CCMP was developed after the 1994 Indian River Lagoon SWIM Plan. The strategies for restoration and maintenance contained within the Indian River Lagoon SWIM Plan may be viewed as the technical backbone of the Indian River Lagoon CCMP or as the phased program approach used to identify and define priority problems, establish causes and devise alternate strategies to address those problems. Five program objectives were developed. One address habitat preservation and restoration. Within these objectives, specific goals and action plans are identified. Examples of restoration action plans are listed below.

- *Seagrass Action Plan:* Implement a program of restoration and management activities to maintain, protect and restore the seagrass and submerged aquatic vegetation community of Indian River Lagoon.

- *Wetlands Restoration and Preservation Plan:* Improve implementation of wetlands protection programs, undertake a regular review of wetlands protection rules and regulations, establish wetlands or shoreline setbacks or buffers; acquire ownership or control of wetlands, reconnect impounded wetlands to the Indian River Lagoon, restore wetlands and shorelines, and remove trash and litter from wetlands and shorelines.

- *Restoration and Management Action Plan:* Identify shorelines or wetlands which are either barren of vegetation or have been invaded by exotic plant species, classify and rank these areas based on the need for restoration and the probable success of restoration projects. Develop partnerships or coalitions with local governments, interest groups, the private sector or other parties to accomplish restoration projects.

- *Impounded Marsh Restoration and Management Plan:* Complete or continue the diagnostic, management or feasibility projects related to marshes impounded for mosquito control found in the 1994 SWIM Plan and continue acquisition of privately owned impounded marshes or obtain conservation easements allowing restoration of their natural function. Plans are being developed for land acquisition, and public and governmental support and involvement.

Biscayne Bay SWIM Plan

Substantial restoration efforts have been undertaken in Biscayne Bay by Dade County and local municipalities. South Florida Water Management District and SWIM funds have been used to support projects to restore mangroves at Oleta River State Recreation Area, restore freshwater wetlands at the Bulk Carrier Site and redistribute flow adjacent to the L-31E Canal. The need for restoration is based on the assumption that some areas have been significantly degraded by pollution, structural change and other human activities. Restoration activities are designed to reduce the influx of excessive amounts of nutrients and other pollutants, and to make structural changes as needed to restore appropriate biotic communities, substrate, hydroponic, or physical conditions that will accelerate recov-

ery of the system. Bayside restoration is targeted toward three major issues: water quality, freshwater inputs, and habitat and living resources. Restoration efforts are limited to areas and methods where success is most likely. Planting mangroves in properly prepared and stabilized substrate, and planting marsh vegetation, have proven effective when planting and maintenance are properly designed and supervised.

Biscayne Bay Island Restoration and Enhancement Projects

Components of these projects include stabilizing shorelines, removing exotic trees and fill, establishing flushing channels, and planting mangroves and native salt/drought-tolerant uplands vegetation. Over the past 10 years, the Department of Environmental Resources Management has coordinated 14 island projects through the cooperative efforts of federal, state and local agencies. Cost-effective techniques were developed and used in implementing these successful projects. Island restoration and enhancement activities are underway to stabilize eroding shorelines, restore historical dune communities and wetlands, eradicate exotic vegetation, and create wetlands, dune, coastal strand and tropical hardwood hammock communities. Island stabilization and enhancement have been funded primarily through the Florida Inland Navigation District Waterways Assistance Program and the Biscayne Bay Environmental Enhancement Trust Fund.

Guana Tolomato Matanzas National Estuarine Research Reserve

The Guana Tolomato Matanzas National Estuarine Research Reserve was established in 1999 and currently encompasses 76,000 acres of protected coastal lands and waters. The reserve management plan was approved by NOAA in 1998. Important habitats that may be useful for investigation and as reference sites include estuarine lagoons, oyster bars, tidal creeks, wetlands, maritime hammock, pine flatwoods, coastal scrub, sand dunes and beaches. Restoration priorities include treatment of surface runoff, establishment of buffers to urban development, and restoring and stabilizing natural shorelines. Current restoration projects are primarily mitigation activities and the conversion of former planted pine plantations to more natural forest and wetland communities.

Remarkable Coastal Places Program

This program was initiated by the Florida Coastal Management Program to better address endangered coastal habitats and other historical and cultural values by providing funding to local governments for projects. This is part of their Coastal Partnership Initiative and could be an avenue for local and state partnerships in restoration.

Optimizing Indian River Lagoon Wetland Habitat Restoration and Management

The goals of this project are to determine if reestablishment of the hydroponic connection between impounded marshes and the Indian River Lagoon (IRL) can restore the ecological function of the impoundments to a state similar to that of “native” marshes, and to determine how continued hydroponic management would affect the restoration process. Many local state and federal agencies, including the U.S. Fish and Wildlife Service, recommended restoration of the hydroponic connection between the marshes and the lagoon. Approximately 28,000 (80 percent) of the 35,000 acres of the IRL's impounded estuarine wetlands are located within the Merritt Island National Wildlife Refuge (MINWR) and are a part of the Kennedy Space Center. The initiative fills needs for a broad range of programs and organizations. This work is directly called for by the IRL National Estuary Program's Comprehensive Conservation and Management Plan to optimize management of IRL wetlands. It supports the objectives of the IRL SWIM Plan. MINWR will manage a selected group of impoundments under various management strategies agreed upon by the participating researchers. At the end of data collection, and when data analysis and results synthesis are complete, a review of wetland restoration techniques and wetland management practices will be conducted. Results of the review will be a series of recommendations for restoration, preservation and management of estuarine wetlands.

South Florida Initiative

Support for habitat restoration also is available through the South Florida Initiative. The South Florida ecosystem is the principal nursery area for the largest commercial and sport fisheries in Florida. It also is the home of the largest wilderness east of the Mississippi River, the location of the only living coral reef adjacent to the United States, the most significant breeding ground for wading birds in North America, the main producer of the nation's winter vegetables, home to two Native American nations, and a major tourist region. Fifty percent of the region's wetlands have been lost to suburban and agricultural development. Altered hydrology and water management throughout the system has had a major impact on the area. To address the issues surrounding the South Florida ecosystem, the U.S. EPA is working in partnership with several local, regional, state and federal agencies. The goal is to assure the long-term sustainability of the region's varied natural resources while providing for the coexistence of extensive agricultural operations and a continually expanding human population. Many simultaneous restoration strategies are underway. A federal task force on South Florida ecosystem restoration was formed in 1993 to integrate, focus and direct ecosystem pro-

tection and restoration efforts. Several ecosystem restoration strategies are underway that, if implemented, would cost over $2 billion. The U.S. Army Corps of Engineers has proposed several structural or operation changes for the Central and Southern Florida (C&SF) Flood Control Project in order to improve hydrologic conditions within the Everglades and Florida Bay. They also are proceeding with a comprehensive review of the C&SF project in an effort to further ecosystem restoration while meeting the projected needs of urban areas and agriculture for the year 2050. Implementation of the selected alternative, the Comprehensive Everglades Restoration Plan, is projected to cost over $8 billion. Phosphorus control programs consisting of agricultural best management practices and constructed wetlands managed for phosphorus removal are underway to reduce phosphorus loading into the oligotrophic Everglades wetlands. The South Florida Initiative also directs agencies to promote opportunities to link restoration plans and projects into federal programs and initiatives that focus on improving water quality.

Comprehensive Everglades Restoration Plan (CERP)

This plan is designed to be a collaborative effort among governmental and nongovernmental entities and provides a 50 percent federal share for projects carried out under the CERP. The overarching objective of the CERP is the "restoration, preservation, and protection of the South Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection." The governing board of the South Florida Water Management District has approved eight contracts totaling more than $68 million for the Everglades Construction Project, an effort designed to improve the quality of water reaching the huge ecosystem (www.everglades-plan.org).

Plan Elements

Goals

Goals of Florida's restoration plans include restoration of habitats that have been converted to mosquito impoundments as well as restoration of seagrasses, mangroves and coral reefs. The plans focus both on habitat and water quality issues with the goal of restoring the natural functions of the ecosystem and reducing nonpoint source pollution (e.g., the SWIM Program). In addition, plans call for stabilization of eroding shorelines and the eradication of exotic species.

Methods

Implementation of the restoration plans calls for designation of special-use areas to provide for restoration. In addition, specific plans for planting seagrasses, mangroves and corals are in place. Florida incorporates restoration programs into some of their regulatory efforts including those for buffers and setbacks. Partnerships among federal, state and local governments and the academic community are common. Use of volunteers for plantings heightens public awareness of issues.

Elements of Success

Elements of success include: stabilizing unconsolidated shorelines with limestone boulders; creating intertidal planters where wetland vegetation can become established while protected from wave action; filling deep, barren bottom areas to raise them to points where light levels can support healthy productive bottom communities; planting of wetland vegetation in appropriate areas; enforcing reduced speed limits for vessels; controlling exotic plants; restoring sheet flow, tidal flushing or water levels in wetlands impacted by fill or excessive drainage; and conducting long-term evaluation.

Coastal marsh restoration and creation efforts have been more successful than similar inland attempts. This success appears to be due largely to researchers' abilities to more accurately predict hydrologic patterns in tidally influenced areas than in freshwater settings. Also, coastal restoration efforts have perhaps had a longer history than freshwater wetland restoration. In the Indian River Lagoon, publicly owned impoundments are under rotational impoundment management to restore connection between impoundments and the lagoon. Restoration is less experimental today, although site preparation and substrate stabilization are critical, and planting and maintenance must be properly designed and closely supervised.

Information Needs

In Florida, continued monitoring of projects is integral to the success of restoration efforts. Coral and seagrass habitats tend to be more difficult to establish in the long-term; more research that focuses on identifying viable restoration techniques for these habitat types is necessary. Adequate training can increase the likelihood of successfully restoring these habitats. Also identified was a need to increase public and government involvement in activities designed to protect and restore the coastal environment.

Puerto Rico and U.S. Virgin Islands Subregion

Description

During the ice ages, Puerto Rico and most of the Virgin Islands, including St. John, St. Thomas and the British Virgin Islands, were a single land mass called the Puerto Rican Bank.

The thousands of islands and cays composing the Greater and Lesser Antilles are among the most biologically interesting areas of the world. Centrally located in the West Indies, Puerto Rico and the Virgin Islands are in the eastern extreme of the Greater Antilles, about halfway between the southern tip of Florida to the north and the Caribbean coast of Venezuela. Puerto Rico is roughly 111 miles long by 36 miles wide. Aside from the main U.S. Virgin Islands, 54 small islands flank St. Thomas, St. Croix and St. John.

Puerto Rico and the U.S. Virgin Islands share the following physical and biological coastal features: a limited coastline extension, a restricted shelf dimension, a permanent temperature gradient, oligotrophic waters and sparse upwelling zones.

The U.S. Virgin Islands and Puerto Rico provide critical nesting, foraging and developmental habitat for three species of sea turtle: the leatherback and the hawksbill, (both endangered species) and the green sea turtle (listed as endangered/threatened). Coral reefs and seagrasses serve as habitat for these species, where they typically remain until they reach maturity. Green and hawksbill sea turtles forage throughout the coastal areas, but the only island which still supports any green sea turtle nesting is St. Croix, with an average of 100 nests each year between 1980 and 1990 (Eckert, 1992).

At present there are 22,138 acres of mangrove forests in Puerto Rico. Mangroves have actually increased due to protection of the resource over the last 20 years. In contrast, marsh areas in 1995 equaled 1,959 acres, a decrease of 42.2 percent since 1936.

Tropical Atlantic seagrass beds in the Caribbean are highly productive systems. They are the most important grazing areas for the green sea turtle and the West Indian manatee. Seagrass beds also are one of the most common coastal zones in Puerto Rico (Pabon and Carrubba, personal communication). They are most extensive on the southeast side of the island, but also can be found off the northwest coast.

Puerto Rico has about 60 estuaries including small drainages (Pabon and Carrubba, personal communication). About half of these are larger systems with drainages that have headwaters in the central mountain ranges and drain to the coast. Note that the classical definition of “estuary” does not apply in the Caribbean islands, where the coastal zone is confined due to the geography and alternately wet-dry climate of the islands.

Puerto Rico also has a number of fresh and saltwater wetlands, coastal barriers, and coastal lagoons, in addition to varying reef structures. Similarly, the U.S. Virgin Islands also have fresh and saltwater wetlands and varying reef structures.

Habitat Issues

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Status and Trends

Increases in tourism and associated real estate development have greatly impacted the key habitats and species of this region. Due to relatively long periods of evolutionary isolation, island ecosystems are more susceptible to change than those on continents. Deforestation and fire, introduction of grazing animals, cultivation and the introduction of weedy plants have all contributed to alteration of the ecosystem. General recognition of the importance of the natural environment by local citizens may help reverse this trend.

Threats

Key threats for this subregion are listed in Table 1.

Restoration Plans

Puerto Rico San Juan Bay Estuary Comprehensive Conservation Management Plan

Goals of the plan include planting mangroves and native trees; increasing acreage in the nature reserve; increasing buffer zones; waste management and recycling of marine debris; improving water quality; increasing and protecting existing habitat; encouraging community involvement; restoring seagrasses; and protecting habitat. Demonstration projects include native tree planting to create buffer zones—especially mangroves—which were severely impacted by Hurricane Georges in 1998.

Saltwater Wetlands Conservation and Management Plan for St. Croix

The Division of Fish and Wildlife of the Department of Planning and Natural Resources formulated a strategy to achieve

"no net loss" of saltwater wetlands on St. Croix and long-term gain through restoration of degraded wetlands. Restoration projects focus on enhancing wetlands as habitat for fish and wildlife and increasing educational and recreational opportunities for the U.S. Virgin Islands' community. A collaborative planning effort will be developed that includes all stakeholders and interested parties. An important part of the process is to develop a set of blanket regulations and permit conditions for any proposed development in adjacent wetlands.

Jobos Bay National Estuarine Research Reserve Management Plan

The Jobos Bay National Estuarine Research Reserve was established in 1981 and currently encompasses 2,883 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 2001. Important habitats that may be useful for investigation and as reference sites include subtropical dry forests, mangroves, salt and mud flats, seagrass beds and coral reefs. Restoration priorities include shoreline erosion on offshore cays, hydrological restoration, and mangrove and coral reef restoration. Current restoration projects include dike removal, channel filling, and studies of soil condition, water quality and mangrove productivity for hydrological restoration and mangrove restoration.

Plan Elements

Goals

Goals of Puerto Rico's restoration plans include habitat protection and restoration, especially for mangroves and coral reefs. They also include "no net loss" of wetlands, watershed restoration, mangrove and coral reef habitat restoration and shoreline erosion control. Plans have also established a goal of shoreline debris removal.

Methods

Implementation of restoration plans primarily involves the planting of mangroves or restoration of coral reef habitats. The Riley Encased Methodology is used to support the base of mangrove plantings to improve their chance of success along high-energy shorelines. Plantings are surrounded by PVC pipe as they grow. Volunteers are key to the success of restoration programs and aid in educating the general public about the importance of protecting natural resources.

Elements of Success

Mangrove plantings often are successful in the Caribbean. Use of the Riley Encased Method (REM) helps protect mangrove seedlings from wave action, tides, upland runoff and debris. There has been an 87 percent survival rate with the use of REM. In addition, the use of volunteers fosters a better understanding and appreciation for the resource. Partnerships between federal and state agencies, universities and citizens are important to the success of restoration projects. In addition, acquisition efforts, primarily in national parks, are critical to habitat restoration and protection (The Nature Conservancy also acquires lands and has a reserve in the U.S. Virgin Islands).

Information Needs

More research is needed on planting methodologies for mangroves. In addition, the success of transplanting and restoring corals requires additional research. Monitoring increases the chance of restoration success and can lead to more effective restoration methods. An effective method used in the emergency restoration of corals off Mona Island, Puerto Rico, was reattaching and stabilizing broken pieces of coral using stainless steel wire and nails. Newly planted mangrove seedlings and restored corals (as well as adult mangroves and corals) can be vulnerable to natural factors.

Successful coral reef, mangrove and seagrass restoration requires adaptive management that responds quickly to changing environmental conditions. This depends on baseline assessments and monitoring programs, as well as thorough, long-term evaluation of completed restoration actions that track coral reef ecosystem health and recovery, and reveal significant trends in their condition before irreparable harm occurs. Assessment and monitoring also play a vital role in guiding and supporting the establishment of management strategies. Information needs include fish and benthic habitat assessments and monitoring in the Florida Keys, the U.S. Virgin Islands and Puerto Rico and better planning and additional resources dedicated to comprehensive evaluation of completed restoration actions to better guide and develop future restoration efforts. There also is a need to conduct locally focused socio-economic studies of high-risk anthropogenic threats in specific southeast coral reef habitats in order to resolve important user conflicts affecting these and other reef areas (Bruckner, personal communication).

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Regional Analyses of Restoration Planning

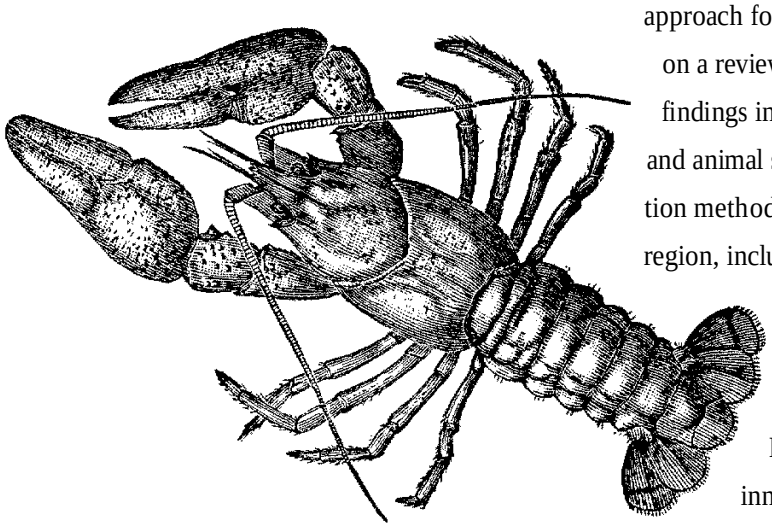
PART 5 – NORTHEAST ATLANTIC

ESTUARIES OF THE NORTHEAST ATLANTIC

The Northeast Atlantic region is defined here as the coastal and estuarine areas of the District of Columbia and the states of Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland and Virginia.

This region:

- Includes 103 estuarine and coastal drainage areas (NOAA, 1990).
- Covers more than 70,000 square miles in area (NOAA, 1990).



SUMMARY

The Northeast Atlantic region is home to some of the most densely populated metropolitan areas, including New York City, Washington D.C., and Boston. Some threats to estuarine habitats and species of concern in all the Northeast Atlantic subregions include coastal development, urban runoff, sewage and septic releases, toxins, overharvesting of fisheries species, invasion by Phragmites australis sea level rise, and subsidence (see Table 3 for a complete list of key threats to estuarine habitats and species of concern in the northeast). An excellent monitoring protocol for tidal marshes has been developed through the Global Programme of Action for the Gulf of Maine and can serve as a model for other restoration programs. Examples of effective partnerships and community involvement include the Maryland Department of Natural Resources' Bay Grass Restoration Partnership. This partnership provides a coordinated approach for promoting citizen-based restoration of bay grass. Based on a review of restoration plans in the Northeast Atlantic region, findings indicate that dozens of endangered and threatened plant and animal species depend on Northeast estuaries. Several key restoration methodologies are being implemented in the Northeast Atlantic region, including a new method currently being developed for submerged aquatic vegetation (SAV) transplantation that is being tested by scientists at the University of New Hampshire. This method is referred to as Transplanting Eelgrass Remotely using Frame Systems (TERFS) and is innovative in that it does not require the use of divers.

