Conclusions

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Importance of Gulf of Mexico Seagrasses

The vignettes in this report quantify and highlight the regional significance of seagrass ecosystems in the northern Gulf of Mexico. Seagrasses make many important ecological and economic contributions to communities around the Gulf of Mexico (fig. 1). These seagrass ecosystems are also of national and even global significance. Seagrass meadows of the northern Gulf of Mexico contain more than 50% of the total U.S. distribution of seagrasses and more than 5% of the known global occurrences of seagrasses (Green and Short, 2003). The areal extent of seagrass meadows in the northern Gulf of Mexico is greater than the known distribution of seagrasses in any other countries except Australia and Indonesia (Green and Short, 2003). Seagrasses of the Florida Keys and Florida Bay in Florida and the adjacent Continental Shelf make up the largest documented semicontinuous seagrass meadow on Earth (Fourqurean and others, 2002). The Gulf of Mexico harbors a significant component of the world's marine biodiversity for seagrass ecosystems.

Seagrass Losses

Over the past 50 yr, seagrass losses of 20% to 100% have been estimated in northern Gulf of Mexico estuaries (Duke and Kruczynski, 1992). Causes of these losses are many and include climate and water-level variations, physical removal, smothering with sediments, light extinction resulting from turbidity or phytoplankton, and inputs of excess nutrients. Natural perturbations, such as storm events, can cause erosion of sediments and high water turbidity that may stress seagrasses.

Human-induced impacts on seagrasses can have more long-lasting, and perhaps synergistic, effects. Seagrasses are found at the downstream position in watersheds and are susceptible to perturbations from many upstream sources. Land-based erosion is a major stress to seagrass systems because it leads to physical smothering and to increased turbidity of the water column and, thus, to decreased light for photosynthesis. Nutrient additions from point and nonpoint sources can result in blooms of phytoplankton that can shade seagrasses and cause stress or death. Stresses can eliminate seagrasses completely or produce patchy, discontinuous beds. Fragmented seagrass beds do not provide the same ecological goods and services as continuous seagrass meadows (Bell and others, 2001; Uhrin and Holmquist, 2003). Once seagrasses are lost from an area, physical binding of sediments by the

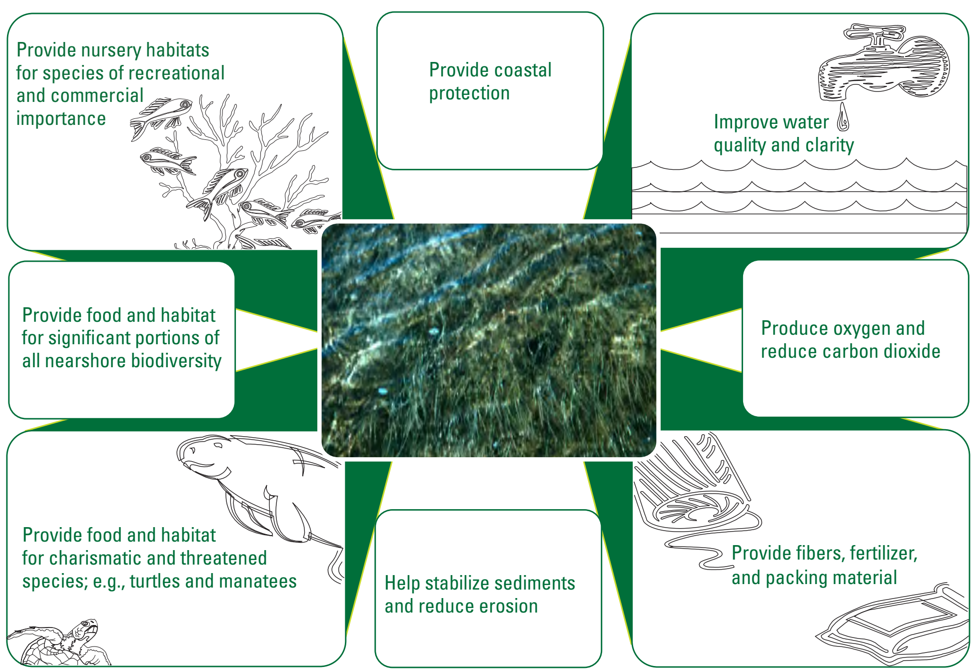

Figure 1. Examples of seagrass functions and values. Photograph by Tommy Michot, U.S. Geological Survey

