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Seagrass Conservation Plan for Texas

Texas General Land Office

Texas Natural Resource Conservation Commission

Artwork on cover: WILDLIFE EXPO 1996 Poster by John Dearman; photo by Earl Nottingham

Seagrass Conservation Plan for Texas

Sponsored by

Texas Parks and Wildlife
Texas General Land Office
Texas Natural Resource Conservation Commission
Galveston Bay Estuary Program
Coastal Bend Bays and Estuaries Program

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TEXAS PARKS & WILDLIFE

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FOREWORD

Submerged seagrass meadows are recognized as a dominant, unique subtropical habitat in many Texas bays and estuaries. They play critical roles in the coastal environment, including nursery habitat for estuarine fisheries, major source of organic biomass for coastal food webs, effective natural agents for stabilizing coastal erosion and sedimentation, and major biological agents in nutrient cycling and water quality processes. Since recent global studies show that seagrasses are sensitive to nutrient enrichment and water quality problems, as well as physical stress from human disturbances, many Texas scientists, resource managers, and environmentally-aware citizens have become concerned about the ecosystem health of these subtropical habitats. Recent declines in seagrasses of Galveston Bay and some Coastal Bend regions has led to a consensus that concerted planning and actions are needed to address seagrass problems and to promote effective conservation and management solutions.

A coastwide Seagrass Conservation Plan for Texas (SCPT) has been developed since 1996, when the Symposium on Texas Seagrasses was held in Corpus Christi. This symposium, attended by over 100 people, resulted in vigorous discussion, brainstorming, and exchange of ideas. Seagrass problems were identified and categorized according to three separate thematic areas: research issues, management/policy issues, and education/public outreach. A variety of strategies and actions dealing with theme issues were proposed for implementation. TPW, TGLO, and TNRCC staff worked closely together with research scientists and educators, as well as staff from the Program Offices of the Corpus Christi and Galveston Bays National Estuary Programs, to prioritize the many issues affecting seagrasses. The results of this planning process are summarized in this document.

The three symposium sponsors, TPW, TGLO, and TNRCC, have taken the lead in producing this document because each agency has certain legislative authority or statutory jurisdiction pertaining to seagrasses or the coastal waters where they occur. The TPW is authorized by Chapter 14 of its code to develop a State-owned Wetlands Conservation Plan in conjunction with TGLO. Special provisions extend to determination of seagrass impacts and protection of seagrasses from various processes (such as boat traffic, altered hydrology, dredging, and non-point source pollution). TGLO is authorized to manage state public submerged lands where seagrasses grow, and in addition is the chief coordinator in the Texas Coastal Management Program process. TNRCC is charged with regulatory authority to enforce water quality programs and develop water quality criteria. Additionally TPW and TNRCC are the state agencies charged with reviewing either Sec. 404 permit impacts or 401 water quality certification in coastal wetlands, respectively.

The three agencies have targeted for immediate action certain critical issues to protect the health and quality of Texas seagrass beds. **Texas Parks and Wildlife** will focus on coastwide efforts to determine status and trends of seagrass beds and species distribution on a regular basis. Distribution data will be maintained in a central seagrass library and database developed by the resource agencies and research institutes. The Department will support public education and outreach activities which help protect seagrasses from human disturbances (such as motorboat prop damage, water quality degradation) through its Conservation Education Program with help from local groups such as the National Estuary Programs. The **Texas Natural Resource**

Conservation Commission with its considerable responsibility for water quality protection of seagrass habitat, will consider the addition of seagrasses as a beneficial aquatic-life use in the Texas Surface Water Quality Standards. TNRCC will also develop more defined procedures for conducting 401 certifications of federal permits which could affect seagrasses and other coastal habitats.

Other proposed measures that cut across agency lines represent cooperative efforts. 1) Coordination procedures in the permit review process will be strengthened and integrated between TGLO, TNRCC, USFWS, NMFS, EPA, and USACOE. Procedures and guidelines dealing with restoration and mitigation projects should be reevaluated and redesigned where necessary to protect existing seagrass beds. 2) The **Texas General Land Office** will work with TPW to take formal action to establish other Coastal Preserve areas, possibly in the Coastal Bend area of Texas, to protect sensitive seagrass ecosystems from coastal development impacts. 3) TNRCC will coordinate with TPW and other resource agencies in order to promote consistency and effectiveness of regulatory, watershed management programs which protect coastal water quality and seagrass habitat.

These efforts are seen as part of a holistic approach to seagrass conservation and are expected to be effective if implementation of high priority actions is accomplished within two years. It is the sponsors' intent that additional implementation of identified strategies and actions would be attempted voluntarily by other groups, when appropriate opportunities arise. However, overall accomplishment of seagrass plan objectives will be achieved, only with the cooperative efforts of all parties. Texas' natural resource agencies (TPW, TNRCC, and the TGLO) have jointly agreed to lead this effort. All are optimistic about the prospect of conserving one of Texas' most valuable coastal resources.

Effective January 1999.

Andrew Sansom
Executive Director
Texas Parks and Wildlife

Garry Mauro
Texas Land Commissioner

Jeffrey A. Saitas, P.E.
Executive Director
Texas Natural Resource
Conservation Commission

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TPW PHOTO

Waterfowl feed extensively on Texas seagrasses during the fall and winter.

ACKNOWLEDGMENTS

It is difficult to recognize everyone who has been involved in developing this Plan. In a general sense, the history of seagrass conservation efforts goes back many years to the early work of coastal biologists and ecologists in Texas. The published plan builds on this strong foundation of scientific knowledge. In recent years, Leland Roberts of TPW was responsible for evaluating seagrass impacts from dredging activity on the GIWW and from coastal boat traffic. Later he became involved in coastal resource environmental planning as part of the coastal management process. Now retired, Mr. Roberts was most instrumental in TPW's seagrass conservation planning work. Under the direction of Dr. Larry McKinney, a management initiative was begun which focused on seagrass impacts from boat traffic under the authority of the TPW code (Chapter 14.002 Sec. 9).