Another successful method in this region is the restoration of shellfish beds through the distribution of clean shells or artificial substrate as a settlement substrate. In the Chesapeake Bay area, an experimental technique is being applied using marine limestone as an alternative substrate for restoring oyster reefs.

Introduction to the Northeast Atlantic

Description

For this discussion, the Northeast Atlantic is defined as the coastal region of the United States from the Maine-Canada border to the southernmost extent of Chesapeake Bay. This region includes 103 estuarine and coastal drainage areas that cover several thousand square miles in area (see Table 1) (NOAA, 1990). For this analysis, the Northeast Atlantic region is divided into three subregions: the Gulf of Maine (Maine-Canada border south to Cape Cod, Massachusetts); Southern New England/New York Bight (Buzzards Bay, Massachusetts, south to the Hudson-Raritan Estuary, New York/New Jersey); and Mid-Atlantic (Barnegat Bay, New Jersey, south to the Chesapeake Bay, Virginia) (see Figure 1). To ensure that this document complements existing programs and projects, these regions and subregions have been chosen on the basis of existing ecological boundaries used in other planning efforts (e.g., NOAA's Coastal Assessment and Data Synthesis/Coastal Assessment Framework; NOAA's Our Living Oceans Habitat Report; The Nature Conservancy's ecoregional planning process; U.S. Fish and Wildlife Service regions and programs; Gulf of Maine Council).

Six of the ten most populous watersheds are found in the Northeast (Hudson/Raritan, Chesapeake Bay, Long Island Sound, Delaware Bay, Great South Bay and Massachusetts Bay). The entire populations of Rhode Island, Connecticut, Delaware, and the District of Columbia fall within coastal counties, as does more than 90 percent of the populations of Maine, Massachusetts, New Jersey and Maryland and at least 67 percent of the population of New Hampshire, New York and Virginia (NOAA, 1999b). Humans place a high value on estuarine areas for living, working and enjoying recreational activities. Estuaries provide cooling waters for industry, and energy production and sites for aquaculture; accommodate the needs of large ships and tanker traffic; buffer coastal areas against storm and wave damage; provide wetlands and bottom habitat; supply space for coastal development; and filter pollutants from the rivers and streams entering coastal waters (USGS, 1998).

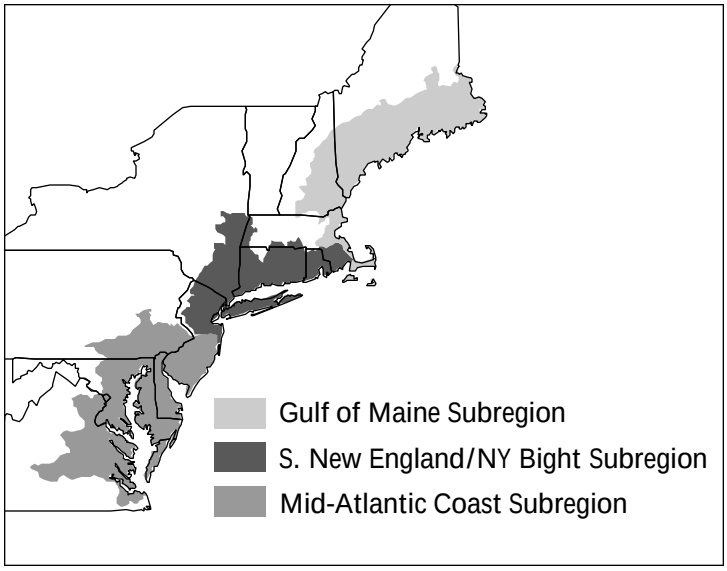


Figure 1. Northeast Atlantic Region and Subregions

Key Habitats and Species

The primary estuarine habitat types found within the Northeast Atlantic region include tidal marshes, submerged aquatic vegetation (SAV), diadromous fish corridors, coastal embayments, shellfish beds, beaches and dunes, intertidal flats, salt ponds and salt pannes, and rocky shores and cobble beaches. The importance of each habitat and its need for restoration, based upon the frequency with which it was mentioned in the restoration plans reviewed, vary somewhat among subregions (see Table 2) although the values and function remain relatively uniform throughout the region.

Table 1. Population and Areal Extent of Northeast Estuaries

Northeast Subregions	Estuarine Drainage Area Pop. (1990 Census)	Watershed Pop. (1990 Census)	Estuarine Drainage Area (sq. mi.)	Total Drainage Area (sq. mi.)
Gulf of Maine	5,208,288	5,974,927	23,300	36,100
S. New England/ New York Bight	22,490,075	24,939,807	18,800	37,300
Mid-Atlantic	16,215,450	22,713,340	29,500	85,500
TOTALS	43,915,803	53,630,064	71,600	158,900

Source: NOAA, 1990

Note: *An Estuarine Drainage Area (EDA) is that component of an estuary's entire watershed that empties directly into the estuary and is affected by tides. EDAs may be composed of a portion of a single hydrologic unit, an entire hydrologic unit, more than one hydrologic unit, or several complete hydrologic units and portions or several adjacent hydrologic units. Every EDA has both a land and water component, with the land portion comprising a mainland component and, for certain EDAs, an island component. Total Drainage Area (TDA) is the EDA plus the fluvial drainage area.*

Marshes provide a broad range of functions and values for a wide variety of living resources. A number of important forage fish species utilize the marsh environment including killifish *(Fundulus majalis)*, Atlantic silversides *(Menidia menidia)* and mummichogs *(Fundulus heteroclitus)*, all of which are vital components to the overall estuarine and marine food web. These species use marsh grasses for protection from storms, as refuge from wave energy, as visual barriers from predators, and as a food source. For a broader range of species (flounder, mussels, calico crab, butterfish), the marsh habitat provides spawning and nursery grounds. Marshes provide aesthetic viewsheds and recreational opportunities for people, serve as stormwater containment, bind certain pollutants and prevent them from re-entering the water column, and contribute to groundwater recharge.

TABLE 2. ESTUARINE HABITATS IN NEED OF RESTORATION IN THE NORTHEAST ATLANTIC REGION

Habitat	Gulf of Maine	S. New England/ NY Bight	Mid-Atlantic
Tidal salt marsh	●	●	●
Submerged aquatic vegetation	●	●	●
Diadromous fish corridors	●	●	●
Coastal embayments	●	●	●
Shellfish beds	●	▲	●
Beaches/dunes	●	●	●
Intertidal flats	●	▲	▲
Salt ponds/ salt pannes	▲	▲	❍
Rocky shore/ cobble beach	▲	❍	❍

KEY: ● High need ▲ Moderate need ❍ Low or no need

Submerged aquatic vegetation (SAV) serves a number of critical functions within the estuarine system. As primary producers they photosynthesize, releasing oxygen into the water column while removing carbons. Blades of seagrass dampen tidal currents resulting in a low velocity zone within the bed itself. The rooted nature of the plants also stabilizes underlying substrates, which prevents scouring and erosion of the bottom. In addition to primary productivity and erosion control, much of the value placed on SAV comes from its function as a highly productive marine finfish and shellfish nursery and refuge habitat. Eelgrass and other SAV species are often associated with or located near shellfish beds. These beds also provide a food source or forage area for finfish, crab, and birds in the form of adult, seed and larval shellfish, and associated organisms.

Submerged aquatic vegetation (SAV) beds are used as attachment sites by the American oyster *(Crassostrea virginica)* during its juvenile state and by the bay scallop *(Argopecten irradians)* during its post-larval period. Juvenile finfish, including winter flounder *(Pseudopleuronectes americanus)*, black sea bass *(Centropristis striata)* and scup *(Stenotomus chrysops)*, utilize SAV beds as a refuge from storm surge and predators. They also depend on SAV as a direct food source and an indirect food source in the form of epiphytes and suspended particles. Adult finfish spawn in the protection of the beds where the eggs can be safely laid in the sediment or attached to the blades. Many forage fish, such as mummichog *(Fundulus heteroclitus)*, Atlantic silversides *(Menidia menidia)* and striped killifish *(Fundulus majalis)*, utilize the SAV beds as refuge from storm surge and predators.

Generally found in areas of soft or consolidated sand and silts, optimal shellfish beds within the northeast are typically zones of higher dissolved oxygen and improved water quality and clarity due to the strong filtration rate of shellfish. Oyster reefs filter impurities and pollutants from the water column. Reef habitats provide forage and protection areas for small finfish and crustaceans, which use the algae growing on the structure for food, and the diversity of the reef surface for hiding from predators.

Intertidal flats are habitat for a diverse array of invertebrates, including amphipods, polychaetes and shellfish. This habitat also provides forage area for fish and migrating shore birds. Intertidal flats also are productive shellfish bed and reef habitat, providing a valuable commercial and recreational resource. The shallow water associated with tidal flats, which is too deep for some shorebirds but too shallow for certain predatory fish, acts as a refuge area for juvenile and small fish.

A review of restoration plans indicated that dozens of plant and animal species that are endangered, threatened or of concern, such as the bald eagle, diamondback terrapin, Shortnose sturgeon, Atlantic salmon, eelgrass and American lobster, depend on the Northeast Atlantic region. Many species important to the economy of the Northeast, including commercial and recreational fisheries, depend on estuaries. Northeast estu-

aries are ecologically significant habitats providing food, shelter and nursery areas for a variety of living resources: plants, invertebrates, fish, reptiles and mammals. Shrimp, menhaden, oysters, flounders and blue crab utilize estuarine habitats for part or all of their life cycles, and Atlantic salmon and Atlantic herring require or prefer estuary areas at some time of the year (USGS, 1998).

The health of non-estuarine habitats, such as coastal grasslands, riparian areas, coastal forests and nontidal wetlands, often has an impact on the health of estuarine habitats. Protection and restoration efforts for these habitats may positively benefit species such as American eel, shad and blue-back herring, as well as promote the downstream drift of clean sediments and vital nutrients into the estuary. Shad and blue-back herring utilize freshwater habitats upstream of the tidal estuarine system as spawning and nursery grounds and return to coastal habitats. These species are commercially important and serve as prey for sport fish such as striped bass. Restoration of historic anadromous fish runs is a critical component of the restoration of estuarine ecosystems of the northeast.

The restoration of diadromous fish to rivers and streams is usually accomplished with either the complete removal of the dam or other obstruction to fish migration or the installation of fish passage structures (dam notches, fish ladders, elevators, baffles, appropriately sized culverts, step pools) where obstructions cannot be removed. In either case, the fish are once again able to access ancestral spawning grounds upriver. In rare cases, fish may have to be restocked into a water body where they have been eradicated by the presence of obstructions over a long period of time. Removal of obstructions or installation of fish passages is often accompanied by restoration of in-stream habitat such as natural stream meanders, placement of boulders, restoration of riffles and pools, and riparian plantings to restore streambank vegetation. These methods help ensure that the fish will encounter a hospitable environment on their way to and from their spawning areas.

Status and Trends of the Northeast Atlantic Region

A significant portion of the coastal habitats within the northeast have been altered, degraded or destroyed by anthropogenic activities. By the late 1930s, about 90 percent of the marshes of the northeast U.S. coast had been extensively ditched to control mosquitoes (Nixon, 1982). Filling and diking of marshland for dredging operations, road construction and commercial and residential development have led to the direct loss of wetland complexes. Table 3 summarizes some of the major past, present and future threats to estuaries in the Northeast Atlantic region. This table is not meant to be comprehensive but rather provides a few examples of key threats in this region.

Threats to tidal marshes are primarily related to tidal restrictions and other hydrologic alterations, filling and runoff from impervious surfaces. Tidal restriction, such as undersized culverts, causeways and tide gates, reduce the magnitude of tidal flushing and frequency, which in turn lowers substrate salinity, may impact elevation of the marsh, and reduces sediment transfer. Each of these factors may result in lost functions and values of a salt marsh as upland vegetation and opportunistic species (*Phragmites australis*, purple loosestrife) are allowed to colonize the marsh. Filling marshes for commercial development, as a component of road construction or as a dredge spoil disposal site creates a similar loss of ecological value and functions as do tidal restrictions, usually within a shorter time period. Hydrologic alterations in the form of ditching, dredging activity or changes in water flow may create increased water velocity through wetlands or expedite surface draining, thereby reducing substrate salinity and promoting opportunistic species invasion.

Impaired water clarity and increased colonization by epiphytes, caused by nutrient input or algal blooms, shades out submerged aquatic vegetation (SAV) and has been shown to destroy entire beds. In the 1930s, a “wasting disease” destroyed eelgrass populations along the east coast. Recolonization has been very slow, with small resurgences of the disease reported in many estuaries. Excessive and repeated boat wakes are believed to uproot aquatic vegetation, while a number of opportunistic species of bacteria, algae and even slime molds outcompete SAV populations by colonizing them as epiphytes. Changes in local hydrology and stronger currents can also damage the beds. Finally, the mechanical harvests of shellfish associated with these beds (such as scallops and clams) have also been shown to adversely impact SAV habitat.

Shellfish beds are threatened by a number of factors, including harmful algal events, diminished water quality, effluent wastes, siltation and other pollutants, decline of brood stock, overharvesting, shellfish parasites and diseases (MSX, Dermo and QPX), and increased predation by opportunistic species. Many historic oyster reefs in the Northeast Atlantic region have been lost to disease such as MSX and Dermo, sedimentation, excessive predation and harvesting, alterations in hydrology, and contamination by chemicals, effluents and oil. Other threats may include the reduction of brood stock or accidental destruction by boat traffic.

Historically, intertidal flats have been filled for development and land expansion. Since tidal flats often are located within

Table 3. Key Threats to Estuarine Habitats and Species of Concern in the Northeast Atlantic region

General Threat	Specific Threat	Gulf of Maine	S. New England/ NY Bight	Mid-Atlantic
Direct habitat alteration	Coastal development	●	●	●
	Dredging	▲	●	●
	Filling	▲	▲	▲
	Tidal restriction	●	●	▲
	Dams	●	●	▲
	Mosquito ditching	●	●	▲
Point and nonpoint source pollution	Urban runoff	●	●	●
	Agricultural runoff	▲	▲	●
	Pathogens	●	●	●
	Aquaculture	●	❍	❍
	Sewage and septic	●	●	●
	Toxins	●	●	●
Resource harvesting and extraction	Forestry	▲	▲	▲
	Mining	▲	▲	▲
	Fisheries	●	●	●
Nuisance, exotic and invasive species	*Phragmites australis*	●	●	●
	Purple loosestrife	●	●	▲
	Canada geese	▲	●	●
Natural disturbance	Ice scour	❍	▲	❍
	Sea level rise and subsidence	●	●	●
	Predation and grazing	▲	▲	▲
	Storms	▲	▲	▲

KEY: ● High concern ▲ Medium concern ❍ Low or no concern

*Phragmites australis *is native to the northeast (see sidebar below). However, it can outcompete other native vegetation and create a monocultural marsh habitat.*

A note about the common reed *(Phragmites australis)*

We know from paleoecological research (data from peat cores) that *Phragmites* is a native plant in the northeast (and other regions of the United States). However, it is now apparently becoming more invasive (Orson et al., 1997; Weinstein et al., 2000) and is widely thought to be degrading essential marsh functions over much of its range. Large amounts of money and effort are being expended to eradicate, control and prevent *Phragmites*, using herbicides, mowing, burning, tidal flow restoration and other methods. Recent research indicates that the problems associated with *Phragmites* may be more perceived than documented. Some *Phragmites*marshes, once thought to be degraded, are much more productive and diverse than any salt marsh counterpart. More research is needed to determine why *Phragmites* is expanding so rapidly and to determine the extent to which it affects habitat quality for fish and wildlife, alters the marsh landscape and its function, reduces ecological diversity and contributes nutrients to the food web. This research will help determine if *Phragmites* should be managed as part of the landscape rather than eradicated. In the fall of 2001, a workshop and symposium was sponsored by USGS and Sea Grant, in New Jersey to provide more insight into the *Phragmites* issue. In any event, restoration of *Phragmites*-dominated marshes should be evaluated based on historic patterns, and research should demonstrate on a site-by-site basis that replacing a *Phragmites*-dominated marsh is truly worth the effort and money spent.

well-protected areas, many are dredged for use as boating facilities. Threats and impacts related to development and conversion for boating use include direct loss of habitat; loss of shallow water habitat; increased freshwater run-off; restricted or enhanced rate of water flow during tidal exchange; erosion and increased sediment transport out of the flats; and input of fuels, oil and other hydrocarbon pollutants. Other impacts related to human activities include disturbances related to overharvesting of shellfish and bait species of invertebrates, algal blooms from increased nutrient loading and alteration of hydroperiod.

Contamination by industrial and residential waste disposal and combined sewer overflow (CSO) events have degraded benthic and wetland surface habitats, reduced viable fish passage and resulted in the closure of shellfish area harvest because of threats to public health. Excess nutrient inputs due to failed septic systems, lawn fertilizers and CSOs along the coast can cause major algal blooms responsible for the degradation of shellfish and seagrass populations.

Bulkheading and other impervious shoreline structures have impeded the natural migration of tidal wetlands. The increase in impervious surfaces, such as roads and compacted earth, increases the potential for stormwater runoff that carries unburned fuels and additives, road salts and sand to estuaries and other coastal waters. Changes in sediment transport and hydrology due to inlet stabilization, culverts, dredging and boat wakes alter the dynamics of wetlands and shellfish beds. Impairments to these vital habitats can be directly linked to the decline of commercially valuable species, such as flounder, cod and scallops, and the overall health of the estuarine ecosystem. Tourism and recreational opportunities in coastal communities are dependent on the health and aesthetic qualities of estuarine habitats. Protection and restoration of these coastal environments also is crucial to the preservation of America's cultural, historic and economic resources.

Regional Planning Efforts

Since the early 1970s, habitat restoration has been used increasingly in the Northeast Atlantic region as a means to reverse the trends of habitat loss and degradation. Today, all the northeast states have active and/or completed restoration projects within their boundaries. These restoration efforts occur under the auspices of federal, state and local authorities as well as through the efforts of nongovernmental entities such as business and industry groups, academic institutions, nonprofit organizations and community groups. In addition, all states in the Northeast Atlantic region have made great strides in the past years to reduce contaminant loadings through permitting discharges.

As part of a Natural Resource Damage Assessment project, more than 250,000 Spartina alterniflora plants propagated from indigenous seeds were used to revegetate marshes in the Arthur Kill that were destroyed by the 1990 Exxon Bayway oil spill (NY-NJ Harbor Restoration Committee, 1995). In Rhode Island, a diverse array of partners (U.S. Army Corps of Engineers, Rhode Island Department of Environmental Management, U.S. Fish and Wildlife Service, Rhode Island Department of Transportation, University of Rhode Island, Save the Bay, and Ducks Unlimited), restored more than 128 acres of salt marsh and 14 acres of tidal creeks at the Galilee Sanctuary, formerly diked off from natural tidal flow and invaded by Phragmites, by removing fill and improving tidal exchange with innovative self-regulating tide gates (Hubbard, personal communication).