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root systems disappears and may result in increased turbidity and more seagrass losses. Physical damage to seagrass systems resulting from cumulative impacts from boat groundings and propeller scarring is also a significant contributor to losses of seagrass communities (Sargent and others, 1995; Uhrin and Holmquist, 2003).

Assessment of seagrass areal coverage and cause of losses for the 14 estuarine systems presented in this status and trends report by the various authors along the Gulf of Mexico coast are summarized in table 1 and show several recurrent themes:

- Historical losses for the most part far exceed any recent gains in acreage.
- The area of continuous coverage of seagrasses has markedly declined, and the area of fragmented beds has increased.
- Development pressure and nutrient additions are the main contributors to historical and continuing losses.
- Variability in climate can cause losses and can interact with human stresses.

Although some estuarine systems in this report document recent increases in seagrass coverage, the losses far outweigh the gains. For example, Laguna Madre, Tex., has lost approximately 10% to 20% of seagrass coverage since 1965, much of which has been due to a recent phytoplankton bloom. The Mississippi Sound, Miss., has lost nearly all of its seagrasses—over 4,500 of 5,250 ha (11,120 of 12,973 acres) of seagrasses—since 1969. Tampa Bay, Fla., has experienced some recent increases in seagrass coverage because of improved water quality, but coverage today is still reduced by 6,000 ha (14,826 acres) from the 1950s.

The principal cause of seagrass loss varies depending upon the location, but there are some commonalities. Physical removal of seagrass and burial with sediments are consequences of initial and maintenance dredging of the Gulf Intracoastal Waterway (GIWW). In Texas, dredging in the lower Laguna Madre resulted in increased turbidity and a significant loss of seagrasses because of physical removal, smothering, and reduced light penetration. Dredging of Redfish Bay not only resulted in a loss of about 536 ha (1,324 acres) of seagrasses but also resulted in a substantial loss (48%) of continuous beds and an increase (88%) in patchy, fragmented beds. Turbidity associated with dredging Redfish Bay, Harbor Island, and the back side of Mustang Island for oil and gas exploration resulted in blanketing seagrass habitats with sediments and subsequent disappearance of seagrasses. In Florida, dredging operations in the 1950s and 1960s were a major cause of seagrass losses.

It is well documented that human-induced sediment and nutrient inputs into estuaries lead to major declines in seagrass coverage and that cessation of those inputs leads to recovery. In Florida, approximately one-half of Tampa Bay's seagrass meadows (16,350 to 21,653 ha (40,401 to 53,505 acres)) were lost between 1950 and 1982 as a result of the combined effects of dredge and fill activities and degraded water quality. Recent improvements in treatment and disposal of wastewater by Tampa, St. Petersburg, and Clearwater have resulted in improved water quality and an increase in seagrass acreage (26,078 ha (64,439 acres)). Seagrass coverage in Tampa Bay during 2002, however, was only 65% of the 1950 values. Wastewater nitrogen loads to Sarasota Bay have decreased from 516 Mg/yr (569 tons/yr) in 1988 to 100 Mg/yr (110 tons/yr) in 1999 (an 80% decrease). This improved water quality has led to increased seagrass coverage in portions of Sarasota Bay (e.g., Little Sarasota Bay).

Natural nutrient releases may also initiate seagrass loss. The bloom of "brown tide" in the upper Laguna Madre in Texas is thought to have begun with inhibition of grazers by hypersalinity followed by a freeze-induced fish kill and a subsequent massive nutrient release. The phytoplankton bloom that occurred because of increased nutrient availability resulted in continuously reduced light penetration from 1990 until 1997, and the brown tide alga has bloomed sporadically since 1997. There has been little recovery of seagrasses because bottom sediments are now more prone to resuspension that results in decreased light availability and further nutrient releases.