Out of these initial management activities emerged Dr. McKinney's idea to develop a formal statewide Seagrass Conservation Plan. This led to the Symposium on Texas Seagrasses, organized and coordinated by Leland Roberts and Dr. Warren Pulich of TPW, held in November 1996. The keynote speaker, Kenneth Haddad from the Florida Department of Environmental Protection, was brought in to discuss the problems and efforts taken to protect seagrass communities in Florida. After the Symposium, a planning team consisting of Leland Roberts, Dr. Warren Pulich, Dr. Ken Dunton, Tom Calnan, and Dr. Jim Lester was assembled to begin the actual process of formulating and writing this plan. While the various chapters were written by some of these individuals, editing of the document was performed by Warren Pulich, with assistance from Tom Calnan.

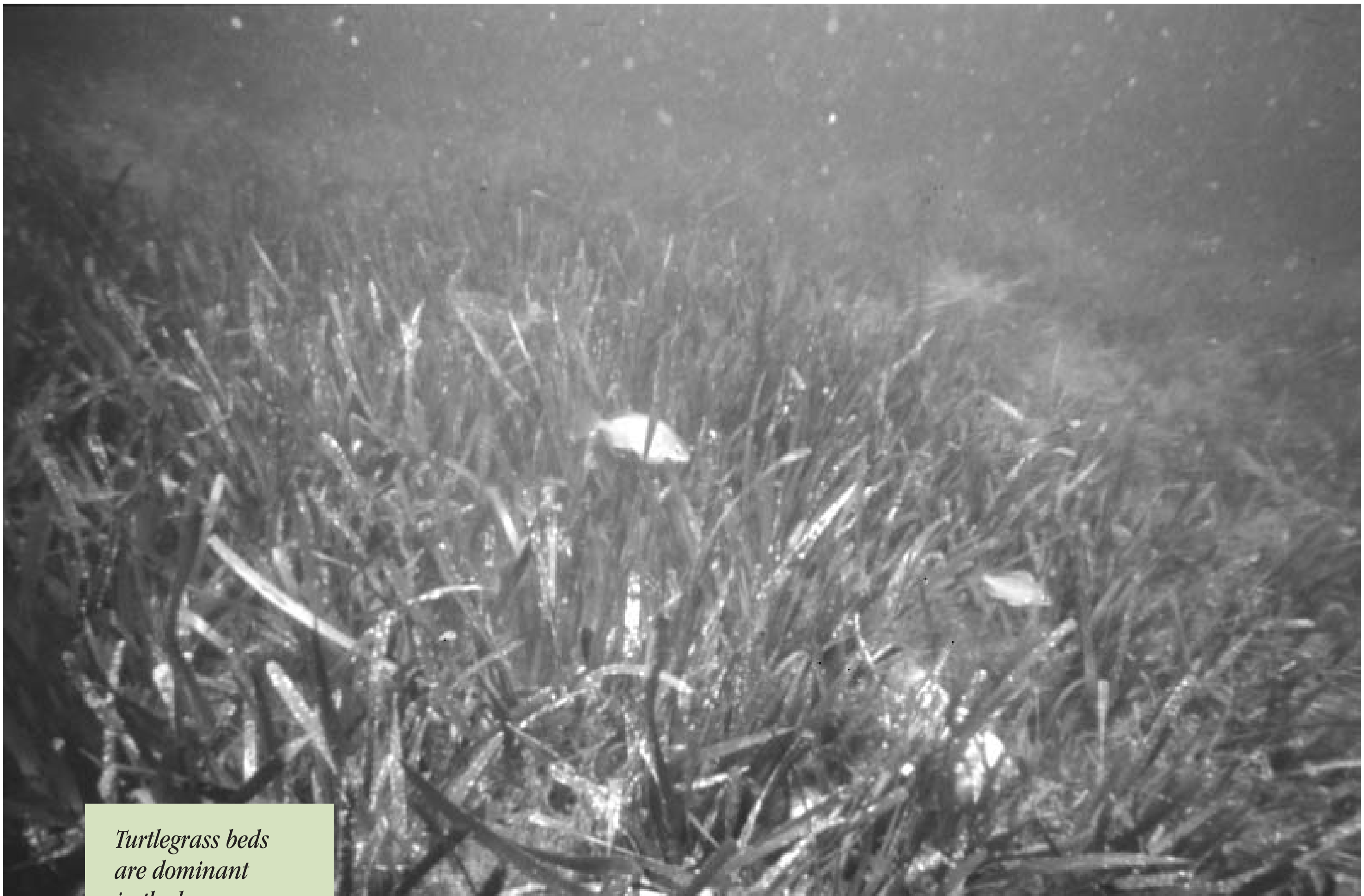
The editors are especially thankful to Dr. Jim Davenport and Mark Fisher of TNRCC for their contributions. Their input has been critical to formulating a practical, but realistic, perspective on water quality problems in seagrass habitats. The Education and Outreach parts of the Plan benefitted from the addition of material by the Coastal Bend Bays and Estuaries Program (Sandra Alvarado and Richard Volk). Material on ecology and research issues was supplied by Dr. Peter Sheridan of NMFS, Galveston. Julie Anderson kindly reviewed the Implementation Chapter and supplied material on the Statewide Wetlands Conservation Plan. Laura Radde and Ken Teague, both of EPA, Region 6, reviewed and offered constructive comments on the draft Plan, particularly the Management and Implementation chapters.

The diligent work of all members of the various Steering Committees is gratefully acknowledged. Many of the critical issues that were later developed into strategies and actions were initially proposed by these committee members. We especially appreciate work by Dr. Christopher Onuf, Robyn Cobb, Paul Carangelo, Rick Tinnin, and Nancy Webb. The Coastal Bend Bays Foundation, in particular Jennifer Lorenz, assisted in the organization and planning of the Seagrass Symposium held in 1996 in Corpus Christi. Rob Youker of the Texas Boating Trades Association and Carole Hemby of TPW also kindly helped with preparations and planning for the Symposium.