Since 1969, at least 1,600 acres of Connecticut's tidal wetlands at more than 50 sites have been restored to more productive use as habitat for fish, birds and plants. Fish passage structures on Rhode Island's rivers have opened more than 57 river miles of habitat to diadromous fish (Lipsky, personal communication; Narragansett Bay NEP, www.nbep.org).

Although there are geographic and ecologic differences among Northeast estuaries, common themes have emerged for important habitats, planning efforts, and information needs essential for the effective restoration of estuary structure and function. A number of agencies and organizations have undertaken restoration planning for coastal and estuarine habitats. Examples of some region-wide plans for the Northeast Atlantic are listed below. Additional plans and detailed information are available through the National Strategy Restoration Plan Database (http://restoration.nos.noaa.gov).

Ducks Unlimited Conservation Plan

This plan is the result of a continuing assessment of Ducks Unlimited's path to ensure it is still in tune with the needs of waterfowl and wetlands conservation. The plan outlines several important habitat areas, their importance to waterfowl, environmental risks, current conservation programs, goals, assumptions and strategies.

Essential Fish Habitat Amendments to the Sustainable Fisheries Act

The purpose of the amendments is to identify and describe essential fish habitat (EFH) for all species of marine, estuarine and anadromous finfish and mollusks managed by the New England Fishery Management Council to better protect, conserve and enhance this habitat. This amendment also identifies the major threats to EFH from fishing and non-fishing related

activities and identifies conservation and enhancement measures.

Partners in Flight: Conservation of Land Birds of the United States

Partners In Flight (PIF) is a consortium of public and private organizations and individuals working to conserve land birds throughout the Western Hemisphere. PIF's guiding principles are to restore populations of the most imperiled species and to prevent other birds from becoming endangered - "to keep common birds common." The PIF partnership has developed a comprehensive set of regional Bird Conservation Plans (BCP) for land birds in the continental United States.

Plan Elements

Many similarities were identified among plan elements for both regional and subregional plans in the Northeast. The discussion below is based on information from all the plans reviewed for the Northeast region, and is applicable to each subregion.

Goals

- A review of restoration plans with a national or regional focus identified similar goals among restoration efforts.
- Forming partnerships and cooperative efforts.
- Developing a strong scientific basis for restoration efforts or identifying this need.
- Setting priorities within a particular geographic zone or range, which varies for different species, habitats, demographics and threats.
- Defining the appropriate geographic scale for given restoration goals.
- Planning with an ecological approach, based on a clear understanding of the cause and effect within the key habitats of a given ecosystem.

Methods

Several restoration plans with a national or regional focus provide some information on methods that have been used or recommended for achieving the region's restoration goals. These methods are briefly outlined below, categorized by key habitats:

1. **Tidal marshes.** Restoration or creation most often involves reestablishing appropriate hydrology and hydroperiod by replacing undersized culverts, repairing malfunctioning tide gates, breaching dikes, removing invasive plants and reestablishing marsh vegetation, reconfiguring stream channels, and regrading the substrate to enhance sediment properties that support growth of marsh species. In areas where the marsh has been grid-ditched in the past for mosquito control, open marsh water management techniques are used to restore marsh function and control pests. In areas where nuisance and/or invasive species (e.g., *Phragmites*, purple loosestrife, water chestnut) are dominant, mowing, burning, herbicide, manipulation of water level and removal by hand may be necessary.

   A common restoration technique is the removal of *Phragmites* and its rhizome structures coupled with physical modification of the site and the planting of native salt marsh vegetation (most often *Spartina alterniflora, Spartina patens,* or other species of concern). Other actions can help restore tidal marshes while maintaining the function of traditional structures. Surface vegetation and substrate can be restored by replacing shoreline hardening such as a bulkheads and riprap with bioengineering (soft solutions) devices such as planted geo-textile tubes. Wave energy deflected off bulkheads and riprap walls can lead to erosion of the marsh surface. Bioengineering uses native vegetation and grading to stabilize coastal banks, absorbing wave energy and protecting the marsh from reflected energy and possible erosion. Standard storm drains can be replaced with systems designed to trap road sand, providing a mechanism to control flooding and to limit indirect filling of marsh surface and channels. Replacing flapper-style tide gates with self-regulating tide gates can maximize tidal exchange and provide flood control during spring tides and storm events.

2. **Submerged aquatic vegetation (SAV).** Restoration techniques for SAV are relatively new, and large-scale efforts have been primarily unsuccessful. Most SAV restoration was attempted by harvesting plants from donor beds and transplanting in locations known to historically support SAV. In some cases, the removal of sections of healthy beds adversely affects the remaining plants, and it is not uncommon for removal to severely impact the donor site. Donor plugs are planted using the staple method, horizontal rhizome method in areas conducive to growth (e.g., areas of relatively low wave velocity, areas of historic eelgrass growth). Transplanted plugs may not be capable of gaining enough root stability to survive storms or currents and may release from the substrate and be lost.

   Recently, new methodology and experimentation has begun to advance the science of SAV restoration through the use of seed and plugs collected from the shore following storms. Methods such as TERFS (Transplanting Eelgrass Remotely using Frame Systems), which creates an anchoring device to provide the plants with the necessary stability to allow development of root mass, and greenhouse germination of

collected seed is being coupled with site selection criteria to add increased ecological benefits and success of SAV restoration projects. More importantly, efforts are increasing to protect seagrass habitats through proactive management (e.g., avoiding impacts or losses and reducing nutrient inputs).

3. **Shellfish beds.** Restoration efforts most often involve quahogs (*Mercenaria mercenaria*), oysters (*Crassostrea virginica*) and soft-shell clams (*Mya arenaria)*. Restoration or enhancement methods are distinct for each of these organisms. Oyster restoration involves the distribution of clean shell material as settlement substrate for juveniles and "seeding" of the shell material with sub-adult-stage oysters. Quahogs and clam beds are restored by spreading ("seeding") juvenile stage individuals over an open flat. This method can be enhanced by mixing juveniles with various size adults to create a range of year classes and by placing a protective cover over the seeded substrate to exclude predators. Once an area has been successfully restored, it is important to set aside refuge areas, closed to harvesting, as sources for brood stock or seeds. Properly managing the refuge and harvested areas can provide a self-sustaining shellfish population.

4. **Shellfish reefs.** Oyster reef restoration has advanced within the past decade throughout the region. The most common process is placing oyster or clam shell on the bottom to create a submerged, three-dimensional reef structure, mimicking the design of natural reefs. These new reefs are sometimes planted with juvenile oysters. Shellfish reefs also have been established or enhanced through the use of natural or artificial reef materials (e.g., shell, rock or stone, concrete modules, decommissioned ships). If shellfish have been totally eradicated from an area, the seeding or stocking of larval, juvenile and adult shellfish may be needed to jump-start the recruitment process.

5. **Intertidal flats.** A few intertidal flat restoration projects have been attempted in the Gulf of Maine, primarily connected with mitigation efforts at port facilities (e.g., Portsmouth, N.H., and Revere, Mass.). The restoration usually involves the removal of contaminated sediments and replacement with clean dredged material; removal of fill material and regrading substrate to re-establish the historic high tide line; the use of best management practices that include diversion of stormwater run-off and sediment control and reduction in the frequency of combined sewer overflow events to minimize nutrient input. Other restoration techniques include restoring historic tidal regime by removing or opening causeways, tide gates and culverts, seeding shellfish and establishing no-harvest areas.

Elements of Success

Of the documents reviewed, most efforts identified the following elements of successful restoration.

- Restoration plans that are part of an overall estuary or watershed-wide plan.
- A priority-setting and ranking scheme to select potential restoration sites.
- A number of criteria for success or performance standards to gauge the progress of restoration projects after a project is completed.
- A series of appropriate local reference sites to provide a comparison between the restoration site and the desired outcome of the project.
- A well-designed pre- and post-project ecological monitoring program which ensures an evolution of knowledge from every restoration project to build on successes and adaptively manage as necessary.
- Sustainable funding to carry the project through completion and post-construction monitoring.
- A comprehensive education and outreach strategy to secure the support and involvement of stakeholders (e.g., general public, elected officials, grassroots groups) in the process.
- Public involvement in the project to generate support for the effort and provide volunteer assistance.
- Partnerships with government agencies, scientists, nonprofit organizations, private citizens, and the formation of multidisciplinary teams (e.g., scientists, planners, economists, community representatives) to create a consensus-based approach to project planning.
- The use of geographic information systems (GIS) for the identification of restoration sites, baseline mapping and the habitat inventory process.
- A standard database and tracking system to help gauge progress and identification of restoration projects toward regional restoration goals.

Information Needs

From the plans reviewed for the Northeast Atlantic region, research and information are still needed.

- Creating a comprehensive region-wide inventory and mapping existing habitats, both functioning and degraded, to support restoration efforts.
- Gaining a better understanding of ecosystem structure, function and the effects of habitat alterations.
- Identifying indicators of impacts on and recovery of habitats and living marine resources.
- Developing criteria for selection and placement of restoration sites.
- Designating scientifically defensible criteria for restoration success and developing the best assessment methodology to

measure return of ecosystem functionality after restoration.

- Developing and testing of quantitative models, at several spatial scales, to predict recovery rates and success of restoration for all habitats, especially salt marsh and submerged aquatic vegetation (SAV).
- Providing technical and planning assistance for habitat restoration at the local and grassroots levels.
- Building partnerships with federal, state, provincial, municipal and nongovernmental organizations (e.g., land trusts, watershed associations), and landowners, to protect and restore estuary habitats.
- Predicting the impacts of climate change and rising sea level on restoration projects.
- Creating mechanisms for information exchange among scientists and restoration practitioners.

In the Northeast Atlantic region, materials and techniques are needed.

- Development and testing of new synthetic materials (non-toxic and cost-effective) for physical habitat manipulation.
- Beneficial use of dredged material for habitat restoration.
- Necessary and effective dimensions for riparian buffer zones.
- Research on the effectiveness of bioremediation at reducing contaminant levels.
- Development and implementation of cost-effective methods to control eutrophication, erosion and runoff (e.g., Total Maximum Daily Loads).

Northeast Atlantic Subregions

Among the subregions of the Northeast Atlantic region, the functions and values, threats and concerns and research needs for estuarine habitats are similar. For example, a healthy tidal marsh in Massachusetts typically provides the same basic function and value as one in New Jersey or Maryland. It has similar threats from changing hydrology, tidal restriction and freshwater intrusion. However, subtle distinctions among the subregions , specifically with regard to threats, were identified that require further review and analysis. A subregional breakdown follows.

Gulf of Maine Subregion

Description

The Gulf of Maine is a semi-enclosed gulf bounded landward by the northeastern states of Maine, New Hampshire and Massachusetts, and the Canadian provinces of Nova Scotia and New Brunswick, and seaward by the north Atlantic Ocean. The Gulf of Maine is strongly influenced by both tides and freshwater inflow, primarily from the Androscoggin, Penobscot, Merrimack, and Kennebec rivers in Maine and the St. Croix and St. John Rivers in Canada. The Gulf of Maine includes more than 23,000 square miles of estuarine and coastal drainage area. Estuaries in this region were formed by glaciers that removed soil cover and left behind rocky shorelines and steep-sided river channels. These estuaries are smaller on average and generally deeper than those found in other regions (NOAA, 1990). The region is influenced by areas of dense human population (Boston, Mass., Portsmouth, N.H., Portland, Maine) as well as large rural, forested and agricultural areas (such as in northeast Maine). More than five million people live within the Gulf of Maine's estuarine drainage areas, and almost six million people live within watersheds that drain into the Gulf of Maine (NOAA, 1990).

Partnerships in this subregion are often multi-state and international, because the Gulf of Maine borders Massachusetts, New Hampshire and Maine and the Canadian provinces of New Brunswick and Nova Scotia.

Habitat Issues

Status and Trends

Maine was third among all U.S. states, behind Alaska and Louisiana, in total value of commercial fishery products landed in 1999 ($265.2 million) (NMFS, 2000). Commercial fisheries in the Gulf of Maine have directly involved some 20,000 persons in harvesting more than 500,000 metric tons of fish and shellfish valued at $650 million each year (Apollonio and Mann, 1995). Lobsters, clams, mussels and marine worms have long been commercially important in various parts of the Gulf of Maine. It is estimated that in Maine alone, the annual value of the fishery for these three species is $13 to $15 million (Harvey et al., 1995). The port of Boston generates more than $2 billion in economic activity each year, and tourism in the area brings in about the same amount of income annually (Platt, 1998).

Many of the coastal habitats within the Gulf of Maine subregion have been altered, degraded, or destroyed. Of the original 11,771 acres of spawning and nursery habitat available to Atlantic salmon, only 52 percent (6,115 acres) remains in Maine's rivers today (USFWS, 1991). Of the approximately 6,200 acres of salt marsh remaining in New Hampshire, about 1,000 acres are seriously degraded by tidal restrictions or other problems (USDA, 1994). In Maine, many of the 255,608 acres of shellfish beds are periodically closed to harvesting, and other coastal areas are often closed to swimming because of bacterial contamination (Maine State Planning Office, 1997). Only about 15 percent of the original salt marshes remain in

the Bay of Fundy region, and less than half remains along much of the rest of the Gulf of Maine coast (Burdick et al., 1994). Massachusetts has lost more than 50 percent of its original salt marsh acreage, and only 36,000 acres remain today in the Massachusetts Bay region (www.state.ma.us/massbays/habitat.pdf) .

However, since the early 1970s, habitat restoration has been increasingly used in the Gulf of Maine subregion to reverse the trends of habitat loss and degradation. More than 700 acres of salt marsh habitat have been enhanced or restored in New Hampshire since 1990 (New Hampshire Estuaries Program, www.epa.gov/owow/estuaries/nhe.htm). Since the early 1990s, more than 2,000 acres of degraded salt marsh habitat have been restored in the Gulf of Maine (Cornelison, 1998).

Threats

Hundreds of dams obstruct the migrations of diadromous fish (e.g., salmon, herring) to and from their spawning grounds, and diking and water control structures have converted more than half of the marshes in the Bay of Fundy to agricultural lands. In Massachusetts, New Hampshire and Maine, a majority of salt marshes have been ditched and drained for mosquito control, and roads and coastal development have severed links between land and sea. Dredging for public and private water access and dockage is resulting in a loss of shallow water habitat. Populations of waterfowl, seabirds and diadromous fish have declined significantly with increased pressures and impacts on coastal habitats. Less obvious impacts, such as poor water quality, have contaminated shellfish beds and decimated meadows of seagrass, which many species of fish and invertebrates depend on for survival (Cornelison, 1998.)

Restoration Plans

Some examples of restoration plans in the Gulf of Maine subregion are listed below. Additional plans and detailed information is available through the National Strategy Restoration Plan Database (http://restoration.nos.noaa.gov).

Casco Bay Comprehensive Conservation and Management Plan

The Casco Bay Plan was developed through a collaborative process involving hundreds of individuals and dozens of organizations and government agencies. The plan's goal is to minimize adverse environmental impacts to ecological communities from the use and development of land and marine resources. Five priority issues of importance to the health of the bay are identified: stormwater, clam flats and swimming areas, habitat protection, toxic pollution, and stewardship. In addition, the plan also identifies actions to protect the bay (including public education, technical assistance, regulation and enforcement, and planning and assessment) as well as a detailed monitoring plan to measure progress in implementation of the plan.

Great Bay National Estuarine Research Reserve

The Great Bay National Estuarine Research Reserve was established in New Hampshire in 1989 and currently encompasses 5,280 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1989 and is currently being revised. Important habitats that may be useful for investigation and as reference sites include upland fields and mixed woods, salt marshes, mud flats, rocky intertidal areas, shellfish reefs and eelgrass beds. Restoration priorities include oyster reef and soft shell clam restoration and anadromous fish habitat restoration. Current restoration projects include eelgrass and salt marsh restoration, Phragmites control, and preparation of a restoration plan for coastal New Hampshire.

Gulf of Maine Council Action Plan 2001-2006

This plan is a sequel to the first ten-year Gulf of Maine Action Plan adopted in 1991 which defined priorities, objectives and timetables for cooperative work. This plan focuses on the next five years and identifies the Council's new focus on coastal and marine habitats.

Management Plan for the Waquoit Bay National Estuarine Research Reserve

The Waquoit Bay National Estuarine Research Reserve was established in Massachusetts in 1988 and currently encompasses 2,600 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 2001. Important habitats that may be useful for investigation and as reference sites include pine and oak forest, salt ponds, coastal sand plains, salt marsh, and barrier beaches and dunes. Restoration priorities include riverine habitat for sea run fish, eelgrass meadows and water column, coastal sand plain habitat, salt pond wetlands and coastal dunes. Current habitat restoration projects include nitrogen loading reduction, endangered plant restoration in a meadow area, controlled burns to maintain a coastal sand plain area, salt pond wetlands restoration, river restoration of sea trout and herring runs and coastal bird restoration by controlling human impacts in habitat areas.

Management Plan for the Wells National Estuarine Research Reserve

The Wells National Estuarine Research Reserve was established in Maine in 1984 and currently encompasses 1,600 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1996. Important habitats that

may be useful for investigation and as reference sites include upland fields and forests, tidal rivers, salt marsh, forested wetlands, dune forest and beaches. Restoration priorities include regional restoration of tidal flow in salt marshes, control and elimination of invasive upland plants and restoration of fish passage for migratory fish in coastal watersheds. Current restoration projects include hydrological restoration of impounded salt marshes and shorebird restoration through monitoring and protection activities for least terns and piping plovers.

Massachusetts Bays Comprehensive Conservation and Management Plan

The Massachusetts Bays CCMP will serve as the blueprint for coordinated action among all levels of government to restore and protect water quality and the diverse natural resources of the Massachusetts Bays estuary. The plan provides specific information on the Bay's five coastal subregions as well as information on a number of major construction projects of regional scope and impact in the Bays region. The centerpiece of the plan is the outline of 15 major action plans for preserving and protecting the Bays' resources. Implementation of these action plans is presented as a series of targeted steps to be taken by federal, state and local agencies.

Southern New England/New York Bight Subregion

Description

The Southern New England/New York Bight subregion is characterized by a diverse system of sounds, bays, lagoons, harbors, coastal streams, tidal rivers, and associated habitat. Because the estuaries (Long Island Sound, Connecticut/New York, Hudson-Raritan, and New York/New Jersey Harbor) span multiple jurisdictions, partnerships are often multi-state. This area has been historically renowned for its rich fisheries, abundance of waterfowl, diverse wildlife, productive marshes, scenic beaches, and outstanding recreational opportunities. As one of the most populous and heavily industrial coastal areas in the world, it has also been an area of unprecedented human population growth—more than 22 million people live in this subregion's estuarine drainage area—and massive urban coastline development that in recent decades has resulted in dramatic declines in its living resources and the large-scale loss and degradation of essential estuarine and coastal habitats (NOAA, 1990; USFWS, 1991, 1997).