Declining water quality because of significant changes in historical land uses is also thought to be a major contributor to seagrass losses in Mississippi Sound, Miss. Agriculture and forestry have given way to urban, casino, industrial, and port developments. Coastal Mississippi has experienced a 21.8% increase in human population over the past decade, which is twice that observed for the entire State. This growth has resulted in increased erosion and point and nonpoint sources of pollution that have detrimentally affected seagrass survival.

Although it has not been proven, the die-off of seagrasses in Florida Bay, Fla., was most probably due to severely reduced freshwater inflow following canal construction during the 1950s to 1970s to drain wetlands and prevent flooding of urban areas in south Florida. The canals routed fresh water to the sea before it reached The Everglades wetlands that form the northern border of Florida Bay. Decreased water flow by design, and a significant drought in the late 1980s, resulted in hypersaline conditions and changed sediment chemistry that stressed seagrasses. Once stressed, seagrass were then susceptible to disease, which may have been the ultimate cause of over 27,000 ha (66,717 acres) of seagrass damaged or lost (Robblee and others, 1991). Resuspension of sediments and phytoplankton blooms have restricted recovery of seagrasses in many areas of Florida Bay.

Propeller scar impacts to seagrass beds are an increasing problem for shallow beds throughout the Gulf of Mexico. The number of boaters continues to increase, which results in an increased threat to seagrass resources. Florida, for example, has documented that approximately 70,000 ha (172,970 acres) of seagrass have some degree of propeller scarring. Moderate to heavy scarring was found to be most prevalent in the Florida Keys, Charlotte Harbor, and Indian River Lagoon. Scarring

Table 1. Summary of areal coverage estimates from Gulf of Mexico nearshore areas and major threats to the resource.

Estuary System	Seagrass Coverage (most recent data)	Major Threats
1. Laguna Madre	69,517 ha (171,777 acres) 1998	1. Dredging 2. Texas brown tide
2. Texas Coastal Bend	11,385 ha (28,132 acres) 1994	1. Nutrient loading 2. Dredging
3. Galveston Bay	210 ha (519 acres) 1998	1. Habitat alteration 2. Nutrient loading
4. Chandeleur Islands	4,511 ha (11,147 acres) 1995	1. Tropical storms 2. Natural loss of sediment
5. Mississippi Sound and the Gulf Islands	298 ha (736 acres) 2002	1. Recreational uses 2. Decline in water quality
6. Perdido Bay	120 ha (297 acres) 2002	1. Wastewater effluent 2. Nutrient loading
7. Pensacola Bay	1,814 ha (4,482 acres) 1992	1. Sewage/industrial waste 2. Dredging
8. Choctawhatchee Bay	1,722 ha (4,255 acres) 1992	1. Boat propeller scarring 2. Nutrient loading
9. St Andrew Bay	3,979 ha (9,832 acres) 1992	1. Stormwater runoff 2. Boat propeller scarring
10. Florida Big Bend	250,000 ha (617,750 acres) 1992	1. Hydrological alterations 2. Nutrient loading
11. Tampa Bay	10,554 ha (26,079 acres) 2002	1. Dredging 2. Nonpoint pollution
12. Sarasota Bay	3,715 ha (9,180 acres) 2002	1. Rapid urbanization 2. Wastewater treatment
13. Charlotte Harbor	21,802 ha (53,873 acres) 1999	1. Increases in turbidity 2. Freshwater inflow
14. Florida Bay	124,787 ha (308,349 acres) 1994	1. Increased turbidity 2. Chronic light reduction

has also been documented in Redfish and Aransas Bays, Tex. Propeller scars may take many years to recover under ideal conditions, and many fail to recover because they are scoured by currents and wave action. Boater education, unambiguous signs, speed restrictions, and motor exclusion zones are being implemented in some areas in an attempt to limit future losses to scarring.