Excellent graphics support and publication assistance on this document were provided by the TPW Information Services Section, in particular Kathleen Martin, Linda Shew and Chris Hunt. We greatly appreciate the clerical support of Bonnie Smith and Misty Goodson at all phases of the process.

Development of this Seagrass Conservation Plan was partially supported by funding from Wetlands Protection State Development grant (CD 996562) from the U.S. Environmental Protection Agency Region VI to Texas Parks and Wildlife. Additional support was provided through funding from the Sport Fish Restoration Program (U.S. Fish and Wildlife Service) under Federal Aid Project F-37-TA-8.

SPORT FISH RESTORATION



Turtlegrass beds are dominant in the lower Laguna Madre.

KEN DUNTON

EXECUTIVE SUMMARY

INTRODUCTION

The development of this planning document started with work by the Resource Protection Division, TPW, when evidence of extensive boat propeller scarring was noted in many seagrass beds of Texas bays. Public relations and education efforts focusing on the problem began in earnest in 1994 with the publication of the brochure Boating and Seagrasses by TPW and TGLO with support from the Boating Trades Association of Texas. This action laid the groundwork for coordination and policy discussions between TPW and TGLO staff, research scientists, and various sportsmen and outdoor interests groups concerned about the status of Texas seagrass beds. With further compilation of coastwide status and trends information for Texas seagrasses by Pulich (1996) and Quammen and Onuf (1993), it has become evident that major conservation and environmental problems affect the remaining 235,000 total acres of Texas seagrasses. In this regard, Texas problems are symptomatic of the national and even global threats to seagrasses.

A decision was made to initiate a conservation planning effort to identify resource management problems, enumerate planning objectives, and develop long and short range strategies and actions to protect and preserve Texas seagrasses. Review of current seagrass status and coastwide trends indicated that various localized processes and factors, both natural and human-induced, affect Texas seagrasses. Trend analysis focused specifically on three well-known bay systems: Galveston Bay, Corpus Christi-Redfish Bays area, and the Laguna Madre. In order to deal effectively with the diversity of issues, planning was focused on three separate issue categories: Seagrass Research, Seagrass Management/Policy, and Seagrass Education/Outreach.

A planning team was organized to draft a conceptual planning document, conduct a Seagrass Symposium and Workshop, and then compile and prepare this published document. These activities have taken place over the last three years (since 1995). Because of statutory management authority over coastal public waters or biological resources therein, three state agencies (Texas Parks and Wildlife, Texas General Land Office, and Texas Natural Resource Conservation Commission) have taken the lead in guiding plan development. In addition, the two National Estuary Programs, Corpus Christi Bay and Galveston Bay, were actively involved. This multiuser/multistakeholder approach provides a good model for resource management and conservation that can be implemented at a local level through such a Seagrass Plan.

RESEARCH ISSUES SECTION

Our ability to successfully manage the valuable seagrass resources of the Texas coast is linked to an understanding of seagrass productivity in relation to changes in the abiotic environment, particularly with respect to light, nutrient, and temperature regimes. A basic knowledge of seagrass biology is required to address questions of management and conservation. Although seagrasses are adapted to withstand the seasonal occurrence of natural disturbances in their physical environment (e.g., turbidity and sedimentation that result from storms and high river inflow events), anthropogenic disturbances often occur on time scales that result in reduced photosynthesis and growth.

Dredging and filling activities have been widely recognized as one of the major anthropogenic disturbances contributing to the destruction of seagrass meadows. The direct and immediate effect of dredging on submerged aquatic vegetation (SAV) is seagrass mortality due to burial. In addition, there are indirect losses resulting from the disturbance of sediments during dredging operations. Since seagrasses have high light requirements, the decreased light availability associated with sediment resuspension has been closely associated with seagrass loss. Furthermore, dredged materials are not always suitable for the colonization and growth of seagrasses. Dredging may also result in hypoxia, which can increase root and rhizome mortality, and cause the erosion of grass meadows through changes in hydrologic conditions that occur from the dredging of navigational channels. Similarly, physical disturbance of grass beds through scarring by propellers often results in clear losses of habitat.

The impact of eutrophication on seagrasses has been associated with the growth of phytoplankton and epiphytic or drift macroalgae stimulated by excess nutrients. Descriptive field studies have found that epiphytic algae may inhibit or eliminate seagrasses entirely. Housing development and nitrogen loading rates are known to result in loss of seagrass habitat. The persistence of dense nuisance algal blooms (e.g., the brown tide), which may be related to anthropogenic changes in nutrient levels, has resulted in seagrass loss in the upper Laguna Madre. The well documented and negative response of seagrasses to nutrient enrichment warrant immediate action to restrict the release of nutrients from point and non-point sources to Texas coastal waters.

Based on our current knowledge of seagrasses that inhabit the Texas coast and the anthropogenic disturbances faced by these communities, the following major objectives were identified as major research issues:

- Regularly assess status and trends of seagrass distribution on a coast-wide basis. This includes the development of long-term monitoring plans for mapping and measurement of key parameters to assess both changes in water quality and seagrass health.

- Determine causes of changes in seagrass species composition and coverage (acreage), including areal losses and gains. Basic research topics under this goal include studies of plant physiology, demography, landscape ecology, process oriented work with respect to sediment/water column interactions and related factors and experimental studies on the creation and enhancement of seagrass beds.

- Identify habitat functions and productivity of natural seagrass community types and identify linkages with other habitats to support habitat conservation, creation, enhancement and restoration. This goal is directed toward ecologically oriented concerns related to functional differences in seagrass habitats as with respect to species, plant age and population structure, patch formation, epiphyte loading and evaluation of mitigation projects.

- Provide data for development of management policies in response to human-induced impacts. Review of existing information on seagrasses, the development of a data clearing-house, and the application of applied studies to specific management questions are the major components of this goal, which builds on the foundation of knowledge provided by monitoring and basic research.