The estuaries of the Southern New England/New York Bight subregion are economically valuable. The fishing port of New Bedford, Mass., is second only to Dutch Harbor, Alaska, in value of commercial fishery products landed in 1999 (National Marine Fisheries Service, 2000). More than 90 percent of the Atlantic mackerel, an estuarine-dependent fish, caught in the United States in 1999 were landed in New Jersey (20 million pounds) and Rhode Island (4.3 million pounds) ports (National Marine Fisheries Service, 2000).

Habitat Issues

Status and Trends

More than 35 percent of Long Island Sound's tidal wetlands have been lost over the past century (Long Island Sound Study, 1994). Dams are present on all of Rhode Island's major rivers, preventing or seriously limiting the spawning migration of diadromous fish. At least 33 percent of Narragansett Bay's shellfish beds (36,000 acres) are closed to harvest because of pathogen contamination. Rhode Island has lost 50 percent of its coastal wetlands since European colonization. Of those that remain, 70 percent suffer from restricted tidal flow, 60 percent are affected by dumping and filling activities and 60 percent are affected by invasive species (Lipsky, personal communication; Narragansett Bay NEP, www.nbep.org). Almost 75 percent of all tidal (fresh and salt) marshes in the Hudson-Raritan Estuary have been lost to development (Willner, personal communication).

Threats

The extinction and extirpation of several species of plants and animals in this area, population declines of others, and consequent biological diminution of the region can be attributed to many factors. Most prominent are the destruction of natural habitats through dredging, filling, ditching and draining of wetlands; highway and building construction; and pollution of sediments and waters by environmental contaminants such as chlorinated hydrocarbons, heavy metals, oil, pathogens and nutrients associated with various human activities. Other factors include overharvesting of fishery resources, intensive recreational use of shoreline beaches, and expanding populations of certain nuisance and exotic species and their competitive displacement of native species (USFWS, 1991, 1997).

Restoration Plans

Some examples of restoration plans in the Southern New England/New York Bight subregion are listed below. Additional plans and more detailed information are available through the National Strategy Restoration Plan Database (http://restoration.nos.noaa.gov).

Comprehensive Conservation and Management Plan for Narragansett Bay

The CCMP establishes a resource-related objective for each chapter and recommends detailed strategies for resolving a specific aspect of an identified environmental "issue of concern" for Narragansett Bay. The overall issues of concern include: impacts of toxic pollutants, impacts of nutrients and eutrophication, land-based impacts on water and habitat quality, health and abundance of living resources, fisheries management, health risk to consumers of seafood, and environmental impacts on commercial and recreational uses of Narragansett Bay. The plan is divided into three sections: source control and reduction, resource protection and areas of special concern.

Final Comprehensive Conservation and Management Plan for the NY/NJ Harbor

The CCMP is a comprehensive plan for the Harbor/Bight watershed. Five primary causes of concern are identified: habitat loss and degradation, toxic contamination, pathogen contamination, floatable debris, and nutrient and organic enrichment. A comprehensive set of commitments and recommendations for each section is provided. A major strength of the CCMP is that it includes many commitments for action from federal, state, interstate and local agencies and also builds on existing base programs of these different agencies.

Habitat Restoration Plan for the Peconic Estuary

This plan outlines criteria for selecting habitat restoration priorities and presents several habitats chosen through a nomination process as priorities for restoration. The goals of the plan include: 1) identifying specific habitat restoration projects within the Peconic Estuary and watershed that are ready for immediate funding and 2) identifying natural habitats throughout the region that are most in need of restoration as well as developing criteria for inclusion of projects in a prioritized restoration list.

Hudson River Estuary Management Action Plan

This action plan addresses key issues and actions that have been identified through consideration of the Hudson River Estuary Management Plan, public comment at hearings and meetings and the Final Generic Environmental Impact Statement. These issues include managing aquatic resources; preserving upland habitat; open space and scenery; enhancing recreation, interpretation and tourism; revitalizing the river-based economy through environmental protection; and promoting stewardship through partnerships. The plan aims to meet ecological needs of the estuary while serving the many user groups that place demands on it. Identifying, responding to and addressing the needs of the estuary's many diverse user groups is key to implementing a management program that addresses the pressing issues in the estuary and evaluates those needs and programs over time.

Hudson River National Estuarine Research Reserve

The Hudson River National Estuarine Research Reserve was established in New York in 1982 and currently encompasses 4,838 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1993. Important habitats at the four reserve components that may be useful for investigation and as reference sites include mixed forests, tidal freshwater wetlands, tidal flats and marshes, and subtidal meadows. Restoration priorities include completing a restoration plan for the Hudson River estuary and a functional assessment model for tidal wetlands. Current restoration projects are freshwater tidal marsh restoration, eagle winter roost creation, nutrient load reduction and Phragmites control. The reserve also serves as a reference site for local researchers and restoration practitioners.

Jacques Cousteau National Estuarine Research Reserve

The Jacques Cousteau National Estuarine Research Reserve at Mullica River and Great Bay was established in New Jersey in 1998 and currently encompasses 114,665 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1998. Important habitats that may be useful for investigation and as reference sites include lowland forests, salt marshes, and barrier islands and dunes. The reserve serves as a reference site for the restoration of former salt hay production areas and salt marsh restoration projects.

Long Island Sound Study Comprehensive Conservation and Management Plan

This plan characterizes the priority problems affecting Long Island Sound and identifies specific commitments and recommendations for actions to improve water quality, protect habitat and living resources, educate and involve the public, improve the long-term understanding of how to manage the sound, monitor progress and redirect management efforts.

Management Plan for the Narragansett National Estuarine Research Reserve

The Narragansett National Estuarine Research Reserve was established in Rhode Island in 1980 and currently encompasses 4,369 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1999. Important habitats that may be useful for investigation and as reference sites include upland fields and forests, freshwater wetlands and ponds, tidal flats, salt marshes and eelgrass. Restoration priorities include restoring flow to a salt marsh

bisected by a road and restoring eelgrass . Current restoration projects include salt marsh and eelgrass restoration, prescribed burning, and meadow restoration by altering mowing practices.

Narragansett Bay Critical Habitat Restoration Plan
This plan identifies critical habitat status and restoration goals and outlines strategies for achieving those goals. The goals outlined in the plan include the restoration of 1,000 acres of eelgrass and 5,000 acres of salt marsh and the reopening of 152 miles of river passage.

Natural Resource Restoration Plan for Oil and Chemical Releases in the NY/NJ Harbor Estuary
This document is a regional restoration plan containing recommendations to restore, replace or acquire the equivalent of natural resources injured by the release of petroleum or hazardous substances into the NY/NJ Harbor Estuary. The plan includes a discussion of the major water bodies emptying into the harbor and the major threats to these areas; criteria for choosing restoration projects; and possible options for restoring areas and resources injured by spills or releases.

MID-ATLANTIC SUBREGION

Description

The estuaries of the Mid-Atlantic subregion are mostly bar-built and drowned river valley-type estuaries. The Mid-Atlantic subregion is characterized both by intensely developed urban areas like Wilmington, Del., Baltimore, Md., Washington, D.C., and Norfolk, Va., as well as large rural areas where agriculture dominates the landscape. More than 22 million people live in the Mid-Atlantic watershed, yet 30 percent of the estuarine drainage area in the Chesapeake Bay, Delaware Bay and Delaware Inland Bays is agricultural (NOAA, 1990). The Mid-Atlantic has the largest estuarine and total drainage areas in the Northeast Atlantic region (29,500 and 85,5000 square miles respectively), with almost half of all freshwater entering estuaries in the Northeast Atlantic region flowing through its tributaries (NOAA, 1990; USGS, 1998).

In this subregion, the partnerships are often multi-state, because the estuaries (Chesapeake Bay, Delaware Bay) span multiple jurisdictions. For example, the Maryland Department of Natural Resources Bay Grass Restoration Partnership provides a coordinated approach for promoting citizen-based restoration of bay grass. The program provides the resources and direction necessary for productive restoration projects by individuals, watershed associations, private organizations and others. It is a cooperative effort of the Maryland Department of Natural Resources, citizens and researchers to restore bay grass in areas with suitable habitat conditions.

Habitat Issues

Status and Trends
More than 30 percent (37,000 acres) of coastal habitat in Ocean County, N.J., was lost between 1953 and 1973 (Barnegat Bay Estuary Program, www.bbep.org). At least 25 percent of the Delaware Estuary's original wetlands have been lost, and more than 33 percent of tidal wetlands in Delaware Estuary are invaded with *Phragmites* (Delaware Estuary Program, 1996). More than 25 percent of tidal wetlands in Delaware's Inland Bays were lost between 1938 and 1973 (Delaware Inland Bays Estuary Program, 1995), and more than 2,000 acres of estuarine habitats have been lost in Maryland's coastal bays since the 1930s, mainly from development (Maryland Coastal Bays Program, 1997). The restoration of oyster reefs and shellfish beds is a primary concern in the Mid-Atlantic. Shellfish habitat in Chincoteague Bay has declined from 2,000 acres in the early 1900s to less than 200 acres today (Maryland Coastal Bays Program, 1997). The Chesapeake Bay has lost more than 60 percent of its historical wetlands, and it is estimated that there are more than 2,500 obstructions (e.g., dams, culverts, bridge aprons) to migration of diadromous fish in tributaries to the Chesapeake Bay. The Chesapeake Bay had an estimated 600,000 acres of submerged aquatic vegetation beds at the time of European colonization. In 1997 only 67,000 acres remained (an 88 percent decline) as a result of disease, nutrient enrichment, development and storm disturbance. Populations of the famous Chesapeake Bay oyster have dwindled to two percent of their historical levels because of overharvest and oyster diseases (Chesapeake Bay Program, 1999).

As part of a large-scale mitigation project related to Public Service Electric and Gas Company's Salem Nuclear Power Station, more than 20,500 acres (32-plus square miles) of degraded tidal marshes in the Delaware Estuary are being restored, enhanced or preserved through the Estuary Enhancement Program (PSE&G, 1999*a*). A partnership between Ducks Unlimited and the Chesapeake Bay Foundation has restored more than 3,300 acres of habitat on public and private lands in the Chesapeake Bay watershed (www.cbf.org/about_cbf/rpp/du.htm). The population of Chesapeake Bay striped bass (Morone saxatilis), severely overfished in the late 1970s, has recovered as a result of harvest restrictions and improved habitat conditions (Chesapeake Bay Program, 1999). Through 1998, more than 645 river miles of habitat in tributaries to the Chesapeake Bay were made available to diadromous fish with the removal of obstruc-

tions and the installation of fish passage structures (Chesapeake Bay Program, 1999).

Threats

The key threats to habitats and species of concern in the Mid-Atlantic subregion, in decreasing order of occurrence in the restoration plans reviewed, are:

- direct habitat alterations due to development, dredging, filling, diking, draining, tidal restriction and alteration, shoreline armoring and hardening, dams, water diversions and low flow, mosquito ditching, and fishing gear;
- pathogens such as *E. coli*, *Pfiesteria*, oyster disease (Dermo, MSX), red/brown tide, and other viruses, bacteria, algae and protozoans that can contaminate or kill shellfish beds;
- nutrient loading from agricultural runoff, urban and stormwater runoff, sewage and septic runoff;
- toxic contamination by heavy metals, PAHs, PCBs, pesticides and other contaminants;
- nuisance, exotic and invasive species (e.g., *Phragmites*, purple loosestrife, Canada geese);
- oil and chemical spills; and
- natural disturbance (e.g., storms, subsidence, rising sea level, predation, grazing).

Restoration Plans

Some examples of restoration plans in the Mid-Atlantic subregion are listed below. Additional plans and more detailed information are available through the National Strategy Restoration Plan Database (http://restoration.nos.noaa.gov).

Barnegat Bay Comprehensive Conservation and Management Plan

This CCMP is a comprehensive environmental management plan for the Barnegat Bay watershed that identifies priority environmental problems and issues of concern. These include stormwater and nonpoint source pollution, nutrient loading, pathogens, water supply, habitat loss and alteration, human activities and competing uses, and fisheries decline. Four action plans and management strategies are put forth to address these problems. Also included in the CCMP are a public participation and education plan, a monitoring program plan, and a section that addresses data management.

Chesapeake Bay National Estuarine Research Reserve (Maryland)

The Chesapeake Bay National Estuarine Research Reserve was established in 1985 and currently encompasses 4,820 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1990. Important habitats at the three reserve components that may be useful for investigation and as reference sites include freshwater and flooded hardwood marshes, brackish marshes, and riverine wetlands. Restoration priorities include submerged aquatic vegetation (SAV) at Otter Point Creek and Jug Bay and restoration of wild rice at Jug Bay. Current restoration projects include SAV monitoring and plantings at Otter Point Creek and Jug Bay and the protection of existing wild rice beds and re-establishment of wild rice in previously existing beds at Jug Bay.

Chesapeake Bay National Estuarine Research Reserve (Virginia)

The Chesapeake Bay National Estuarine Research Reserve was established in 1991 and currently encompasses 4,435 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1991. Important habitats at the four reserve components that may be useful for investigation and as reference sites include upland and forested wetlands; tidal freshwater, brackish, and salt marshes; intertidal sand and mudflats; and extensive submerged aquatic vegetation beds. Current restoration projects include riparian revegetation and development of stream drainages.

Delaware Estuary Comprehensive Conservation and Management Plan

This plan establishes a guide for action to achieve its stated goals for the Delaware Estuary Watershed. Several actions were proposed as habitat enhancement opportunities such as restoring and enhancing poorly functioning tidal wetland impoundments (restoration of 10,000 acres of tidal wetland impoundments within 10 years) and restoring fish passages.

Delaware Inland Bays Comprehensive Conservation and Management Plan

In 1988 the Inland Bays Estuary Program convened a management conference to decide what actions to take to protect and restore the estuary. The management conference agreed on goals and objectives for the program which, along with the findings of the report The Characterization of the Inland Bays and other studies, formed the basis for the CCMP. Five action plans are outlined in the plan including an education and outreach plan, an agricultural source action plan, an industrial, municipal and septic system action plan, a land-use action plan, and a habitat protection action plan.

Delaware National Estuarine Research Reserve

The Delaware National Estuarine Research Reserve was established in 1993 and currently encompasses 8,600 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1993 and is currently being revised. Important habitats that may be useful for investigation

and as reference sites include forests, freshwater marshes and ponds, salt marshes and mud flats. Restoration priorities include tidal wetlands, Phragmites control, shoreline restoration, reforestation of disturbed uplands and purple loosestrife control. Current restoration projects include shellfish habitat restoration and prescribed burning of Phragmites.

Maryland Coastal Bays Watershed Conservation and Management Plan

This plan pinpoints conservation goals for the 177 square miles of the Coastal Bays area and strategies needed to accomplish those stated goals. The plan is divided into four sections: Water Quality, Fish and Wildlife, Recreation and Navigation, and Community and Economic Development. Each section provides information on priority issues, such as bay grasses and fish and shellfish populations, and solutions and actions to address those issues.

Phragmites-Dominated Wetland Restoration Management Plans

Three plans have been developed: the Alloway Creek Watershed, the Cohansey River Watershed, and the Delaware *Phragmites*-dominated Wetland Restoration Management Plans. All three plans provide a description of the pre-restoration natural and cultural resources of the various *Phragmites* sites and the restoration design and management provisions for each site.

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Regional Analyses of Restoration Planning

PART 6 – GREAT LAKES

ESTUARIES OF THE GREAT LAKES

Situated on the mid-western border between the United States and Canada, the Great Lakes is the world's largest system of fresh surface water.

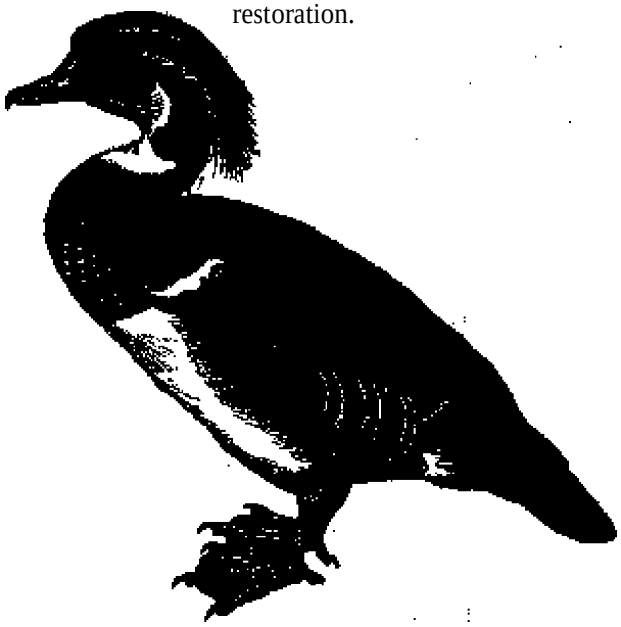
This region:

- Contains nearly 95 percent of the United States' supply and 20 percent of the global supply.
- Covers a surface area of 94,710 square miles and has over 5,500 cubic miles of water; with a combined U.S.-Canadian shoreline measuring 10,210 miles, including islands and connecting channels (excluding the St. Lawrence River).

For the purposes of this discussion, the term estuary includes near coastal waters and wetlands of the Great Lakes that are similar in form and function to estuaries (Section 103[2] Estuary Restoration Act of 2000) and is limited to the U.S. shoreline of the Great Lakes (Lakes Superior, Michigan, Huron, Erie and Ontario) and their connecting waters (St. Marys River, St. Clair River, Lake St. Clair, Detroit River, Niagara River and the St. Lawrence River to the Quebec border).

SUMMARY

The Great Lakes region contains many habitats that are considered rare in this region because of the unique formation of ecosystems (due to large freshwater lake influence). Coastal wetland restoration planning across this region as a whole is still in its beginning stages. Most coastal wetland planning efforts are conducted as part of a broader ecological effort. Many estuarine-like systems have only recently been formally identified as target areas for protection or restoration by agencies or nongovernmental organizations. One of the most significant environmental agreements in the history of the Great Lakes took place with the signing of the Great Lakes Water Quality Agreement (GLWQA) between the United States and Canada. The agreement committed both parties to address water quality issues of the Great Lakes in a coordinated, joint fashion. Both parties agreed to develop and implement *Lakewide Management Plans* (LaMPs) for lake basins and *Remedial Action Plans for Areas of Concern*. LaMPs have been developed for all of the Great Lakes except Lake Huron and include specific objectives for coastal habitat restoration.



Introduction to the Great Lakes Region

Description

Situated on the mid-western border between the United States and Canada, the Great Lakes is the world's largest system of fresh surface water. The Great Lakes extend approximately 850 miles east to west and 700 miles north to south. Covering a surface area of 94,250 square miles and having over 5,500 cubic miles of water, the total U.S. and Canadian shoreline measures 10,210 miles, including islands and connecting channels. Of that figure, approximately half of the Great Lakes shoreline is in Canada and the remainder occurs in the states of Michigan, Wisconsin, Minnesota, Illinois, Indiana, Ohio, Pennsylvania and New York.