Significant changes in seagrass coverage can result from natural causes, but it is sometimes difficult to separate the impacts caused by nature from those caused by humans since they are often intertwined. For example, Hurricane Beulah (1967) caused the loss of 100% of seagrasses in Nueces Bay, Tex. This loss may have been exacerbated by poor erosion controls in adjacent farmlands which experienced record-level rainfall from the storm. Galveston Bay, Tex., was subjected to major destruction from Hurricane Carla (1961), and in the subsequent two decades lost 100% of its seagrasses. During that time, however, seagrasses experienced increasing stresses because of subsidence, erosion, and shoreline development in and around the bay. A 33% reduction in seagrass bed acreage in the Mississippi Sound, Miss., was attributed to a combination of erosion and sedimentation during Hurricane Camille (1969) and subsequent reductions in salinity because of flooding. Recent decreases of seagrass coverage in Sarasota Bay, Fla., have been linked to the 1997–98 El Niño event that resulted in rainfalls 20%–48% higher than average. Excessive nutrients and sediment loads most likely caused a decrease in water clarity and subsequent seagrass losses.

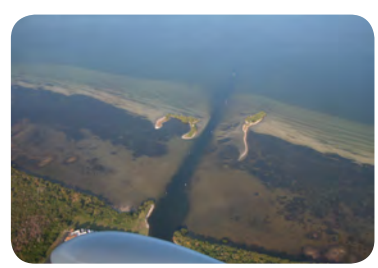
Other climatic variations can initiate changes in seagrass coverage. The Chandeleur Islands of Louisiana are a dynamic barrier island chain where the land area decreased 65% from 1855 to 1999 (including a 40% decrease with the passage of Hurricane Georges in 1998). Seagrass area surrounding those islands seems to decrease during and immediately after tropical cyclone passage and to recover between storm events. Winter storms and low water associated with cold front passages contribute to natural losses of seagrasses in Louisiana and other areas.

Sea-level rise as a result of the current global warming trend has resulted in gains of seagrass coverage at Harbor Island and Mustang Island, Tex. Elsewhere, seagrass increases with sea-level rise can be expected to occur in areas where depth, water quality, and sediment stability are suitable for seagrass colonization and growth.

Seagrass Decline Leads to Economic and Aesthetic Losses

Seagrass meadows are one of the building blocks that modulate productivity of coastal and estuarine ecosystems in the northern Gulf of Mexico. They are highly productive plant communities that provide habitat and forage for fish and wildlife, stabilize coastal sediments, and decrease wave energy. The biodiversity and productivity of seagrass meadows are directly linked to coastal economies (Duarte, 2000, 2002). Healthy seagrass meadows also filter nutrients and contaminants from the water, thus improving water quality. The resources that State and Federal agencies have expended to provide this status and trends report attest to the recognition of the goods and services that seagrasses provide.

Species that are dependent upon seagrass beds include large, charismatic herbivores, such as redhead ducks (*Aythya americana*), manatees (*Trichechus manatus*), and green sea turtles (*Chelonia mydas*), as well as resident and transient fishes and invertebrates, such as pinfish (*Lagodon rhomboides*), grass shrimp (*Palaemonetes* spp.), and seahorses (*Hippocampus erectus*), and their foods. Many species use seagrass beds as feeding and nursery areas, such as red drum (*Scianops ocellatus*) and bonefish (*Albula vulpes*). It has been estimated that 70% to 90% of economically important fishery species spend part of their life histories in seagrass beds, including penaeid shrimps, spiny lobster (*Panularus argus*), blue crab (*Callinectes sapidus*), and a wide variety of fishes. Although estimates of their monetary value vary widely, all Gulf of Mexico States agree that maintenance of healthy seagrass communities is essential for maintaining coastal economies. For example, seagrasses were determined to be worth $9,000 to $28,000 per acre for commercial, recreational, and storm protection functions in Texas. The loss of seagrasses can lead to changes in the types, abundance, productivity, and diversity of aquatic species and communities in an estuary.



These changes will eventually translate into altered economic and aesthetic values.