MANAGEMENT/POLICY ISSUES

A sound management process that coordinates agency policies, public awareness, and existing research knowledge is needed to achieve effective seagrass conservation, while allowing for economic development. Management objectives were identified that address four problem areas: (1) seagrass beds are being lost or degraded, and/or species composition is changing; (2) lack of agency coordination may hinder management; (3) data synthesis and monitoring are insufficient for management decisions and need to be focused on management needs; and (4) public outreach is too limited to achieve the goal of public awareness. Objectives addressing these problems fall into three primary categories – regulatory, management, and educational policies.

Regulations

Regulatory policies for effective management involve ensuring water and sediment quality and coordinating and strengthening the mitigation sequence and guidelines. Beneficial water and sediment quality for seagrass communities involves establishing seagrass habitat as a specific aquatic life use in the Texas Surface Water Quality Standards. Additional evaluation would be needed to develop criteria or screening levels, such as suspended sediment, nutrient concentrations, turbidity, and salinity, for seagrass protection. Watershed management programs can protect water and sediment quality by promoting non-regulatory management activities. Implementation of Best Management Practices (BMPs), especially water-based BMPs, are needed to address impacts from runoff.

Federal and state regulations and programs that help protect seagrasses are primarily the Section 404 and 401 Permits of the Clean Water Act and the Texas Coastal Management Program (CMP). The mitigation sequence of avoidance, minimization, and compensation is in the Section 404(b)(1) Guidelines and is the substantive environmental standard by which all Section 404 permit applications are evaluated. The Texas Natural Resource Conservation Commission rules for Section 401 Certification and the CMP policies have incorporated key components of the Section 404 (b)(1) Guidelines. However, improvement is needed in coordinating the permitting process. In addition, the mitigation sequence needs to be strengthened and guidelines for avoidance of seagrass impacts emphasized.

In order to increase the success rate of restoration projects, management efforts need to be directed toward strengthening current restoration guidelines and providing increased research on successful planting techniques.

Management Programs

Management programs focus on 1) seagrass restoration, enhancement, and creation; 2) dredging and shoreline development; 3) policy consistency; and 4) research, data acquisition, and monitoring. Restoring and enhancing seagrasses was originally reported as being largely unsuccessful. Recently, many seagrass restoration projects have been successful, especially the restoration of shoalgrass (*Halodule wrightii*). In order to increase the success rate of restoration projects, management efforts need to be directed toward strengthening current restoration guidelines and providing increased research on successful planting techniques. For example, standard methods for removal of donor plants are needed so that seagrass beds in public waters are not damaged by removing plants. Where feasible, seagrass functions and values need to be restored at a watershed or system-wide level. This would require the development of a watershed plan for habitat needs and for the identification of compensatory mitigation opportunities and appropriate ratios.

Dredging of new canals and maintenance dredging of channels may cause mortality of seagrasses from burial or inhibit growth from turbidity and light reduction. Development along shorelines may affect conditions of water depth and currents and cause loss of seagrasses. Best Management Practices are needed to protect seagrasses while allowing for development of coastal resources.

Consensus among user groups over controversial issues involving natural resource use is difficult to achieve. The 1994 Beneficial Uses Group Plan for the Houston Ship Channel deep-draft navigation project is an example of a model plan or consensus agreement that minimized the ecological and sociological impacts of dredging by maximizing the beneficial uses of dredged material. Similar plans could be developed for estuarine systems, such as Laguna Madre, where seagrasses are dominant.

Policies affecting seagrasses are present in many agencies and may be written with only one agency and its specific regulatory authority in mind. Future policies should be prepared in a holistic framework and existing policies examined for flexibility and to ensure that goals are achieved.

Research, data acquisition, and monitoring need to be focused on management needs, i.e., on the water quality requirements of seagrasses. Management efforts will depend upon the development of new approaches that utilize a watershed approach to using water quality parameters to control import of nutrients into estuaries. Monitoring programs are needed for status and trends information and to help evaluate management actions. Ecological studies are needed to develop dependable restoration techniques. Sound, scientific data are needed to provide reliable information for application to management.

EDUCATION/OUTREACH ISSUES

Education, not regulation, has the greatest potential for conservation and restoration of seagrass ecosystems in Texas estuaries. A diverse group of stakeholders in Texas' coastal ecosystems developed a vision and plan for education and outreach in support of seagrass conservation. We envision a Texas where awareness, knowledge, concern, and skills will result in responsible behavior that conserves the seagrasses of our state. Conservation education programs can take citizens from ignorance of seagrass ecosystems through awareness, understanding, and concern to practicing responsible behavior in regard to this ecosystem.