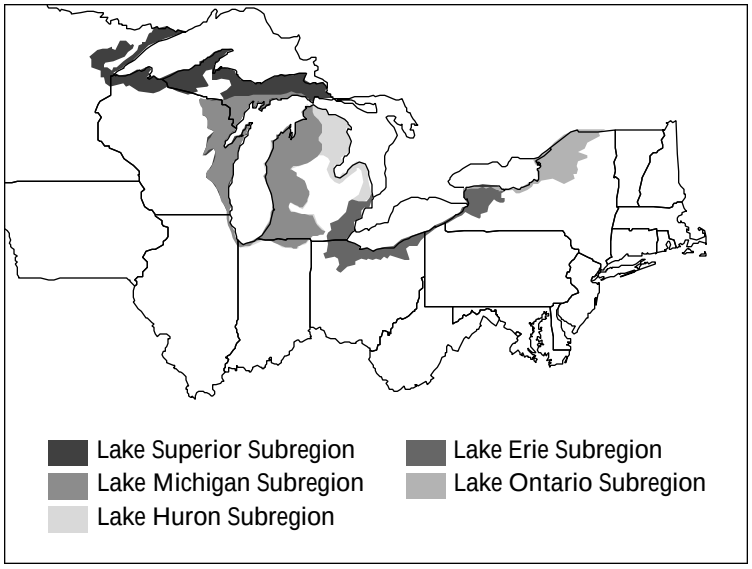


Figure 1. The Great Lakes region

Although each of the Great Lakes has its own separate characteristics, they are all part of one massive integrated water system. The lakes act as their respective drainage for their tributary waters. Lake Superior drains to Lakes Huron and Michigan (which are at the same level) through the St. Marys River. Lakes Huron and Michigan drain to the south and east though the St. Clair River into Lake St. Clair, and then through the Detroit River to Lake Erie. Lake Erie drains into Lake Ontario via the Niagara River. Together, the lakes discharge 6.5 billion gallons every hour into the St. Lawrence River at the east end of Lake Ontario (EPA, 1980).

For the purposes of this discussion, the term estuary includes near coastal waters and wetlands of the Great Lakes that are similar in form and function to estuaries (Section 103(2) Estuary Restoration Act of 2000). Great Lakes coastal wetlands differ from inland wetlands due to the influence of large lake processes, including large waves, wind-driven tides (seiches), and especially the seasonal and long-term fluctuations of Great Lakes water levels (Wilcox and Maynard, 1996).

Seiches with an amplitude of 20 to 30 centimeters and period of four to 14 hours occur regularly on the Great Lakes or within large embayments. Extreme seiches have been recorded on Lake Erie with amplitudes as great as five meters. Great Lakes levels fluctuate annually, in periods of 30 years, and periods of 150 years. Annually, high lake levels occur in early summer and low lake levels in early winter. The range between annual highs and lows since 1918 to present varied from as little as 1.19 meters on Lake Superior to as much as 2.04 meters on Lake St. Clair (USACE 1999, in Wilcox and Whillans, 1999). During the past 4,700 years, short-term fluctuations with a range of .5 to .6 meters occurred about every 30 years and longer-term fluctuations occurred with a range of .8 to .9 meters about every 150 years (Wilcox and Whillans, 1999).

Although there are substantial estuarine systems on the Canadian shore, and the ecosystem processes that are influenced by the lakes do not respect political boundaries, this discussion is limited to coastal wetlands on the U.S. shoreline of the Great Lakes (Lakes Superior, Michigan, Huron, Erie and Ontario) and their connecting waters (St. Marys River, St. Clair River, Lake St. Clair, Detroit River, Niagara River and St. Lawrence River).

In 1981, Herdendorf et al., surveyed and mapped all wetlands greater than one acre in size that occur wholly or partially within 1,000 feet of the Great Lakes shoreline. However, not all wetlands identified in this study are directly influenced by Great Lakes water levels. Wilcox and Maynard (1996) and Chow-Fraser and Albert (1999) have re-analyzed Herdendorf as part of providing information for SOLEC (State of the Lakes Ecosystem Conference) conferences. For the purposes of providing summary data for this report, these studies and additional data provided by Minnesota and Wisconsin's Coastal Zone Management Programs were combined. There are at least 883 different coastal wetland ecosystems covering at least 393 square miles on the U.S. side of the Great Lakes. It is important to note that these numbers are approximate and that they more than likely under report Great Lakes estuarine systems.

Key Habitats and Species

Great Lakes coastal wetlands include the following basic wetland types: aquatic beds dominated by floating-leaved and submergent macrophytes, emergent marshes dominated by emergent macrophytes, beach strands dominated by annual herbs, wet meadows and fens dominated by sedges, dune and swale complexes, bogs dominated by *Sphagnum sp.*, and swamps forested by a variety of lowland conifers and deciduous trees.

TABLE 1. ESTUARINE HABITATS IN NEED OF RESTORATION IN THE GREAT LAKES AND THEIR CONNECTING CHANNELS

Habitat	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
aquatic beds	❍	●	●	●	●
emergent marshes	●	▲	●	●	●
beach strands	❍	❍	❍	❍	❍
wet meadows and fens	▲	●	●	▲	▲
dune and swale complexes	▲	●	▲	▲	●
bogs	●	▲	▲	▲	▲
swamps	●	▲	▲	▲	▲

KEY: ● High Need ▲ Medium Need ❍ Low/No Need

Based on a review of the existing information and restoration plans, the natural occurrence and need for restoration, based upon the frequency with which it was mentioned in the restoration plans reviewed, varies somewhat between each Great Lake (see Table 1).

Marshes are the most common type of coastal wetland and are dominated by emergent macrophytes. This vegetation type can tolerate the short- and long-term fluctuations in water levels that occur in the Great Lakes. In fact, they actually require these fluctuations to maintain their species diversity (Wilcox and Maynard, 1996). Fen communities in the coastal Great Lakes are characterized by moderately decomposed peat, and have diverse plant communities dominated by sedges. Swamps are found along the upland margin of coastal wetlands, many of which are influenced by the Great Lakes only during periods of high water. Peatlands or bog communities usually occur towards the landward margin of coastal wetlands and in some cases form floating mats that adapt to lake-level changes (Wilcox and Maynard, 1996).

Coastal wetlands occur along the Great Lakes shorelines where erosive forces of ice and wave action are low, allowing the formation of wetland plant communities. They can occupy a wide variety of geomorphological settings that can be grouped into three broad categories based on their physical and hydrologic characteristics: open coast, drowned river mouth/flooded delta, and protected. A continuum exists between these categories, and given the dynamic nature of the shorelines, many coastal wetlands have systematically or episodically migrated along the continuum (Keough et al., 1999).

The Great Lakes coastal wetlands are critical to the Great Lakes ecosystem as a whole. Coastal wetland systems are the most productive aquatic systems in the Great Lakes, and support diverse assemblages of invertebrates, fish, reptile, amphibians, birds and mammals. Whillans (1987) determined that over 90 percent of the roughly 200 fish species in the Great Lakes are directly dependent on coastal wetlands for some part of their life cycle. In terms of waterfowl, 24 species of ducks, four species of geese, and three species of swans are known to use Great Lakes coastal wetlands. These areas are important for many birds other than waterfowl, including shorebirds, wading birds and neotropical migrants (Wilcox and Maynard, 1996).

The Great Lakes coastal systems are important regional and global reservoirs for biological diversity. In a 1994 report on the conservation of biological diversity in the Great Lakes region, The Nature Conservancy identified 131 natural heritage elements (species and natural ecological community types) within the Great Lakes Basin that are critically imperiled, imperiled or rare on a global basis. Of these, 91, or 70 percent of the occurrences, are associated with coastal systems (TNC, 1994).

In addition to providing critical fish and wildlife habitat, Great Lakes coastal wetlands perform a variety of ecological functions important to the healthy functioning of the Great Lakes ecosystem, including flood storage, sediment control, water quality improvement, shoreline erosion protection, food web production and nutrient export.

Habitat-Dependent Activities

Estuarine systems served as the focal point for settlement of the Great Lakes region by Native Americans and Europeans. Historically, due to the ecological functions they provide, estuaries have been preferred as human habitat, and today they are linked inextricably to our economy and our quality of life. The commercial success and the economic importance to the country of cities such as Duluth, Green Bay and Detroit relate directly to the ecological functions that estuaries provide. Today, coastal wetland systems contribute to recreational, commercial, residential, agricultural and industrial activities.

Coastal marshes are great places for non-consumptive recreational uses such as bird watching, nature study, photography and general tourism. Recreational fishing is very important in coastal wetlands. The most sought-after species that use these systems include northern pike, muskellunge, large- and smallmouth bass, yellow perch, white and black crappie, bluegill, channel catfish, black and brown bullhead, carp and bowfin

(Wilcox and Maynard, 1996). In 1983, there was a total of 110,341,000 angler days logged on the Great Lakes (GLNPO, 1988). Waterfowl hunting provides the basis for the recreational hunting industry in coastal wetlands of the Great Lakes. Recreational boating is very popular in the Great Lakes, with Michigan sporting the largest number of registered boaters in the country. Recreational fishing and hunting contribute to local economies through the purchase of food, lodging, equipment and guide services. Although no aggregate numbers of recreation and tourism revenue are available for the Great Lakes Basin as a whole, tourism in Michigan alone is a $10 billion per year industry.

Commercial fisheries associated with coastal wetlands have operated in the Great Lakes for over 125 years. In addition to fish such as northern pike, bass and walleye taken for human consumption, various minnow species are also caught in coastal wetlands as part of an important bait fishery (Wilcox and Maynard, 1996). However, not all commercial use of coastal wetlands has been sustainable. Due to the steady supply of fresh water and access to the Great Lakes for inexpensive shipping of goods and services, many estuarine systems were developed as industrial centers. For example, the Rouge River delta (Detroit, MI) is the home of the Ford Motor Company's Rouge Plant. At one time this marsh habitat was used by Native Americans to harvest wild rice, fish, and fur bearers. Today the entire lower stretch of the Rouge has been channelized and practically all wetlands have been filled (Stapp, personal communication, 2001). Likewise, the river mouths of the Milwaukee (Milwaukee, Wis.), Calumet (Gary, Ind.), Cuyahoga (Cleveland, Ohio) and other rivers have been completely urbanized.

Coastal wetlands in Michigan and Ohio also have suffered severe impacts from drainage for the purpose of agriculture. Because the entire system is freshwater, there are no problems with saltwater intrusion in coastal agricultural fields. Drained wetlands are the most productive agricultural lands in the Great Lakes Basin. Hundreds of square miles of wetlands have been drained around Michigan's Saginaw Bay and in the Maumee Watershed (formerly known as the Black Swamp). Despite the huge loss of wetlands to agriculture, wetlands drained for agricultural purposes that have not been filled or converted to other uses provide the greatest potential for wetland restoration.

Because of the recreational opportunities provided by Great Lakes estuaries, and their scenic beauty, these areas are sought after for resort-residential or second home development. Resorters, or "cottagers," are seasonal residents who provide a critical boost to local economies but also put stress on coastal resources. Beyond the direct loss of wetland as a result of filling for development, improper stewardship by landowners can result in additional stress on the coastal wetland habitats. Many residents who develop in these areas, for example, attempt to control the dynamic nature of the system by removing vegetation to achieve an unfettered view during periods of low water levels. When the lake levels again rise and their shoreline erodes due to lack of wetland vegetation, they then pressure state and federal agencies to regulate water level fluctuations in the Lakes.

The various habitat-dependent activities affect both the structure and function of the estuarine resources on which they depend. Estuaries have experienced some of the most severe human-caused degradation of any habitat type on earth. Throughout the Great Lakes, estuarine systems have been altered by many of the factors affecting estuaries worldwide. As Great Lakes coastal areas continue to increase in population and popularity, the human impacts on estuarine resources can be expected to increase as well.

Habitat Status and Trends

There are approximately 883 different coastal wetland ecosystems covering approximately 393 square miles on the U.S. side of the Great Lakes. The extent of coastal wetlands (and knowledge about them) varies for each of the Great Lakes. Specific status and trend data is noted in the discussions of each of the Lakes below. Based on a review of available literature and restoration plans, Table 2 offers a general summary of key threats to estuarine habitats in the Great Lakes and connecting channels.

There are numerous natural and human-induced factors that have impacted, and continue to impact, Great Lakes coastal wetlands. Natural stressors include water level fluctuations (both long- and short-term), damage from ice and storms, sediment supply and transport, and biological stressors such as invasive native species or disease (Keough et al., 1999). It is important to note that Great Lakes coastal wetland systems benefit from natural stressors such as water level fluctuations. Sediment supply and transport can be both a positive and a negative for the health of a particular system. The formation of barrier beaches or sand spits can protect macrophytes from waves, but their erosion can expose wetlands to wave action.

Human induced stressors include drainage, filling, dredging, shoreline armoring and modification, changes in water level regime, toxic and nutrient pollution, fragmentation, urban runoff, exotic species invasion, diking of wetlands and global

TABLE 2. KEY THREATS TO ESTUARINE HABITATS IN THE GREAT LAKES AND THEIR ASSOCIATED CONNECTING CHANNELS

General Threats	Specific Threats	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Direct Habitat Alteration	Coastal Development	▲	●	●	●	●
	Dredging	▲	●	●	●	▲
	Filling	▲	▲	▲	▲	▲
	Vegetation Removal	❍	▲	●	▲	❍
	Shoreline Armoring and Modification	❍	▲	●	●	●
	Road Crossings	●	●	●	●	●
Hydrologic Modifications	Dams	❍	▲	▲	❍	❍
	Artificial Changes in Water Level Regime	●	❍	❍	❍	●
	Drainage	❍	●	●	●	●
	Diking	❍	●	▲	●	▲
Nonpoint Source Pollution	Urban Runoff	▲	●	●	●	●
	Agricultural Runoff	❍	▲	●	●	●
	Sewage and Septic	❍	●	●	●	●
Toxic Loading	Point Sources	●	●	●	●	●
	Atmospheric Deposition	●	●	●	●	●
Resource Extraction	Mining	●	▲	▲	❍	❍
	Forestry	●	❍	❍	❍	❍
	Fisheries	❍	❍	▲	▲	▲
Climate Change		●	●	●	●	●
Nuisance, Exotic, and Invasive Species	Purple Loosestrife	❍	●	●	●	●
	Phragmites australis	❍	▲	●	●	●
	Carp	❍	▲	▲	●	●
	Zebra Mussel	▲	▲	●	●	●
	Cattails	❍	▲	●	●	●
	Others (+130 exotics in Great Lakes)	▲	▲	▲	▲	▲
Natural Stressors	Water Level Changes	▲	▲	▲	▲	▲
	Sediment Supply and Transport	❍	❍	❍	❍	❍
	Ice and Storms	▲	❍	❍	❍	❍
	Natural Biological Stressors	❍	❍	❍	❍	❍

KEY: ● High Concern ▲ Medium Concern ❍ Low or No Concern

climate change. This range of stressors has resulted in the loss of coastal wetland habitats and the degradation of the habitat that remains.

It is important to note that these specific threats seldom occur as discrete isolated events. There is interaction between human and natural stressors (e.g., efforts to armor the shoreline during period of high water or to plow shoreline vegetation during low water levels) and substantial interactions among human-induced stressors (e.g., coastal development is typically associated with some sort of hydrologic alteration and always results in non-point source pollution). The cumulative impacts of multiple stressors operating in the same time and place can have synergistic effects well beyond the sum of the individual stressors.

Although no comprehensive studies have been conducted to evaluate the coastal wetland loss rates for the Great Lakes Basin as a whole, studies of specific coastal wetland systems suggest that the losses have been substantial. A study comparing current land use data in Michigan with historical information gleaned from General Land Office (GLO) Surveys conducted in Michigan prior to widespread European settlement found that coastal communities in southeast Michigan (along Saginaw Bay, the Detroit River, and the western shore of Lake Erie) have lost between 90 percent and 97 percent of their original emergent wetlands (many of which were associated with the Great Lakes coast) (Comer, 1996). Similar losses have been reported in southern Ontario. For example, 83 percent of the original 9,367 acres of western Lake Ontario coastal wetlands from Niagara River to Oshawa have been lost, with some sections suffering 100 percent loss due to filling.

The impacts of these losses have not been comprehensively assessed. As noted above, there are numerous species and ecological communities that are globally rare or imperilled in the coastal zone of the Great Lakes. Although the loss of coastal wetland habitats has slowed since the heyday of dredging, draining and filling wetlands, losses in area and wetland function continue to occur.

Regional Planning Efforts

The unique qualities of the Great Lakes and their importance to the U.S. and Canada—both ecologically and economically—have made conservation and restoration of coastal habitats a key objective for bi-national, federal, state and regional planning efforts. Regional efforts of note are highlighted below.

Lakewide Management Plans and Remedial Action Plans

One of the most significant environmental agreements in the history of the Great Lakes took place with the signing of the Great Lakes Water Quality Agreement (GLWQA), between the United States and Canada. The agreement committed the U.S. and Canada (the Parties) to address water quality issues of the Great Lakes in a coordinated, joint fashion. The GLWQA was amended in 1987 and the Parties agreed to develop and implement, in consultation with state and provincial governments, Lakewide Management Plans (LaMPs) for lake basins, and Remedial Action Plans (RAPs) for Areas of Concern (AOCs). LaMPs have been developed for all of the Great Lakes except Lake Huron and include specific objectives for coastal habitat restoration. LaMPs for each lake are briefly described below. Forty-three AOCs were identified: 26 located entirely within the United States; 12 located wholly within Canada; and five shared by both countries. Some RAPs have been completed and are now in the implementation stages, others are still in the development process. Many RAPs contain coastal wetland restoration as a key component.

Lake Huron does not have a Lakewide Management Plan. The Great Lakes Office of the Michigan Department of Environmental Quality, with the U.S. Environmental Protection Agency and Environment Canada as partners, has undertaken the development of the Lake Huron Initiative Action Plan. One purpose of the plan is to determine priority issues and future efforts needed to ensure a sustainable Lake Huron watershed. Immediate future efforts focus on two key issues: critical pollutants and use impairments, and critical habitat and diversity of fish and wildlife populations.

The Nature Conservancy's Ecoregional Planning

In 1996, The Nature Conservancy's (TNC) Great Lakes Program launched a collaborative initiative to develop an ecoregional plan that would identify high priority biodiversity conservation sites in the Great Lakes Region. In 1999, TNC completed a major portion of the plan; this first iteration focussed primarily on selecting sites important for target species and natural communities. Published in 2000, Toward a New Conservation Vision for the Great Lakes Region: A Second Iteration expands the plan to include sites that are important for aquatic systems, reptiles and amphibians. Through the ecoregional planning process, The Nature Conservancy and partners have identified 271 sites that represent the tremendous biological diversity of the Great Lakes region. Of the 271 sites, 166 sites (over 60 percent) are irreplaceable—meaning that these places represent the only opportunity to protect certain species, natural communities, aquatic systems, or assemblages of these targets in the Great Lakes region. Over three-quarters of the sites will need attention within the next 10 years, and more than two-thirds of the sites need more immediate action. Very few of the sites have completed site conservation plans.

Completed plans that contain a restoration component have been included in the discussions for each subregion below.

North American Waterfowl Management Plan

The Upper Mississippi River & Great Lakes Region Joint Venture Implementation Plan establishes the region's goals for the North American Waterfowl Management Plan (NAWMP). It identifies specific habitat objectives for focus areas with the overall objective of increasing populations of waterfowl and other wetland wildlife by protecting, restoring and enhancing wetland and associated upland habitats within the Joint Venture region.