Resource Management and Monitoring

The States that border the northern Gulf of Mexico have significant natural beauty, and their coastal economies are dependent upon the maintenance and restoration of their natural resources. The States have recognized the importance of seagrasses to the coastal economies and must be congratulated for their conservation efforts and the effort and expense to conduct the status and trends monitoring reported in this document. It is hoped that these efforts can be made more consistent between States so that a gulfwide area figure can be regularly and accurately estimated.

The states have been pursuing a variety of regulatory programs in order to reduce seagrass losses and to promote recovery of stressed seagrass beds. Mississippi has imposed a ban on trawling within 1.8 km (1 mi) of the shoreline of Gulf Islands National Seashore in an effort to reduce turbidity adjacent to seagrass beds. Texas and Florida have enacted "no combustion engine zones," improved signage, and education programs to reduce propeller scarring of seagrass beds. States are also considering restricting the size (draft) of vessels using certain waterways because of continuing losses to propeller wash and chronic sediment disturbance.

There is a need to reduce nutrient loading to surface waters from wastewater and stormwater. Coastal areas are generally not suitable for septic tank treatment of wastewater because of high water tables and paucity of nutrient binding and rapid percolation in sandy soils, and underlying karst in Florida. A major goal of the U.S. Environmental Protection Agency (EPA) Gulf of Mexico Program and of the seven gulf National Estuarine Programs is to provide an awareness the water quality issues through education, and to work with the gulf coast States and counties to (1) improve inadequate sewage treatment systems and septic systems, (2) replace wastewater treatment systems with state-of-the-art systems that provide improved treatment and disposal of wastewater, and (3) assist in the adoption and enforcement of stormwater treatment ordinances that will reduce runoff of untreated stormwater to surface waters. The example of Tampa Bay in reducing nutrient loads since the early 1990s illustrates that Federal agencies, State agencies, and local governments can work together to provide ecological payoffs that include the increase in seagrass habitat in the bay.

Planting of appropriate nonvegetated areas with seagrass shoots or seeds may increase the rate of recovery of an area towards a vegetated bottom. Methods to maximize success of creation or restoration of seagrass beds have been reviewed and analyzed by Fonseca (1994) and Fonseca and others (1998). There are, however, many examples of failed seagrass restoration efforts. To avoid failure, first and foremost, the area must have suitable environmental conditions for seagrass survival and growth. Restoration of areas devoid of seagrasses can only be successful if the physical and chemical conditions are amenable, or can be made amenable to seagrass survival. More research is needed on the definition of conditions that are conducive to seagrass growth and survival. Timing of plantings, genetic makeup of plant material, storage of plant material, anchoring methods, fertilization rates, currents, local stresses such as boat traffic, and other variables must be considered in developing seagrass restoration plans.

Proactive management of seagrass ecosystems requires the identification of indicators of seagrass health. Regular monitoring of those indicators will be required to detect areas that are stressed so that the proper responses can be applied to quickly and efficiently remove the stresses. More research is required on this important topic (Coles and Fortes, 2001).

Regular mapping of seagrass beds is required to define and quantify changes in coverage and may assist in monitoring progress toward restoration goals. Data from monitoring and mapping activities are particularly important in justifying the large expenditures required to produce changes in water quality conducive to seagrass survival and growth; however, accuracy of periodic gulfwide estimates of seagrass coverage will depend on standardization of the procedures used to make the estimates in different geographic areas. At present, there are different methods and definitions used between and within States. The EPA's Gulf of Mexico Program provides an excellent forum to work toward standardization of techniques and definitions as well as for coordination of gulfwide mapping efforts.

Field of Dreams or Empty Meadows: If You Build It, Will They Come?

Most restoration goals are based on area of habitat restored (e.g., the Estuary Restoration Act of 2000, S. 835), but habitats are defined by the associated plants and animals, that is, the communities in the seagrass meadows, not just the areas of seagrasses. The ultimate goal of restoration should be the rejuvenation of the former seagrass habitats, their biodiversity, and the ecological services that they provide (fig. 1).