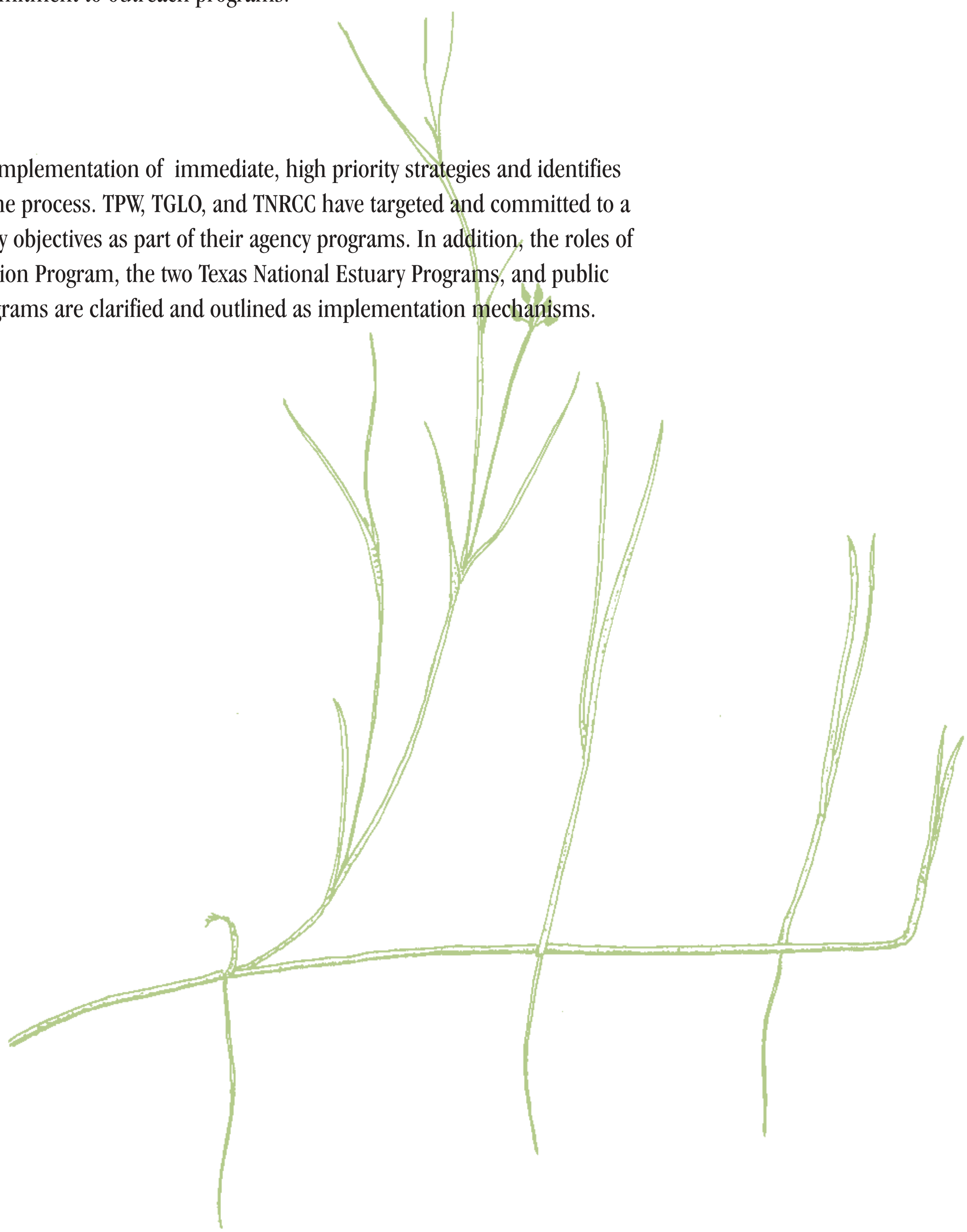
A variety of human activities directly damage seagrass meadows or produce conditions injurious to their survival. Conserving seagrass resources depends on enhancing their perceived value to estuary users. The education program must overcome the view that seagrass meadows have no value because they are common property and the plants are not harvested for consumption. They must be given value as components of a productive ecosystem and habitat for seafood species.

An education and outreach program must employ trusted messengers who will deliver information in appropriate language. Conservation messages must be designed for the situation in which people will receive them. Public messages need to tell citizens how they will benefit by adopting non-destructive behavior. Seagrass conservation can be advanced by changes ranging from coastal households reducing non-point source pollution to corporations adopting environmental accounting methods. This conservation education effort can be modeled on other programs that have changed societal attitudes toward litter and recycling.

Education and outreach objectives should assist in developing a sense of community stewardship and individual responsibility for seagrass conservation. Relevant information should be presented clearly, accurately, and with common-sense ideas for the public. State and federal agencies should strengthen their commitment to outreach programs.

PLAN IMPLEMENTATION

The final section deals with implementation of immediate, high priority strategies and identifies appropriate participants in the process. TPW, TGLO, and TNRCC have targeted and committed to a number of these high priority objectives as part of their agency programs. In addition, the roles of the State Wetlands Conservation Program, the two Texas National Estuary Programs, and public education and outreach programs are clarified and outlined as implementation mechanisms.




WARREN PULICH

Shoalgrass beds offer a sheltered water habitat with very high productivity.

CHAPTER 1.
INTRODUCTION

Warren Pulich, Jr.
Texas Parks and Wildlife
Resource Protection Division

Seagrass beds have long been recognized as critical coastal nursery habitat for estuarine fisheries and wildlife. They also function as direct food sources for fish, waterfowl, and sea turtles, major contributors of organic matter to estuarine and marine food webs, participants in nutrient cycling processes, and stabilizing agents in coastal sedimentation and erosion processes. In recent years they have received attention as biological indicators of estuarine water quality and ecosystem health as a result of their sensitivity to nutrient enrichment and eutrophication (Dennison et al. 1993, NOAA-ORCA, 1995). Because of the high quality and limited extent of seagrass beds along the Texas coast (approximately 235,000 total acres in 1994), any detrimental impacts to this important shallow-water habitat raise concern from resource managers, coastal scientists, environmentalists and sportsmen.

Over the past 20 years, there has developed a growing awareness of major factors that affect seagrass productivity, distribution, growth dynamics, and susceptibility to human disturbance (McRoy and McMillan 1977). Seagrass issues are not only of local, but also national and international scope, as evidenced by increased global eutrophication problems. In Texas, state and federal agencies (especially TPW, TGLO, TNRCC, USFWS, NMFS, EPA, and USACOE) and the scientific research community have recognized the need to address seagrass problems in the context of coastal zone planning, fisheries and waterfowl habitat management, and environmental monitoring (e.g., brown tide blooms, channel dredging and dredge material disposal, motorboat disturbance). Through special projects focused on these problems, some progress is being made, albeit in a fragmented manner. Proactive efforts directed at seagrass habitat restoration, as well as public education and outreach activities, have been started to foster stewardship towards seagrass resources. The challenge remains to effectively coordinate seagrass conservation and management actions in Texas, and to reduce the alarming pressures on sensitive, coastal seagrass communities.

Seagrass issues in Texas parallel those identified at the national and international scales.