State of the Lakes Ecosystem Conferences

The State of the Lakes Ecosystem Conferences (SOLEC) are hosted every two years by the U.S. Environmental Protection Agency and Environment Canada on behalf of the two Countries in response to the binational Great Lakes Water Quality Agreement. The conferences are intended to provide a forum for exchange of information on the ecological condition of the Great Lakes and surrounding lands. SOLEC conferences are intended to focus on the state of the Great Lakes ecosystem and the major factors impacting it. In addition to reporting on the health of the living system, the conferences report on the underlying conditions. This reflects the increased recognition that the condition of the ecosystem is being determined by three major factors: habitat loss, pollution and exotic species.

State Wetland Management Strategies

Through the US EPA's state wetland development grant program, various states in the Great Lakes Basin have developed state-wide wetland management plans. These plans provide information regarding the status of wetlands in the state, regulatory frameworks, non-regulatory management and protection efforts, and in some cases, recommendations for restoration of the state's wetland resources. State Wetland Management Strategies have been completed for Minnesota, Michigan, Indiana, Illinois, Ohio and New York.

State and Federal Public Land Management

There are numerous state game areas, federal wildlife refuges, Forest Service land, and national parks and lakeshores throughout the Great Lakes Basin. Due to the ecological functions provided by coastal wetlands, many wildlife management areas include substantial coastal wetland systems. Many national wildlife refuges in the coastal areas of the Great Lakes are managed as wilderness. For many state wildlife areas, management plans focus on re-creating or manipulating the system to benefit certain species or hunting opportunities. Wetland restoration is a high priority in many state game areas. By way of an example, selected wildlife management areas are briefly described in the body of this text.

Great Lakes Subregions

In an overview of controlling abiotic factors, Dr. Leah Minc divided the U.S. Great Lakes shoreline into 77 regions characterized by distinctive conditions for coastal wetland development based on differences in climate, bedrock geology, glacial geomorphology, shoreline configuration and soils, as well as land use and disturbance factors (Minc, 1997). In an effort to simplify and to minimize the number of subregions for the purposes of this report, the Great Lakes Region has been divided into five subregions based on geographic boundaries. Each subregion includes the U.S. territory of one of the Great Lakes and the associated downstream connecting channels. The Lake Superior subregion includes Lake Superior and the St. Marys River. The Lake Michigan subregion includes Lake Michigan to the Mackinac Bridge. The Lake Huron subregion encompasses Lake Huron, St. Clair River, Lake St. Clair, and the Detroit River. The Lake Erie subregion includes Lake Erie and the Niagara River. The Lake Ontario subregion encompasses Lake Ontario and the St. Lawrence River downstream to the Quebec border.

Lake Superior Subregion

Description

The Lake Superior subregion includes Lake Superior and the St. Marys River, which flows from the southeast corner of Lake Superior into Lake Huron. Lake Superior is the largest and coldest of the Great Lakes and is the largest (by surface area) body of freshwater on earth. The lake itself is characterized as oligotrophic, with low levels of nutrients, little plant life, high levels of dissolved oxygen, and a long retention period (191 years). Coastal wetland development is constrained by large areas of bedrock at or near the surface, shallow soils and a northern climate. This northern climate is reflected in the more boreal nature of the wetlands that are typically rich in bog or poor fen species (Minc, 1997). The St. Louis River Estuary and the Bad River and Kakagon Sloughs are significant estuarine systems which comprise a large proportion of the total coastal wetlands in Lake Superior.

The St. Marys River extends 112 kilometers, draining Lake Superior into Lake Huron. The river drops 6.7 meters along its length, mostly at the 1.2 kilometer-long St. Marys Rapids in Sault Ste. Marie. The upper river above the St. Marys Rapids has sandy and rocky shores, with emergent wetlands occurring only in protected areas. The lower river is bordered by exten-

sive emergent marshes in shallow areas of the large lakes, bays and islands (Wilcox and Maynard, 1996).

Habitat Issues

Status and Trends

There are no comprehensive estimates of coastal wetland losses for Lake Superior. In highly developed areas, such as Duluth, Minn. and Superior, Wis., impacts to coastal wetlands have been severe. Because the shoreline is sparsely populated and shoreline development has been minimal, coastal wetlands along Lake Superior are comparatively less affected by human stressors than those of the other Great Lakes. However, due to the relative rarity of wetlands in the Lake Superior system as a result of abiotic factors, those estuarine systems that do exist are particularly important to fish and wildlife populations. (Wilcox and Maynard, 1996). Species of management concern include a variety of freshwater mussels, birds such as the piping plover, peregrine falcon, bald eagle and many rare neotropical passerines, and fish such as the lake sturgeon.

Water level regulation is the most widespread stressor and many other stressors affect wetlands on a site-specific basis. Water level regulation has affected all coastal wetlands in Lake Superior. Water levels on Lake Superior have been regulated for much of the 20th century as a result of the locks at Sault Ste. Marie (Wilcox and Maynard, 1996).

Site-specific stressors include shipping, dredging, filling, harbor and marina development, shoreline development, road construction, nutrient enrichment, logging, and toxic contamination. Watershed runoff of sediments, especially from logging activity, can dramatically increase sediment inputs into tributaries which also can affect coastal wetlands near river mouths, especially in western Lake Superior where watersheds are dominated by fine clay soils. There are three Areas of Concern (AOCs) on the U.S. shoreline of Lake Superior. AOCs are defined as severely degraded areas where beneficial uses are threatened or impaired due to toxic contamination. The entire St. Marys River has been designated an AOC due to elevated contaminants in the water and the sediment.

Threats

Ongoing threats to estuarine systems vary depending on the location of the shoreline. Remote areas are seeing a growth in resort residential development which results in additional pressure on the estuarine resources. In more developed areas, such as Duluth, Minn., and its sister city, Superior, Wis., the threats are many and severe, including dredging and filling, polluted runoff, resuspension of contaminated sediments, hydrological manipulation, shipping and exotic species invasion. At the other end of the lake, the primary threats to the St. Marys River system include resort and residential development and commercial shipping. The passing of large commercial vessels in the narrow reaches of shipping channels causes increased current speed, greater wave action, more erosion, and more turbidity in these coastal wetlands, affecting plant rooting and growth, and associated invertebrates and fauna (Manny et al., 1987 in Wilcox and Maynard, 1996). Vessel speed controls the degree of damage caused by this particular stressor. These threats were addressed in 1998 by a historic multi-party agreement placing permanent speed limits and other conditions on vessel passage (Kavetsky, personal communication).

Restoration Plans

Lake Superior Lakewide Management Plan

The Lake Superior LaMP contains appropriate funded and proposed (non-funded) actions for restoration and protection to bring about improvement in the ecosystem. Actions include commitments by the Parties, governments and regulatory programs, as well as suggested voluntary actions that could be taken by nongovernmental partners. Lake Superior habitat objectives include addressing nearshore, shoreline and wetland habitats through identification, protection and restoration of sites for reproduction and rearing of fish, water birds, mammals and other wildlife and plants.

Minnesota's Lake Superior Coastal Program

Coordinated by the Minnesota Department of Natural Resources, this program was designed to meet the requirements for participation in the federal Coastal Zone Management Program. The goal of this program is to preserve, protect, develop and where possible, restore and enhance coastal resources for present and future generations. It was developed to encourage greater cooperation, to encourage simplification of governmental processes, and to provide tools to implement existing policies, authorities and programs within the area defined by the program boundary. It is not another plan to implement, but rather a new tool to implement existing programs in the most efficient manner, and to provide funding for unique or underfunded opportunities.

Chequamegon Bay Watershed Site Conservation Program

A program of The Nature Conservancy, the Chequamegon Bay Watershed Site Conservation Program encompasses two large and numerous small watersheds, and covers three counties in northern Wisconsin. Conservation targets for the program have been identified and include the Kakagon and Bad River Sloughs. Called 'Wisconsin's Everglades,' the Slough system

covers 16,000 acres and is the largest undeveloped system in the upper Great Lakes. Goals for the Slough include: maintaining the integrity and diversity of natural communities; maintaining the natural processes, including lake level fluctuations, flooding, ground water recharge and water quality; controlling aggressive exotic species; and increasing forest cover within the watershed to reduce indirect stresses.

Habitat Plan for Lower St. Louis River

In 1987, the Lower St. Louis River was designated by the International Joint Commission as one of 43 Areas of Concern (AOC). Development of a Remedial Action Plan (RAP) resulted in 43 recommendations. Published in 1995, the RAP contains many habitat-related recommendations. Recommendation 38 calls for the creation of the Habitat Plan for Lower St. Louis River. The goal of the Habitat Plan is to design and implement a coordinated comprehensive plan for the protection and furtherance of biodiversity and ecological diversity within the Area of Concern, without seeking to restore the estuary to its presettlement condition, through the creation, restoration, reclamation, enhancement and management of a desired mix of ecosystems and habitat. The Habitat Plan, managed by the St. Louis River Citizens Action Committee, will focus on the lower 21 miles of the river, a 12,000-acre freshwater estuary from below Fon du Lac, Minn., to its outlet in Lake Superior.

Wisconsin Coastal Management Program

The Wisconsin Coastal Management Program (WCMP) was established in 1978 under the federal Coastal Zone Management Act to protect, restore and enhance Wisconsin's Lake Michigan and Lake Superior coastal resources. The WCMP is a voluntary program that works through a governor-appointed council to award federal funds to local governments and other entities for the implementation of coastal initiatives. The program's goal is to achieve a balance between natural resource protection and coastal communities' need for sustainable economic development.

The WCMP provides grants to encourage the protection and wise use of Wisconsin's coastal resources. One of the four types of matching grants is wetlands protection. A Data Compilation and Assessment of Coastal Wetlands of Wisconsin's Great Lakes was funded in part through this grant program. Goals of this project were to compile existing information on coastal wetlands for Lakes Superior and Michigan in Wisconsin, select ecologically significant primary coastal wetland sites, and identify existing data or inventory gaps. There are 28 primary sites in Wisconsin's Lake Superior coastal region. The report notes that there are relatively few known information gaps in this coastal zone, but that recently some very rare species have been found that need to be inventoried.

Michigan Upper Peninsula Coastal Wetland Project

A Ducks Unlimited proposal to the North American Wetlands Conservation Council, the Michigan Upper Peninsula Coastal Wetland Project is a multi-partner, multi-phase landscape-scale project to protect, restore and manage coastal wetlands and associated uplands within nine focus areas in the Lake Superior and St. Marys watersheds in Michigan. The peninsula has not seen the same great wetland losses as lower Michigan, with the exception of the Rudyard Clay Plain, and for this reason the project focuses on preventing destruction of coastal wetland areas and associated uplands with habitat restoration and enhancement as a secondary objective. Phase I of the project will protect and/or restore 2,826 acres of wetlands and associated uplands through land acquisition in seven focus areas, restoration projects (such as constructing ditch plugs, removing drain tile, and scraping basins in the clay soils) in three focus areas, and enhancement (such as increasing food and habitat resources in a deteriorating impoundment through drawdown and reflooding) in four focus areas. Three additional phases are anticipated.

Munuscong Wildlife Area Management Plan

The Munuscong Wildlife Area is adjacent to Munuscong Lake and the St. Marys River in east-central Chippewa County in Michigan's Upper Peninsula. The management goal for this area is to restore and maintain biotic communities and public use opportunities through practices and improvements that do not disturb existing unique features and which complement, rather than combat, natural processes. Examples of primary objectives are to: “naturalize” a dysfunctional dike and restore the open-system dynamics of the Munuscong Bay coastal marsh while enhancing reproduction opportunities for island-nesting wildlife; maintain upland grassland communities for wildlife species currently using this cover type and create “emergent-marsh” wetlands to enhance grasslands for species dependent on grassland-wetland complexes; and acquire coastal wetlands, grasslands and other tracts within the dedicated wildlife area boundary and manage them as sustainable, naturally functioning systems. Coastal wetland management strategies include work on the dike system, prescribed burns and control measures for purple loosestrife.

Plan Elements

Goals

Habitat goals for the Lake Superior subregion focus on preserving, protecting and restoring coastal wetlands, biodiversity and ecosystem diversity, by restoring natural ecological

processes and addressing the myriad of natural and human induced threats to the system.

Methods

To achieve the subregion's goals, both general methods, such as creating partnerships and building networks, and specific methods were discussed. Examples of specific methods include restoring hardened shorelines and inactive boat slips to natural habitats, eliminating sewer overflows and failing septic systems, toxic remediation, working with local zoning commissions to modify current zoning regulations to ensure appropriate land uses within the watershed, restoring hydrologic regimes, and facilitating consolidation of coastal development including relocating businesses, and using existing facilities versus constructing new ones.

Elements of Success

All of the plans have evolved through, and stress the need for, continued broad participation from federal, state, local and tribal governments, nonprofit organizations and citizens in order to succeed. Most acknowledge the value of supplementing current efforts versus duplicating or recreating existing plans. Site specific measures of success include making measurable progress toward the long-term abatement of critical threats and the sustained maintenance or enhancement of conservation target viability at identified sites.

Information Needs

All plans specify the need to identify highest priority areas for restoration, continue the acquisition of information through research, and secure additional funding sources. The Habitat Plan for the Lower St. Louis River identifies the need to fill data gaps, determines the degree of degradation at specific sites, and determines the need for unified compilation of historical records and resources.

Lake Michigan Subregion

Description

The only Great Lake entirely within the United States, Lake Michigan is the third largest Great Lake, the sixth largest freshwater lake in the world, and has a retention time of 99 years. The Lake Michigan watershed includes part of Indiana, Illinois, Wisconsin and Michigan. The northern watershed is covered with forests, sparsely populated and economically dependent on natural resources. The southern portion is heavily populated with intensive industrial development and rich agriculture areas along the shores (Marine Advisory Service, 1985). Lake Michigan contains 40 percent of the coastal wetland systems along the U.S. Great Lakes shoreline (Lake Michigan Technical Committee, 2000).

Lake Michigan may be the most diverse of any of the Great Lakes. Its shoreline changes from one major landform to another, with each type extending for hundreds of miles. Given the Lake's north-south axis, climate plays a major role in determining the community composition of the various wetland habitats (Minc, 1997). It has lakeplains, high clay bluffs, low erodible bluffs, vast dune fields, rocky cliffs, glacial drift bluffs, sand ridge shores, and clay and pebble embayments flanked by ancient ridges. Lake Michigan's coastal wetlands are equally diverse, including embayed, barrier beach, lagoon, and riverine habitats. Deltaic formation occurs in some Green Bay sites, but shore currents quickly carry away alluvium or detrital accumulations in other areas (Wilcox and Maynard, 1996). Lake Michigan's coastal systems are host to a wide variety of plants, fish and wildlife, including several state and federally listed species such as the Houghton's goldenrod, dwarf lake iris, Pitcher's thistle and the piping plover.

Habitat Issues

Status and Trends

Lake Michigan's water quality and wetlands have been severely degraded. There are ten Areas of Concern in the Lake Michigan Basin, more than any other Great Lake. The Green Bay area has suffered severe losses and degradation of its wetlands as a result of conversion to agriculture, urbanization, and toxic contamination. Along the western shore from Sturgeon Bay, Wis. to Chicago, Ill., urbanization has virtually eliminated former wetlands that once existed near river mouths. South of Chicago and around the bottom of Lake Michigan are many smaller and remnant wetlands and larger interdunal wetlands that survived the heavy industrialization of the area. The drowned river mouths of the Michigan shoreline have had their hydrology altered by road crossings (increasing sediment deposition) and have been affected by ditching, agricultural practices and colonization by invasive plant species. In the less populated, northern extent of Lake Michigan, many of the estuarine systems remain intact.

Threats

In addition to the ongoing problems noted above, current threats to Lake Michigan's coastal wetlands are primarily related to ever-increasing pressure to develop the shoreline. Attracted by the rich recreational opportunities and scenic beauty, the counties at the northern tip of Michigan's lower peninsula have the fastest growing populations in the state. The vibrant tourist and resort economy puts exceptional pres-

sure on the coastal wetland ecosystems. In addition to direct impact on wetlands through dredging and filling for resort residential and marina development, the additional polluted runoff threatens the very resources that tourists and resorters are flocking to the area to enjoy.

Restoration Plans

Lake Michigan Lakewide Management Plan 2000

The Lake Michigan LaMP contains appropriate funded and proposed (non-funded) actions for restoration and protection to bring about actual improvement in the ecosystem. Fifteen recommended management actions and activities have been developed and are expected to be completed in the next 14 years. Recommendation Management Action 4, Protect Habitat, addresses wetland restoration with an emphasis on areas connecting to Lake Michigan.

Site Conservation Plan for the Red Banks and Door Peninsula and Islands Landscape

The Northern Door Peninsula and Islands Landscape site begins near the city of Sturgeon Bay, Wis. and covers the northern portion of Door County. This portion of the Door Peninsula extends about 50 miles in a northeast bearing, separating Green Bay from the larger body of Lake Michigan. This plan was developed by The Nature Conservancy through a series of meetings with their conservation partners including the Door County Land Trust, Wisconsin Department of Natural Resources and the U.S. Fish and Wildlife Service. The plan includes two planning units: Red Banks, and the Northern Door Peninsula and Islands Landscapes. The combined acreage of the two sites is 190,000 acres; 2,000 and 188,000 respectively. Each planning unit has site conservation targets with specified goals. Several of the sites, such as Mink River Estuary, North Bay-Mud Lake-Ridges and Kangaroo Lake provide specific strategies to conserve these important coastal wetland systems.

Wisconsin Coastal Management Program

The Wisconsin Coastal Management Program (WCMP) was established in 1978 under the federal Coastal Zone Management Act to protect, restore and enhance Wisconsin's Lake Michigan and Lake Superior coastal resources. The WCMP is a voluntary program that works through a governor-appointed council to award federal funds to local governments and other entities for the implementation of coastal initiatives. The program's goal is to achieve a balance between natural resource protection, and coastal communities' need for sustainable economic development.

The WCMP provides grants to encourage the protection and wise use of Wisconsin's coastal resources. One of the four types of matching grants is wetlands protection. A Data Compilation and Assessment of Coastal Wetlands of Wisconsin's Great Lakes was funded in part through this grant program. Goals of this project were to compile existing information on coastal wetlands for Lakes Superior and Michigan in Wisconsin, select ecologically significant primary coastal wetland sites, and identify existing data or inventory gaps. There are 36 primary coastal wetland sites in Wisconsin's Lake Michigan coastal region. The report identified several major gaps for this region including outdated site descriptions, outdated or missing element occurrence data, inventory of other coastal areas, bird information and dams.

Indiana Dunes: Dunes Creek and the Great Marsh

The Indiana Dunes National Lakeshore and Indiana Dunes State Park protect a large portion of Dunes Creek and what remains of the Great Marsh in northern Indiana. Plans include enhancement of 4,600 acres of currently degraded wetlands through the National Lakeshore's efforts to restore hydrology by plugging man-made ditches and tile drainage and removing fill that obstructs surface water. Specific sites for placement of the ditch plugs and road fill cuts are based on a priority system as determined by need and impact. The Indiana Dunes State Park is developing a comprehensive resource management plan for the park. The plan includes Dunes Creek and Dunes Nature Preserve. In addition, Indiana is developing the Lake Michigan Coastal Program in partnership with the federal Coastal Zone Management Program. The Lake Michigan Coastal Program will work with local governments and organizations to protect and restore important tributaries and natural communities such as Dunes Creek and the Great Marsh.