Most of our conservation and restoration focus for seagrasses in the Gulf of Mexico has been on the seagrasses themselves; we need to expand our vision for success. The underlying and often untested assumption of restoration efforts (e.g., by replanting or by improving water clarity) is that “If you build it, they will come.” That is, once the gardens of seagrasses are reestablished, the typical plants and animals of seagrass communities will come swimming and drifting back. We know from extensive research that this is a bad assumption for many salt marsh restoration projects (Minello and Webb, 1997; Zedler, 2000; Zedler and others, 2001). Some research in seagrass restoration indicated that plants and animals can return quickly (Fonseca and others, 1996), and overall our success in restoring seagrasses and their communities is likely to be higher than for salt marshes (French McCay and Rowe, 2003); nonetheless, we need to better monitor not only the acreage of seagrasses in the Gulf of Mexico, but also the communities that inhabit them. A common fallacy is that this community-level monitoring must be time- and cost-intensive. We can use presence and absence surveys of plants and animals and analyze those data with nonparametric, multivariate statistics that can robustly identify changes in seagrass communities (Warwick and Clarke, 1991; Clarke 1993; Anderson and Underwood, 1994). Similar community-based monitoring protocols are widely used in Europe and Australia, and we encourage their use in the Gulf of Mexico (Short and Coles, 2001).

Conservation Is a Necessary and Proactive Management Tool

Much of the focus of seagrass management has been on restoration of areal coverage, as discussed in the vignettes of this report. Some great strides have been made in restoration, for example in Tampa Bay, Fla., but we are still learning how to correct previous mistakes in management. It must be recognized that this form of retroactive management (i.e., restoration of lost resources) is expensive. The current restoration efforts in Florida in The Everglades and Florida Bay, and to a lesser extent in Tampa Bay, illustrate how expensive it can be for tax payers to redress problems with historical management practices.

There are many good opportunities for proactive management of seagrasses in the northern Gulf of Mexico. To be able to move forward on any cost effective conservation opportunities, however, we need to first remove ourselves from the endless cycle of crisis management. When funds are allocated and priorities are set for restoration activities, they should go hand in hand with conservation allocations and priorities.

There are places in the northern Gulf of Mexico where some relatively cost-effective restoration and conservation efforts can yield substantial benefits in seagrass meadows of regional and global significance. For example, the Big Bend of Florida contains the largest and least impacted seagrass meadows in the United States, and possibly the world. Mattson and others (this report) concluded that a conservation focus is needed to protect those meadows. The importance of conservation of Big Bend seagrass meadows is also highlighted in The Nature Conservancy’s regional plan for the northern Gulf of Mexico (Beck and Odaya, 2001). Nutrient levels in the coastal rivers and streams of the Big Bend are rising, and coastal development is impinging rapidly from the northwest along the Florida Panhandle and from greater Tampa/St. Petersburg area in the south. The current quality and health of these seagrass ecosystems in the Big Bend could decline rapidly. Although monitoring records are admittedly incomplete and inconclusive, it appears that there have been recent habitat losses in this area. The conditions that led to the declines of seagrasses throughout much of the rest of the Gulf of Mexico are set to be replayed in the Big Bend. Have we learned enough from the past to not allow history to repeat itself?

Another high priority area for conservation action is the Laguna Madre of Texas, which contains the largest seagrass area in the western Gulf of Mexico subregion. Previous studies have shown that maintenance dredging of the Gulf Intracoastal Waterway, which represents one of the largest impacts to seagrasses in this bay, is not only harmful to seagrasses, but is also cost inefficient. Very few ships use the waterway in this region, and there are several more practicable alternatives for transporting supplies along this route while maintaining habitat quality (Diaz and Kelly, 1994; Onuf, 1994; Sheridan, 2004).