STATUS AND TRENDS OF TEXAS SEAGRASSES

A geographic overview of the current status and trends in distribution of Texas seagrasses provides a useful perspective for designing effective programs on research, management, and education. This background information will illustrate the major problems now affecting seagrass systems in Texas. Although we recognize the existence and importance of freshwater submerged aquatic vegetation (SAV) which occurs (often abundantly) in the river delta portions of many Texas bays, we are focusing our attention on true salt-tolerant seagrasses. The main reason stems from differences in the plant ecology of the species. Such freshwater SAV consists predominantly of annual species, which reestablish annually from seeds or root tubers, unlike the perennial seagrasses of higher salinity coastal areas. Thus, population dynamics are inherently different for the two types of plants. Since responses to environmental conditions may or may not be the same, this would complicate the discussion and detract from the focus on coastal seagrass species.

WARREN PULICH

Male flowers of shoalgrass shown here are relatively obscure and easily overlooked.

Five seagrass genera (*Halodule, Thalassia, Syringodium, Halophila,* and *Ruppia*) occur in Texas. These species represent highly specialized marine flowering plants (but not actually true grasses) that grow rooted and submersed in the higher salinity waters of most Texas bays and estuaries. The well-known annual species, widgeongrass (*Ruppia maritima*, technically not a seagrass because it tolerates very low salinity, even fresh water) and the perennial, shoalgrass (*Halodule wrightii* [formerly *Diplanthera*]), often occur mixed in the higher salinity parts of all Texas bays and estuaries except for Sabine Lake. Shoalgrass, a subtropical species, is the most abundant seagrass coastwide, with the most extensive beds in Upper Laguna Madre. The tropical species, turtlegrass (*Thalassia testudinum*) and manateegrass (*Syringodium filiforme*), for all practical purposes occur only as far north as Aransas Bay, and are most abundant in the Lower Laguna Madre or Corpus Christi Bay area. This dominance of seagrass habitat makes Texas, in the western Gulf of Mexico, similar to the tropical eastern Gulf state, Florida.

Based on mapping surveys using color aerial photography over the last 20 years and field monitoring studies mentioned below, the status of Texas seagrass distribution is fairly complete at the standard scale of USGS 1:24,000 scale quadrangle maps. This qualification is made to emphasize that seagrass beds are very dynamic at larger scales (higher resolution), and these smaller, intra-bed changes are difficult to map regularly, especially on a coastwide or even regional basis. Recent mapping inventories by 1) TPW Coastal Studies Program, 2) USFWS National Wetlands Research Center, Corpus Christi and 3) University of Texas - Bureau of Economic Geology, show the overall distribution and abundance at 1:24,000 scale, especially of pristine, extensive seagrass beds. This distribution, and also species occurrence, reflects a clearcut separation between the more temperate upper Texas coast and the subtropical lower coast.

Fluctuations in seagrass distribution and abundance can indicate significant environmental disturbances or merely typical response to natural processes. However, trend dynamics are poorly studied, despite the fact that results from trend analysis can identify problem areas and provide a baseline to assess future impacts on seagrasses. In several bays where reliable historical data are available, especially from studies by TPW (McMahan 1967-68, West 1971-74) and Texas A&I University (Merkord 1978), the contribution of different environmental factors and coastal processes to seagrass landscape changes have been evaluated (Quammen and Onuf 1993). In recent times, the application of GPS technology and underwater photography has expedited ground-truthing and greatly increased map precision and accuracy.

Current Status

Recent (1994) total coastwide seagrass acreage was approximately 235,000 acres (95,142 hectares). This applies to permanently established beds of the four perennial seagrass species and annual widgeongrass beds (Tables 1-1 and 1-2). Seagrass inventories by individual bay systems (Tables 1-1 and 1-2) show that the vast majority of seagrass (79.1%) occurs in Laguna Madre (Upper and Baffin Bay = 28.6% and Lower = 50.5%), while only 1.7% occurs north of Pass

Table 1-1. Status and Trends in Texas Seagrass – Upper Coast

Bay System	Current Acreage	Percent of Coastwide	Species*	Trends
Galveston	280	0.1	Rup, (Hph, Hd, Th)	Gone (except in Christmas Bay)
Matagorda East Matagorda	3,830	1.6	Hd, Rup, Hph	Possibly decreasing
San Antonio Espiritu Santo	10,600	4.6	Hd, Rup, Hph	Fluctuates with inflows
Copano St. Charles Aransas	8,000	3.4	Hd, Rup Hd, Rup All five	

Source: TPW (Pulich et al., 1991, 1994, 1997); TAMU (Adair et al. 1994).
Acreage excludes freshwater SAV in/near bay deltas.
*Hd = Halodule, Rup = Ruppia, Hph = Halophila, Th = Thalassia, Syr = Syringodium

Table 1-2. Status and Trends in Texas Seagrass – Lower Coast

Bay System	Current Acreage	Percent of Coastwide	Species*	Trends
Nueces Corpus Christi Redfish	24,600	11.2	Hd, Rup All five All five	Fluctuates with inflows Acreage stable, some bed fragmentation (Corpus Christi, Redfish)
Upper Laguna Madre	62,000	26.4	All, except Th	Slight decrease since 1990
Baffin	5,200	2.2	Hd, Hph, Rup	Decreasing since 1990
Lower Laguna Madre	118,600	50.5	All five	Decreasing and species changing since 1970s

Source: Corpus Christi/Redfish/Baffin data, TPW (Pulich et al. 1997); Laguna Madre data, USFWS (Quammen & Onuf, 1993).

Cavallo in Matagorda Bay (roughly the mid-coast boundary). The remaining 19.2% is found in the San Antonio/Aransas/Corpus Christi Bays area. The low-salinity tolerant species, widgeongrass, is also found occasionally in back-bay parts of the Sabine Lake system. Shoalgrass is the predominant species north of Redfish Bay/Aransas Bay, and usually, some widgeongrass also occurs mixed in with it during the spring and early fall seasons. Small amounts of the minor, understory species, clovergrass (*Halophila*) are found in all bay systems with shoalgrass. The most extensive shoalgrass beds are found in the Upper Laguna Madre, while turtlegrass and manateegrass are the dominant species in the Lower Laguna. Except for a relict population of turtlegrass still located in Christmas Bay, presently no other populations of this species or manateegrass are known further north than southern Aransas Bay.