Lower Green Bay and Fox River Remedial Action Plan (RAP)

The Lower Green Bay and Fox River RAP was developed by the Wisconsin Department of Natural Resources for the Lower Green Bay and Fox River Area of Concern (AOC), consisting of the lower 11.2 kilometers of the Fox River below DePere Dam and 55 square kilometers of southern Green Bay out to Point au Sable and Long Tail Point. The three-phase plan includes a multi-stakeholder partnership with four technical advisory committees and a citizen's advisory committee. Since the RAP was adopted in 1988, 38 of the 120 recommended remedial actions have been implemented. Some of the actions taken to enhance fish, wildlife and habitat are: species reintroduction; creation of walleye spawning habitat; construction of a permanent barrier to sea lamprey at three Fox River sites; and acquisition of 68 hectares of wetlands along the West Shore Wildlife Area.

Muskegon State Game Area Master Plan

The Muskegon State Game Area is located in west central Michigan along a 10-mile stretch of the Muskegon River. It lies mostly in a flood plain, which is forested with lowland hardwood or open marsh, and is largely wetlands wildlife habitat. The major objective of this plan is to maximize management efforts toward waterfowl production, to encourage use of the area by migrant waterfowl, and to provide a quality waterfowl hunting area for sportsmen of Michigan. Wetland habitat protection and restoration will be accomplished primarily through land acquisition and water level control measures.

Plan Elements

Goals

Plans in the Lake Michigan subregion identify both short-term and long-term actions and goals to protect and preserve Lake Michigan coastal regions. The Lake Michigan LaMP identifies 15 management actions for the next 14 years. Examples of these are developing standards or guidelines for ballast water control; completing work on all Clean Legacy Sites by 2005; determining a priority for habitat preservation sites; and filling in data gaps. For the Door Peninsula, The Nature Conservancy sets specific goals for each conservation target, which correlate with strategies for the ecoregional sites. For example, goals for the Hine's emerald dragonfly include maintaining at least two breeding areas within each sub-population on the Door Peninsula, protecting all sub-populations regardless of size, establishing a monitoring plan for each population, and protecting the habitat and processes supporting the species.

Methods

Several methods are suggested for achieving the plans' goals. By 2005, the Lake Michigan LaMP plans to identify and map critical habitats in the watershed for all listed species, which will assist in filling data gaps of coastal habitat. For priority conservation sites in the Door Peninsula, The Nature Conservancy utilizes acquisition and conservation easements to conserve and protect habitat for species such as the Hine's emerald dragonfly.

Elements of Success

As with the other subregions, the ability to build partnerships, link with existing planning efforts, educate and involve the public, and secure continued funding will contribute to the success of the plans. Progress toward reaching tangible improvements (in wetland areas or target species populations) is also a key measure of success.

Information Needs

The Site Conservation Plan for Red Banks and the Door Peninsula provides a detailed matrix of research and inventory needs for conservation targets and assigns a priority to each of the needs. Determining the hydrologic links in the Dolomite-sand-peat landscape, feasibility of exotics control, and relationship of the matrix landscape to the health of the identified targets, are a few examples. The Lake Michigan LaMP identifies the need to fill in gaps of information and verify that available information is still current.

Lake Huron Subregion

Description

The Lake Huron subregion includes Lake Huron, the St. Clair River, Lake St. Clair and the Detroit River. At 59,600 square kilometers, Lake Huron is the second largest of the Great Lakes (after Superior). Lake Huron includes the two largest bays on the Great Lakes, Georgian Bay (in Canada) and Saginaw Bay (Michigan Seagrant, 2000). Lake Huron features a mix of bedrock and glaciated landforms. Rocky shores associated with the Precambrian shield cover the northern and eastern shores and limestone underlies the Drummond Island-Manitoulin Island Group; glacial deposits of till, gravel and sand predominate further south. The diversity of the shoreline and landforms in this subregion is reflected in the wetland habitats, which range from and include sheltered bays and river mouths in Lake Huron to the broad deltaic wetland systems in Lake St. Clair (Minc, 1997). Along the U.S. shoreline, Saginaw Bay has been identified as an Area of Concern (AOC).

The St. Clair River, 64 kilometers long, drains Lake Huron into Lake St. Clair. It is located on the international border between the U.S. and Canada and is a major shipping channel. It forms a large bird-foot delta with many distribution channels and wetlands where it meets Lake St. Clair. The river above the delta is a uniform channel with few bends, no cutoff channels or oxbow lakes, and only two islands. Most of the U.S. shoreline is now artificial and the lack of shoreline complexity, along with the fast current, depth of the river and wave forces generated by large commercial vessels limit wetland development along the banks of the river. The entire St. Clair River has been declared an AOC.

Lake St. Clair is a shallow productive lake located between the St. Clair and Detroit Rivers. Where the St. Clair River meets Lake St. Clair, an expansive bird-foot delta—the largest freshwater delta in the world—has formed with many distribution channels, islands and wetlands. The entire U.S. shoreline of

Lake St. Clair consists of flat, clay lakeplain characterized by slopes of less than one percent with wet loamy clayey soils prevalent (Minc, 1998). At the time of European contact, the Lake St. Clair shoreline was bordered by extensive swamp forests, wet prairies and wet meadows. Shallow water areas contained a nearly continuous band of emergent marsh, while deeper water supported large beds of *Vallisneria americana,* an important food for waterfowl (Minc, 1997). The Clinton River, a tributary to the lake, has been declared an AOC.

The Detroit River connects Lake St. Clair to Lake Erie. It is 51 kilometers long and drops only 0.9 meters along its length. The shoreline stretches 127 kilometers on the U.S. side and several islands occur in the river, with the largest, Grosse Isle, near its mouth. About 95 percent of the total flow in the river enters from Lake St. Clair, and the remainder flows from tributaries and sewer systems, which drain a watershed of 1,844 square kilometers. The natural shoreline consists of clay banks, but 87 percent of the U.S. shoreline is now artificial with revetments and other shoreline hardening structures. Commercial traffic on the river is heavy and Detroit is the busiest port on the Great Lakes. The Detroit River and the Rouge River (a tributary) have both been identified as Areas of Concern (Wilcox and Maynard, 1996).

Habitat Issues

Status and Trends

No comprehensive estimates of coastal wetland loss are available for this subregion. Main causes for wetland losses have been shoreline modification, road construction, filling for urban and resort residential development, and dredging and channelization associated with marina development. The Saginaw Bay area historically contained some of Michigan's most extensive coastal wetlands, but extensive drainage for agriculture and ongoing pumping of diked wetlands for farming purposes have resulted in substantial losses.

Some wetland loss appears to have occurred along the shores of the St. Clair River above the delta, but there is no comprehensive estimate of the extent of loss. Almost all of the U.S. shoreline of the St. Clair River consists of residential, recreational and industrial developments and has been extensively modified. Wetland loss in the river appears to be largely related to extensive bulkheading, shoreline hardening, filling, channelization and dredging along the shores of the river.

Lake St. Clair and the St. Clair Delta have been extensively studied in terms of wetland loss. On the Michigan side of the lake and delta, 4,375 hectares, or 51 percent, of the original wetlands were lost between 1873 and 1968. These losses occurred mostly in the St. Clair Delta, along Anchor Bay and near the mouth of the Clinton River. In 1868 the Clinton River had over 1,295 hectares of wetlands, but by 1973 that amount had been reduced to 221 hectares (Edsall et al., 1988 in Wilcox and Maynard, 1996). Agriculture and urban, residential, and recreational development (e.g., marinas) are the major causes of wetland loss.

From depth surveys of the Detroit River in the 1870s, wetlands and large submergent macrophyte beds were nearly continuous along the shores in historic times. Emergent marshes extended inland from 0.3 meters to 2.0 meters in depth and were sometimes over one kilometer wide, especially near the mouths of tributaries such as the Rouge River. Today, around 87 percent of the U.S. shoreline of the Detroit River has been filled and bulkheaded (Manny and Kenaga, 1991 in Wilcox and Maynard, 1996).

Threats

Threats to the estuarine systems in this subregion become more severe in the southern portions and connecting channels. The northern Lake Huron watershed is still mostly forested, with the main impacts to coastal wetlands resulting from recreational boating and marina development, shoreline development, and mechanized vegetation clearing in the coastal zone. Due to its larger population relative to the northern half of Lake Huron, the stressors on Saginaw Bay's wetlands are even greater. In addition, toxic contamination due to resuspension of contaminated sediment, continued drainage for agricultural purposes, and exotic species such as zebra mussels, carp, and purple loosestrife threaten the integrity of Saginaw Bay wetlands.

On the St. Clair River, continued shoreline hardening, filling, channelization and dredging along the shores fragment the few remaining wetlands along the river, and urban encroachment continues to cause wetland loss and impairment. Ship wakes from large commercial vessels are an important stressor to shoreline habitats, including remnant coastal wetlands, by eroding the shoreline and hampering the establishment of aquatic macrophytes (Wilcox and Maynard, 1996).

Most of the U.S. shoreline of Lake St. Clair and the St. Clair Delta is now developed with marinas, urban or residential developments. Urban, recreational and agricultural encroachment continues to threaten existing wetlands and make restoration very challenging. Another major stress is the diking of wetlands. About half of the wetlands in Lake St. Clair and the St. Clair Delta have been diked. They are managed mainly for waterfowl hunting at the expense of other wetland functions. Diking isolates these wetlands from the upland and lake envi-

ronments, and many wetland functions are impaired. Furthermore, the diversity of wetland habitats are decreased since water level controls are used to maintain particular vegetation and environmental conditions. Other stressors to these wetlands include sediment and nutrient loading from tributaries and invasive species (Wilcox and Maynard, 1996).

Many human stressors continue to impact remaining wetlands on the Detroit River, including erosion from shipping, shoreline modification, dredging and channelization, excess nutrients, contamination of water and sediments with toxic chemicals, agricultural and urban encroachment, and invasive non-indigenous species (Wilcox and Maynard, 1996).

Restoration Plans

Lake Huron Initiative Plan

Initiated by the Department of Environmental Quality's Michigan Office of the Great Lakes with the U.S. Environmental Protection Agency and Environment Canada as partners, The Lake Huron Initiative Action Plan identifies issues of importance to Lake Huron, actions that need to be taken to protect and restore the Lake Huron ecosystem, and development of partnerships to begin undertaking efforts that cannot be accomplished by individual agencies alone. The plan identifies immediate future actions focusing on two key issues: critical pollutants and use impairments, and fish and wildlife populations (habitat and biodiversity).

Measures of Success: Addressing Environmental Impairments in the Saginaw River and Saginaw Bay

The Saginaw Bay Watershed, located along Michigan's east coast on Lake Huron is Michigan's largest watershed and is the largest contiguous freshwater coastal wetland system in the United States. The Measures of Success report was prepared and produced under the guidance of the Partnership for the Saginaw Bay Watershed and represents the collective thoughts of technicians, public officials (federal, state and local), stakeholders and watershed citizens. It provides a brief account of the historical practices responsible for impairments identified in the Saginaw River/Bay Remedial Action Plan, celebrates progress to date in addressing the problems, and proposes measurable goals for the future. In regard to wildlife and habitat, it identifies protecting the ecological integrity of the remaining coastal marsh areas for use by fish and wildlife as the single most important goal in sustaining the diversity and abundance of species. The area below the 585-foot contour within Saginaw Bay and the lower portions of the Bay's tributary streams are identified as the critical coastal marsh areas in need of protection and restoration.

Tobico Marsh Hydrologic Study

Tobico Marsh Hydrologic Study was completed by Resource Management Group, Inc., under contract to Bay County, utilizing funds provided by the Michigan Department of Natural Resources under the Saginaw Bay National Watershed Initiative. The purpose of the study was to determine the nature and extent of historic changes within the Tobico Marsh watershed and determine marsh management options for the future.

Crow Island State Game Area Master Plan

State ownership of the Crow Island State Game Area began in 1953. The Game Area lies within the Saginaw Bay lakeplain, formerly characterized by swamp forest, wet and wet-mesic prairie and emergent marshes. The management plan was developed for the purposes of providing recreation, protecting biodiversity and improving waterfowl production. Examples of habitat management objectives include restoring specified areas (including prior converted wetlands) to functional marshes through controlling water levels, plantings and prescribed burns.

Nayanquing Point Wildlife Area Master Plan

The Nayanquing Point Wildlife Area is located in the east central portion of Michigan's Lower Peninsula, lying along the west side of the Saginaw Bay. The Michigan Department of Natural Resources' overlying intent of management at Nayanquing Point is based on providing suitable habitat to enhance the welfare of the wildlife resource. Improved habitat will serve the needs of local and migrant waterfowl, shorebirds and other wetland wildlife species. Specific management goals and actions are outlined for species, water level control, land acquisition and a barrier beach in the Wildlife Area.

Wigwam Bay Wildlife Area Management Plan

The Wigwam Bay Wildlife Area (WBWA) has an east and west unit, both located in Michigan's Arenac County in the Saginaw Bay area. The Plan's goals and objectives were developed in response to the Michigan Department of Natural Resources' concern for the protection and propagation of wildlife and enhancement of the associated habitat types, as well as the public's desire for the recreational use of the area. The goal is to provide essential habitat for migratory and resident wildlife and recreational opportunities for hunting, trapping and wildlife viewing. Its objectives are: to maintain viable populations of all plants and animal species native to the area with an emphasis on waterfowl and other wetland-related species; to operate and maintain facilities in a cost- effective manner with agricultural practices (intensive management) not promoted; and to manage for specific recreational and species targets. Land acquisition activities are noted as a primary management consideration.

Quanicasse Wildlife Area Management Plan
The Quanicasse Wildlife Area is located along the south shore of Lake Huron's Saginaw Bay. This part of the Saginaw Bay is a valuable marsh and wetland wildlife habitat. The Michigan Department of Natural Resources' primary management goal is to preserve this area for wildlife, thereby preventing future residential or commercial development which would ultimately destroy wildlife values. As such, the main objective relates to land acquisition with management of the area consisting of preserving the marsh in its natural condition.

Saginaw Bay Wetlands Initiative - Phase II
A proposal prepared by Ducks Unlimited and presented to the North American Wetlands Conservation Council, the Saginaw Bay Wetlands Initiative - Phase II continues and broadens a successful multi-year multi-partner effort to protect and restore wetlands and adjacent habitat on public and private lands within Michigan's Saginaw Bay watershed. The focus of Phase II will be protection and restoration of Great Lakes coastal marshes and their associated habitats along Saginaw Bay, expansion of existing state and federal wildlife areas with the restoration of newly acquired lands where possible, and restoration and enhancement of small wetlands and associated uplands important for waterfowl production on private lands throughout the watershed.

St. Clair Flats Wildlife Area Master Plan
The St. Clair Flats Wildlife Area is located in southeastern Michigan on the delta of the St. Clair River as it enters Lake St. Clair and is managed by Michigan's Department of Natural Resources. Some of the primary objectives to preserve or improve wetland type habitat for game and non-game species are: to provide a refuge and food supply for migrating waterfowl, shorebirds and wading birds; and provide more hunting opportunities and improved quality hunting experiences. Several work items are discussed regarding wetland wildlife including vegetative control, water level management, controlled burns and land acquisition.

St. John's Marsh Wildlife Area Habitat Development Plan
The St. John's Marsh Wildlife Area is located in southeastern Michigan, along the northeastern shoreline of Lake St. Clair's Anchor Bay. The marsh makes up the northern portion of the St. Clair Flats Wildlife Area. The Habitat Development Plan's goal is to preserve, protect and enhance existing marsh and upland habitats (3,000 acres), to meet the needs of breeding and migratory waterfowl, along with other wildlife species, while providing practical recreational opportunities for the benefit of all people. To meet the plan's goal, the Michigan Department of Natural Resources established 17 objectives with related action items, such as installation of specified water level control systems.

Plan Elements

Goals
Goals in the Lake Huron subregion focus on restoring and maintaining the chemical, physical and biological integrity of the waters, tributaries, and nearshore terrestrial and aquatic ecosystems. This includes identifying and protecting existing high-quality fish and wildlife habitat sites, as well as the ecosystem processes required to sustain such areas. The Saginaw Bay's Measures of Success plan references the goal of creating 500 acres of wetlands annually for the next 15 years.

Methods
The Lake Huron Initiative discusses many actions needed to protect and restore habitat for the short-term (one to three years) and long-term (longer than three years). Examples include identifying dams and other barriers that are having major ecological impacts; pursuing long-term remediation efforts; supporting development of upstream fishways and downstream passage facilities; and developing lakewide or shared policies on dams, dam removals, maintaining run-of-the-river flows, and dam retirement funding approaches.

Elements of Success
In discussing key concepts for protecting and restoring important habitats, the Lake Huron Plan identifies achieving no net loss of productive capacity of habitats as a sign of success. The Saginaw Bay's Measure's of Success plan references the goal of creating 500 acres of wetlands annually for the next 15 years and states that it is not the physical limitations but rather the economic and social implications of wetland restoration that may make this goal difficult to achieve in the short-term. The social and economic cost of removing land from agricultural production may be too high. For this reason, protecting the ecological integrity of the remaining coastal marsh areas for fish and wildlife is the most important single goal for successfully sustaining the diversity and abundance of species in the Saginaw Bay. As with the other subregions, involving stakeholders and coordinating with other efforts are important to the success of the plans.

Information Needs
There is a need for additional information to better understand the natural processes that support the estuarine systems and the ecology of species of concern in order to ensure that conservation management is most effective. Additional information regarding economic assessment of wetlands and alternative

ecologically sustainable economic activities will also be very important.

Lake Erie Subregion

Description

The Lake Erie subregion includes Lake Erie and the Niagara River. Lake Erie is the smallest of the Great Lakes in water volume, as well as the most shallow, and has a retention/replacement time of 2.7 years. Lake Erie is the most southern of the Great Lakes, and its more moderate climate is marked by the appearance of a distinctively southern floristic component. In addition, the shallow waters of Lake Erie respond rapidly to the annual thermal heating and cooling cycle, creating a distinct growing season environment. However, its east-west orientation parallel to the prevailing storm track makes Lake Erie very susceptible to the passage of storms. Lake Erie is noted for its severe storms, intense wave action and rapid water level changes (Herdendorf and Krieger, 1989 in Minc, 1997).

A large number of coastal wetlands border the low-lying shorelines and estuaries of western Lake Erie in Michigan and Ohio. Along the U.S. shoreline of Lake Erie there are 87 wetlands, encompassing more than 7,937 hectares (Herdendorf et al., 1981b in Minc, 1997). Wetlands of Lake Erie are predominantly lagoon, embayed and drowned river mouth emergent marshes. Many have barrier beaches, but several have been diked for increased shoreline protection and intensive wetland management (Wilcox and Maynard, 1996).

The coastal wetlands of Lake Erie support the largest diversity of plant and wildlife species in the Great Lakes. The moderate climate of Lake Erie and its more southern latitude allow for many species not found along the northern Great Lakes. As a result of this diversity, coastal wetlands of Lake Erie provide habitat for many rare species of plants and wildlife, such as Pennsylvania smartweed, Jefferson's salamander, spotted gar and king rail, and rare wetland communities such as coastal meadow marsh (shoreline fen) occur at several locations (Wilcox and Maynard, 1996).