Towards Restoration and Conservation Success

The completion of this gulfwide status and trends report is particularly timely. The first global survey of changes in seagrass acreage recently revealed that approximately 15% of this marine resource has been lost in the last 10 yr (Green and Short, 2003). In 2000, the World Summit on Sustainable Development (Johannesburg, South Africa) adopted a commitment to reverse the trend of seagrass losses by 2010. Hard facts, such as those presented in the United Nations

Environment Programme document, will help persuade countries of the need for their improved stewardship of this important natural resource. Similarly, it is hoped that this status and trends report will go a long way in providing the justification for strong actions by Gulf of Mexico States to their remaining seagrasses and restore their eliminated or degraded seagrass beds.

For successful protection and restoration of seagrasses of the Gulf of Mexico, this status and trends report points to the need for a program to inventory and monitor seagrass change around the Gulf of Mexico, develop a restoration plan, identify the Federal, State, and local governments' partnerships, and develop priorities for the implementation of the plan and program. The program and plan would devote more time and effort for research and monitoring of these ecologically important, nearshore nursery areas and the essential fish habitat that they provide. In particular, the National Oceanic and Atmospheric Administration has a mandate to better identify, manage, and conserve these habitats, and the EPA is required to assess the impacts of coastal water quality on nearshore environments.

Opportunities should also be created for more private investment in coastal restoration and conservation. State and local governments often rely on public-private partnerships to achieve restoration of coastal habitats, and overall these have been quite successful; however, much more effort is needed. For example, Gulf of Mexico coastal States have the opportunity to lease submerged lands specifically targeted for the restoration and conservation of nearshore habitats. Submerged lands are widely available for lease and ownership in the United States. These lands have been sold almost exclusively to business interests for the exclusive use, management, and harvest of natural resources (McCay, 1998). For example, Florida leases submerged lands to more than 22,000 marinas. The leasing of submerged land for fisheries and aquaculture is a large and growing business (Goldburg and Triplett, 1997; DeVoe, 1999). More than 160,000 ha (395,360 acres) of the coast of Louisiana have been leased for oyster harvest (Louisiana Department of Wildlife and Fisheries, 2003). The leasing and ownership of submerged lands by individuals and groups, however, have rarely been used as tools for marine restoration or conservation.

A few groups are testing leasing and ownership of submerged lands for restoration and conservation, and the public-private partnerships they engender may be a welcome addition to coastal management (Beck and others, 2004). Existing statutes in Texas make it possible to lease submerged lands for restoration and conservation purposes, and these opportunities are being used to help restore and conserve salt marsh habitats in Galveston Bay (Beck and others, 2004). More such experiments in public-private conservation need to be attempted in the Gulf of Mexico, particularly for seagrass habitats.

For the past decade, the Gulf of Mexico coastal States of Texas and Florida have increased planning and conservation activities toward seagrass habitats, and the State of Mississippi has been gradually moving forward with conservation activities for the past couple of years; however, in all cases funding for seagrass inventory, monitoring, protection, and restoration has not been available for full implementation of the State plans. In addition, within the Federal Government seagrass habitat has not been a high priority for program development and action toward seagrass restoration and conservation. Small steps have been made, some independent and some coordinated, calling to action State, local, and Federal Government agencies for seagrass inventory, monitoring, protection, and restoration, for example this report on Seagrass Status and Trends in the Northern Gulf of Mexico: 1940–2002, and the EPA Gulf of Mexico Program and The Nature Conservancy which has identified priority estuaries in the northern Gulf of Mexico (Beck and others, 2000; Beck and Odaya 2001), that provide reasonable starting points for discussions on development and implementation of goals and objectives surrounding seagrass restoration and protection.

Potential priority areas like the Big Bend of Florida and the Laguna Madre of Texas represent only a portion of restoration and conservation priorities for seagrasses and their communities in the northern Gulf of Mexico. The identification of priority areas is not meant to dissuade agencies, groups, and citizens from acting to better manage seagrass meadows in all of their local embayments; however, there are areas of regional and even global importance for seagrass conservation within the northern Gulf of Mexico, and there are key opportunities to act with forethought to conserve and to restore those areas.

It is our duty to provide future generations with the opportunity to enjoy the benefits of a healthy coastal ecosystem. Expanses of healthy seagrass meadows are an integral part of that vision.

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