Map 1-1. Seagrass Distribution in Texas Bay Systems

To a large extent, seagrass distribution in Texas parallels the precipitation and inflow gradients along the Texas coast (Map 1-1). Seagrasses are dominant on the middle to lower coast where rainfall and inflows to the bays are low and evaporation is high. This correlates with average baywater salinities above 20 ppt. Conversely seagrass is scarce in bays of the upper coast where rainfall and inflows are high and salinities are lower. Seagrass distribution seems to correlate with the growth requirements of these submerged vascular plants for clear, warm polyhaline (> 18 ppt) waters. Salinity and turbidity control the distribution of true seagrasses on the upper coast (Sabine Lake and upper Galveston Bay), as well as preventing their growth generally in the upper parts of other estuaries. This is evident from a comparison of the salinity tolerance of three submerged species, shoalgrass vs. widgeongrass vs. wild celery (*Vallisneria*) (10 - 60 ppt vs. 0 - 60 ppt vs. 0 - 10 ppt, respectively). The combined stress of rainfall/inflow patterns, lower salinity regimes and muddy, turbid bay waters keep seagrasses along the upper coast essentially on the edge of their range.

Historical Trend Analysis

Availability of reliable photography and good historical field data limits seagrass trend analysis to only about the last 40-50 years. This perspective is important to recognize since long-term cycles may require more time to detect. With this in mind, we will briefly review historical seagrass trends in three major bay systems where data exists, to show how different dynamic processes affect seagrass. Results from Galveston Bay, Corpus Christi/Redfish Bays, and the Laguna Madre System represent three degrees of seagrass change, ranging from complete loss to fairly stable systems.

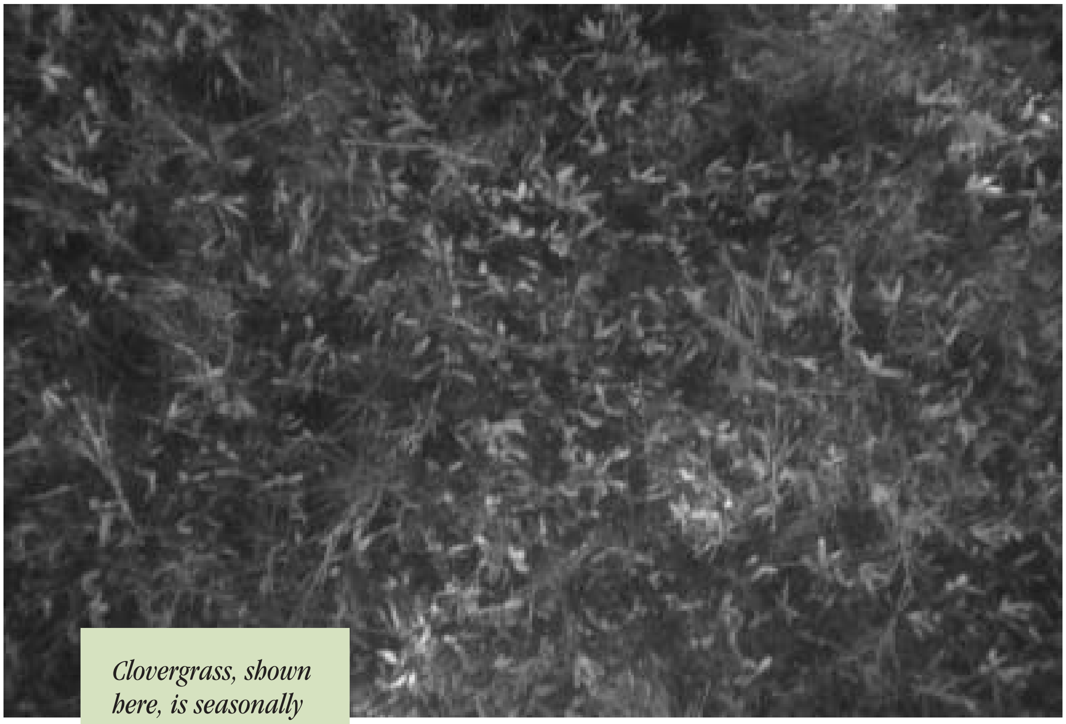
Galveston Bay Trends. Practically all seagrass beds have been lost from the Galveston Bay system since the late 1970s (Pulich and White, 1991). Only *ca* 275 acres of true seagrass remains (mostly shoalgrass with patches of turtlegrass and clovergrass) in the lower bay region of Christmas Bay, a secondary bay. Some widgeongrass does occur scattered throughout the bay system, even in upper Trinity Bay near the River delta. Although 1956 is our earliest reference point, it is interesting to note that seagrasses were generally more abundant in the Galveston Bay system (even in East Bay and upper Galveston Bay) during the early part of the century based on anecdotal information. Small localized patches of turtlegrass also occurred formerly (late 1960s) in West Galveston Bay. Probable causes of decline include direct impacts from hurricanes, land subsidence, shoreline developments and urbanization along the mainland and Galveston Island, and large amounts of dredge-and-fill activities. Indirect effects are suspected from nutrient/pollutant loading (Pulich and White, 1991).

Trends in Corpus Christi/Redfish Bays. In the Corpus Christi/Redfish Bays area, net seagrass bed acreage appears fairly stable over a 40 year time frame, but with cycles and changes in grassbed distribution at discrete "hotspots." A recent mapping study by Pulich et al. (1997) for the CCBNEP determined trends in grassbed distribution in this area. Comparisons between 1958, 1975 and 1994 inventories show some evidence of bed fragmentation and seagrass loss in the Redfish Bay area, but increases in bed acreage along Mustang Island, in the Harbor Island complex and in the Nueces Bay parts of the system.

Aerial photographs reveal seagrass distribution and changes in the Redfish Bay area.