The Niagara River drains Lake Erie into Lake Ontario. It flows northerly from Lake Erie at Buffalo, N.Y., to Lake Ontario, at Niagara-on-the-Lake. Over the river's 58-kilometer course, it drops almost 100 meters in elevation; 56 meters occurring as the river cascades over the Niagara Escarpment at Niagara Falls. The fast flow of the river has historically precluded wetland development along some reaches of the river (Minc, 1998), and many wetland areas have been degraded or lost. A few wetlands and beds of submergent macrophytes are present in the upper reaches of the river associated with the low sandy shores of islands (Wilcox and Maynard, 1996).

Habitat Issues

Status and Trends

Along the U.S. shore of Lake Erie, large areas of coastal wetlands have been lost over the past 150 years, especially in the western basin of the lake. Prior to 1850, an extensive coastal marsh and swamp system covered an area of approximately 122,000 hectares between Vermilion, Ohio and the mouth of the Detroit River in Michigan, and extending up the valley of the Maumee River. This was part of the Black Swamp, a vast wetland complex 160 kilometers long and 40 kilometers wide (Herdendorf, 1987 in Wilcox and Maynard, 1996). As a result of the development of Toledo at the mouth of the Maumee and the extensive agricultural drainage throughout the watershed, this extensive estuarine system has been nearly completely converted. Today, only about 5,300 hectares of western Lake Erie's coastal marshes remain (Bookhout et al., 1989 in Wilcox and Maynard, 1996). Site specific incremental loss is still occurring from dredging and filling, especially near harbors, marinas and waterfront developments.

There have been no specific studies on wetland loss in the Niagara River, but many wetlands have been reduced in size or lost, and both the Niagara and Buffalo Rivers have been declared AOCs. A large portion of the U.S. shoreline is developed, especially in the Buffalo area where extensive filling has occurred. For instance, the Tifft Street area in Buffalo was formerly the largest emergent marsh on the eastern end of Lake Erie; it was fragmented and largely filled for industrial and railroad development. Similarly, the marsh and submergent macrophyte beds around Rattlesnake Island and in small embayments in the Tonawanda Channel have been filled or dredged for residential or marina developments (New York State Department of Environmental Conservation, 1994 in Wilcox and Maynard, 1996).

Threats

The quality of many of Lake Erie's remaining wetlands has been and continues to be degraded by numerous stressors, especially excessive loadings of sediments and nutrients, contaminants, shoreline hardening, dredging, filling, changes in sediment budgets, exotic species and diking of wetlands.

While excess loadings of phosphorus from point and nonpoint sources have reduced over the last two decades due to control measures, nitrogen loadings from nonpoint sources, mainly

agricultural runoff, have increased in several watersheds (Richards and Baker, 1993 in Wilcox and Maynard, 1996). Many stretches of the U.S. shoreline in western Lake Erie have been modified with dikes, revetments or other shoreline structures for protection of built-up areas and agricultural fields against periodic high water levels and potential for flooding, erosion and property damage. While diking allows for more intensive management of waterfowl and other fauna, it also isolates it from the open waters of the lake, thus impairing many wetland functions.

The extensive use of revetments and other structures has limited the supply of sediments in the littoral drift in western Lake Erie. As a result, the barrier beaches and sand spits that protect wetland plants from wave action are no longer being replenished at a rate equal to or greater than the rate of erosion. As a result, these wetlands are becoming increasingly exposed to wave erosion. Examples occur along Cedar Point in Ohio and Woodtick Peninsula in Michigan. The restoration of Metzger Marsh, a 300-hectare wetland embayment protected from waves by a barrier beach, involved the establishment of a dike to mimic the protective function of the lost barrier beach. Finally, one of the most common stressors in wetlands along the shore of Lake Erie is invasive non-indigenous species including purple loosestrife, zebra mussels and carp.

In addition to many of the stressors discussed above, the Niagara River also is impacted by water withdrawal. More than half of the flow of the Niagara River is diverted for power production, causing dewatering of some marsh areas. This is exacerbated in some areas by road crossings, which restrict wetland hydrology (Wilcox and Maynard, 1996).

Restoration Plans

Lake Erie Lakewide Management Plan

The Lake Erie LaMP is being developed by 20 federal and state agencies along with the Lake Erie Binational Public Forum, a group of Lake Erie citizens interested in improving the lake. The LaMP contains appropriate funded and proposed (non-funded) actions for restoration and protection to bring about actual improvement in the ecosystem. Actions include commitments by the Parties, governments and regulatory programs, as well as suggested voluntary actions that could be taken by non-governmental partners.

The Lake Erie LaMP has defined loss of habitat as a major stressor and a beneficial use impairment. Several habitat projects have been completed over the years and a number of others are underway or proposed. Additionally, it proposes a foundation for developing a Lake Erie habitat restoration and protection plan and outlines screening criteria to assist in selecting and highlighting habitat projects that will most strongly support the goals of the Lake Erie LaMP.

Management Plan for Old Woman Creek National Estuarine Research Reserve and State Nature Preserve

The Old Woman Creek National Estuarine Research Reserve was established in Ohio in 1980 and currently encompasses 571 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 2000. Important habitats that may be useful for investigation and as reference sites include upland forests and old-field succession, swamp forests, freshwater marshes, streams and a barrier beach along Lake Erie. Restoration priorities include stream corridor buffer strips and exclusion of carp from the estuary, and serving as a reference site. Current restoration projects include stream bank stabilization.

Erie Marsh Restoration Project

The Erie Marsh Restoration Project is a proposed project of The Nature Conservancy (TNC). Erie Marsh, located 15 miles southwest of Monroe, Mich., is composed of 1,100 acres of diked marshland and 1,068 acres of open water. The area sited for restoration, Widgeon Hole, is 83 acres near the center of the marsh. The area will be managed for *Phragmites australis* control. Necessary steps include draining the Widgeon Hole, prescribed burning to remove biomass, and herbiciding the *Phragmites* followed by flooding. The site will be managed to promote native plant species and attract waterfowl by recreating marsh habitat. The restoration will serve as a pilot project to determine whether Great Lakes marsh habitat can be restored within a system that is controlled by dikes. It will be monitored by TNC to determine the success of invasive species removal, viability of native seed bank versus manual seeding of the site, and locations and abundance of the state-threatened Eastern fox snake.

Lake St. Clair/Western Lake Erie Watershed Project

A Ducks Unlimited proposal to the North American Wetlands Conservation Council, the Lake St. Clair/Western Lake Erie Watershed Project will continue and broaden existing efforts to protect and restore wetlands and adjacent habitat on public and private lands within the Lake St. Clair and western Lake Erie watershed including the Detroit River. The focus of the project will be on protection and restoration of Great Lakes coastal marshes and their associated habitats, expansion of existing state and federal wildlife areas, and restoration and enhancement of small wetlands and associated uplands important for waterfowl production on private lands throughout the watershed.

Erie State Game Area Master Plan

Michigan Department of Natural Resources' Erie State Game Area is located in the extreme southeastern corner of Michigan's Monroe County on Maumee Bay, an estuary of Lake Erie. The primary objectives of the master plan are to preserve and maintain wetland habitat for game and non-game species; to restore and create up to 2,000 acres of marsh; to provide increased nesting cover, food and resting area for migrating waterfowl; to provide increased recreational hunting opportunities near a heavily populated area in Michigan, and to provide for public uses such as wildlife viewing, photography and trapping. The plan proposes a barrier island be constructed to prevent further erosion and installation of water control structures and pumps.

Lake Erie Marshes Focus Plan

A flagship project under the North American Waterfowl Management Plan's Lower Great Lakes/St. Lawrence Basin Joint Venture, the Lake Erie Marshes Focus Plan encompasses the Ohio counties of Lucas, Wood, Ottawa, Sandusky and Erie. Managed by the Ohio Department of Natural Resources' Division of Wildlife in cooperation with the U.S. Fish and Wildlife Service, the project's goal is to provide at least 17,540 additional acres of high quality wetland habitat in the Lake Erie Marsh (Great Black Swamp) region. To meet this goal, two major habitat objectives have been identified: 1) wetland habitat protection; and 2) wetland habitat restoration and enhancement. Wetland habitat protection is defined in a broad sense and includes any legal arrangement that results in habitat protection and/or requires an expenditure of time or money to bring about. The protection goal is 10,764 acres, with 7,639 in fee title acquisition. The wetland habitat restoration and enhancement goal is 6,776 acres on federal, state and private lands.

Pointe Mouillee State Game Area Master Plan

The Pointe Mouillee State Game Area is located on the Lake Erie shoreline in the southeast corner of Michigan between Detroit and Toledo. Phase 1 of the project called for restoration of 1,900 acres of marsh through construction of dikes and installation of water control structures, duplicating the former creeks and channels that existed in the marsh in the early 1950s. Phase II of the plan involves basic marsh management (no construction) such as de-watering the lake bottom between the barrier island and dikes by pumping and establishing emergent plant communities on the exposed mud flats. The restored marsh will be maintained in as natural a condition as possible with free flow of waters from Lake Erie. Changes in this basic plan will take place only where changes in Lake Erie water levels or other factors cause deterioration in the optimum growth of emergent and submergent aquatic plant communities. Management practices including de-watering (drawdown), or flooding by pumping or gravity flow, may be necessary to assist nature in maintaining the desired balance.

Lake Erie Protection and Restoration Plan

The Lake Erie Protection and Restoration Plan was produced by the Ohio Lake Erie Commission (Commission), a state agency comprised of the directors of the Ohio Department of Natural Resources, Ohio Environmental Protection Agency, and the Departments of Agriculture, Development, Health, and Transportation. In 1998, the Commission released the Lake Erie Quality Index, which evaluated 10 separate indicators of Lake Erie quality, including habitat. The evaluation of indicators showed positive trends, as well as areas with little progress toward mitigating impacts of past practices. The Quality Index set environmental, recreational and economic goals and objectives. The plan identifies 84 specific recommendations to accomplish these goals and objectives and includes protection and restoration of valuable coastal properties.

Strawberry Island/Motor Island Shallows Restoration Plan

The Strawberry Island/Motor Island Shallows is located near the southern tip of Grand Island where it has been endangered due to gravel dredging and the erosive forces of the Niagara River's strong currents and ice flows. Strawberry Island, the upstream sentinel of the complex, once totaled more than 200 acres of wetland habitat and forest but now consists of only five acres. The New York State Department of State officially designated this area a “significant coastal fish and wildlife habitat.” A $1 million restoration project is underway to protect shorelines and restore the endangered aquatic habitat. The project is jointly sponsored by a variety of federal, state and local government and natural resource management organizations, and it is funded by the New York State Clean Water/Clean Air Bond Act and State Department of Transportation funds.

Plan Elements

Goals

Goals in lakewide plans that benefit wetlands are general, including coordination of management efforts, protection of existing estuarine systems, reducing contaminant loading, managing phosphorus, managing changes in land use, controlling exploitation by sport and commercial harvest, and creating and restoring natural landscapes.

Methods

Methods include reducing toxic and sediment loads, perma-

nent land protection (through purchase or easement), expanding research, coordinating management among various agencies, controlling exotic species through herbicide use and prescribed burning, managing recreation, re-establishing native vegetation, restoring natural littoral processes, restoring natural lake level fluctuations, and expanding education and outreach.

Elements of Success

Key elements of success include public education and involvement, cooperation and coordination of a wide range of stakeholders, and achieving progress on measurable indicators of success related to the particular estuarine system to be restored (e.g., increase in target species population and expansion of vegetated areas).

Information Needs

The plans acknowledge the need for additional information to apply sufficient understanding of the natural processes that support the estuarine systems and the ecology of species of concern in order to ensure that conservation management is most effective. The response of target species to the restoration activities will be monitored, and this information will be used to modify future restoration efforts.

Lake Ontario Subregion

Description

The Lake Ontario subregion includes Lake Ontario and the St. Lawrence River to the Quebec border. Lake Ontario is the smallest of the Great Lakes in surface area (18,960 square kilometers) but is relatively deep, with an average depth second only to Lake Superior. Water levels in the lake are controlled by dams and locks in the St. Lawrence River, and natural lake level fluctuations have been dampened significantly (Minc, 1997).

Along the U.S. side, Lake Ontario is bordered by low glacial till bluffs. As a result, most of Lake Ontario's shoreline (85 percent) is characterized by regular shorelines sloping rapidly into deep waters, which preclude extensive wetland development (Minc, 1997). In the U.S. portion of Lake Ontario, 168 wetlands covering 5,529 hectares are present (Herdendorf et al., 1981a in Wilcox and Maynard, 1996). Wetlands are most abundant along the eastern end of the lake owing to sand accumulation in the form of barrier beaches. Dominant wetland types include barrier-beach lagoons and partially barred lacustrine estuaries (Minc, 1997). In addition to these emergent and submergent marsh communities, there also are some swamps and a few rare shoreline fen communities. These coastal wetland systems provide important fish and wildlife habitat for the entire lake ecosystem.

The St. Lawrence River is the sole outlet of the entire Great Lakes. From its origin near Wolf Island, it flows northeast between New York and Ontario for 182 kilometers before entering the Province of Quebec. Water level and flows for this section of the St. Lawrence River have been regulated since the construction of the St. Lawrence Seaway in 1959. Since then, dams and water control structures have greatly changed the character of the river and its wetlands. The Thousand Islands section lies in the uppermost reach of the river. It has a rocky shoreline and many islands, bays and shoals with extensive wetlands. Downstream from the Thousand Islands, the St. Lawrence River goes from a single deep and wide channel with fast currents and a relatively uniform shoreline to a lacustrine-like system (created as a result of dam construction for the Seaway) with extensive wetlands located at creek mouths, in embayments and surrounding islands (Grant, 1995 in Wilcox and Maynard, 1996).

Habitat Issues

Status and Trends

Along the entire U.S. shore, Lake Ontario wetland losses have been estimated to be near 60 percent (Busch et al., 1993 in Wilcox and Maynard, 1996). Most of the losses are associated with the heavily populated areas surrounding Oswego and Rochester, but losses have also occurred as a result of resort residential and marina development, especially around large barrier beaches. Three Areas of Concern (AOC) are located in the Lake Ontario subregion including Eighteen Mile Creek, Rochester and Oswego in New York.

Water levels in Lake Ontario and the St. Lawrence River have been regulated in the lake since construction of the St. Lawrence Seaway in 1959. Prior to regulation, the range of water level fluctuations during the 20th century was about two meters. Following regulation, this range was reduced slightly between 1960 and 1976 and was reduced to about 0.9 meters after 1976. The lack of alternating flooded and de-watered conditions at the upper and lower edges of the wetlands decreased wetland area and the diversity of plant and wildlife communities (Busch et al., 1990; Wilcox et al., 1993 in Wilcox and Whillans, 1999). Upland species became more prevalent along the upper edges of the wetlands, emergent communities declined in area, aquatic macrophyte beds increased, and invasive plants began to dominate wetland communities. Extensive stands of cattail are now established in these wetlands, and many areas are dominated by purple loosestrife, reed canary grass and various shrubs.

The St. Lawrence River has experienced a wide variety of environmental disturbances since the channel was modified for shipping purposes. The largest disturbance was associated with the construction and operation of the St. Lawrence Seaway. Impacts include inundation from dams, regulation and stabilization of water flows, and direct impacts from dredging and filling. The St. Lawrence River is a focal point for a strong resort residential and tourist economy. Like other parts of the Great Lakes system, this has brought with it shoreline development, road construction, and dredging and filling associated with marina development and operation.

Threats

The remaining wetlands in Lake Ontario and the St. Lawrence River are affected by several human stressors, including manipulation of lake levels, toxic contaminants, high sediment loads, excess turbidity related to urban and agricultural runoff, excess nutrients, shoreline modification, dikes and revetments. Small-scale wetland loss continues as a result of shoreline development, especially around large barrier beaches and near larger cities, and dredging and filling associated with harbors, marinas and waterfront developments.

Restoration Plans

Lake Ontario Lakewide Management Plan 2000

The Lake Ontario LaMP contains appropriate funded and proposed (non-funded) actions for restoration and protection to bring about actual improvement in the ecosystem.

Eastern Lake Ontario Megasite Site Conservation Plan

The Nature Conservancy (TNC) has prepared a Site Conservation Plan for the Eastern Lake Ontario Dune and Wetland Complex, which includes a core of 16,000 acres, along 17 miles of Lake Ontario shoreline in Oswego and Jefferson Counties, New York. The plan identifies long-term conservation goals and describes a proposed five-prong approach to conservation and restoration of ecoregional targets. Targets include Great Lakes dunes and the coastal marsh ecosystems, and species such as the Champlain beachgrass, bog buckmouth and bog turtle. The plan also identifies the following declining and vulnerable bird targets: black tern, American bittern, sedge wren, and migratory stopover habitat for landbirds, shorebirds, raptors and waterbirds.

Eastern Great Lakes Lowlands Program Area Strategic Plan

Ducks Unlimited's Eastern Great Lakes Lowlands Program Area Strategic Plan covers 32,500 miles of low-lying lake plain habitats in New York, Pennsylvania and Ohio. The Plan establishes focus areas, with some addressing coastal wetlands such as Pennsylvania's St. Lawrence Valley and Northwest Counties focus areas. The plan sets five-year goals which include protecting 5,000 acres of wetland and associated upland habitat through acquisition and conservation easements, restoring and enhancing 9,000 acres of wetland habitat, and reducing sediment, nutrient and toxic loading into Lakes Erie and Ontario.

French Creek Wildlife Management Project

The French Creek Wildlife Management Area is located in the town of Clayton in Jefferson County, 20 miles north of Watertown, N.Y. It consists of 2,265 acres of small streams, cattail marshes, open meadows and upland hardwood forest that provide habitat for endangered, threatened and species of concern including the American bald eagle, osprey, black tern, Blandings turtle, pugnose and blackshin shiners, and a variety of migratory waterfowl and fur-bearing species. In order to mitigate the negative effects of the St. Lawrence Seaway System's hydrology, the restoration project involves design and construction of an earthen dam and innovative gate water level control system. The system provides the flexibility for current and future biodiversity management needs with the ability to adjust water levels while allowing fish passage.

Plan Elements

Goals

Goals in these plans range from the very broad (e.g., society acts with responsible stewardship of the Lake Ontario basin) to the more specific. Specific goals include long-term maintenance of functioning dune and bluff barrier systems, managing recreation on undeveloped portions of the barrier dune and beach systems, and maintaining a mosaic of healthy wetlands to support populations of the vast assemblage of rare and common plants and animals.

Methods

Methods include reducing toxic and sediment loads, protecting land through conservation easement or purchase; expanding research and the application of scientific information; coordinating management among various agencies; controlling exotic species; managing recreation; re-establishing native vegetation; restoring natural lake level fluctuations; and expanding education and outreach.

Elements of Success

Key elements of success include public education and involvement, cooperation and coordination of a wide range of stakeholders, and achieving progress on measurable indicators of success.

Information Needs

The plans acknowledge the need for additional information to apply sufficient understanding of the natural processes that support the estuarine systems and the ecology of species of concern in order to ensure that conservation management is most effective.

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