Harbor Island/Redfish Bay contains the most extensive area of pristine seagrass beds outside the Laguna Madre, ca 14,000 acres (57 km^2); this is also the northern range limit for large beds of turtlegrass and manateegrass. Change dynamics between 1958, 1975, and 1994 indicate about a 13% decrease (ca 815 acres total) in mostly turtlegrass beds for Redfish Bay, while a 72% increase in shoalgrass beds (2140 acres) occurred in Harbor Island. Dredging of the GIWW and other navigation channels, boating activity and possible nutrient enrichment from non-point source discharges are suspected of causing the decreases in *Thalassia.* Spread of seagrasses onto intertidal flats due to long-term increases in bay water levels or land subsidence can account for grassbed expansion in the Harbor Island and Mustang Island areas since the late 1950s. These dynamics reveal the geographic variability of grassbed changes, and localized causes, within an estuarine system.

Trends in Upper Laguna Madre System. The Laguna Madre system has undergone dramatic seagrass changes since the 1950s, primarily in response to salinity regime modification. Analysis of upper Laguna trends by USFWS (Quammen and Onuf, 1993), based on new surveys in 1988 and review of historical data collected by TPW (MacMahan, 1960s) and Merkord (1978), documents major seagrass changes. Between 1967 to 1976, there was a 66% increase (to 49,200 acres total) in primarily shoalgrass (but also clovergrass and widgeongrass), and from 1976 to 1988, a



Clovergrass, shown here, is seasonally abundant in Laguna Madre.

WARREN PULICH

29% total increase (to 61,750 acres). However, from 1988 to 1994, a 3.8% decrease (2320 acres) in shoalgrass has occurred due to a continuous brown tide algal bloom which has occurred. In addition, some patches of manateegrass have recently become established in the system and this species continues to spread.

These changes are attributable to various combinations of interacting factors. Increases in shoalgrass and manateegrass have resulted from salinity moderation in the shallow, clear Laguna Madre waters. In general, GIWW and other channel modifications since 1950 have allowed salinities in the system to stabilize. Decreases since 1990 are due to the brown tide phytoplankton bloom which has caused light attenuation and loss of seagrass in water > 1.5 m depth. Onuf (1996) has predicted that 18% to 27% of upper Laguna shoalgrass could disappear in deeper waters if underwater light levels stay reduced until the system reaches steady state.

Lower Laguna Madre. In recent years (since 1970s), major divergence is evident in the dynamics of the upper and lower Laguna. In the lower part, Quammen and Onuf (1993) also determined that between 1967 to 1988, shoalgrass decreased 60% (330 km^2), while mostly manateegrass (and some turtlegrass) increased by 270% (190 km^2). Overall, bare unvegetated area in this southern Texas system increased 280% (140 km^2). This reflects the large decrease in shoalgrass which is attributed to maintenance dredging of the GIWW and competitive success of the climax species, turtlegrass and manateegrass.

Conclusions from Trends Studies

Such case histories demonstrate the effects on seagrasses of critical environmental factors. These environmental factors fall into two categories, including natural and human-induced processes. Factors can have either positive or negative effects. From the list of factors below, it is difficult to generalize about seagrass impacts in all bays, since conditions vary geographically between and even within individual bays. Every bay must be examined on a case by case basis to assess contributions from different source processes. This requires careful analysis of seagrass distribution changes and correlation with appropriate environmental factor data.

VISION AND PURPOSE OF SEAGRASS PLAN

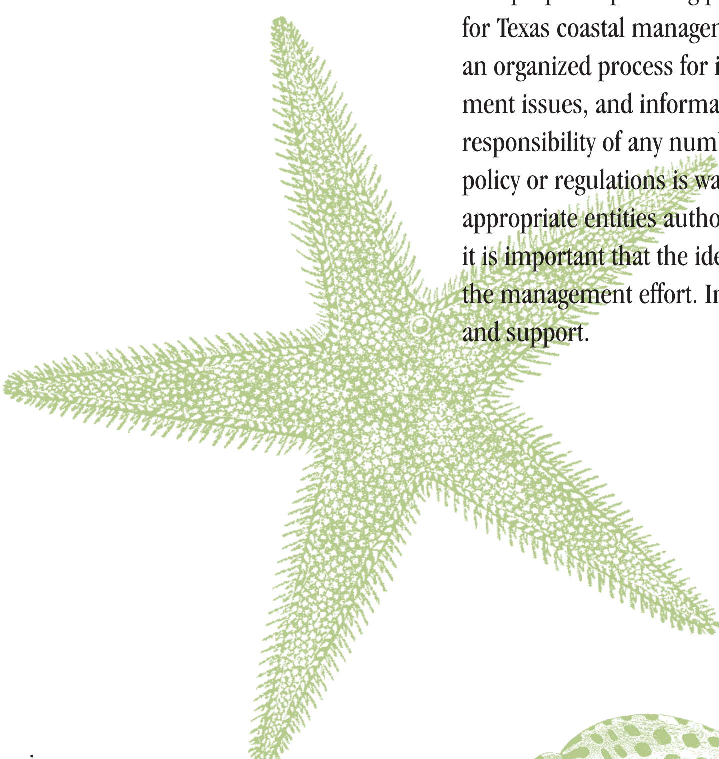
These trend results reveal the critical need for a statewide plan to coordinate research, conservation, and management activities that focus on coastal Texas seagrasses. This plan, with defined goals, objectives and actions agreed upon by experts knowledgeable about Texas seagrasses, would address the following major questions: What are the critical research and management needs, and in what order of priority should they be addressed? What types of programs can be developed to solve the problems? How do these programs relate to the Texas State Wetland Conservation Plan which is under development? What stakeholders or agencies with interests in coastal

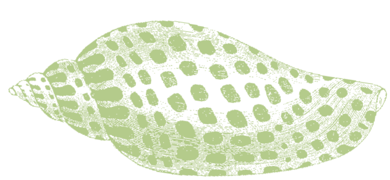
ENVIRONMENTAL FACTORS	REFERENCES
1. Natural Processes	
Water (Sea) Level Changes	White, et al (1983), Pulich and White (1991)
Hurricanes	Eleuterius (1987), Van Tussenbroeck (1994)
Climatic Cycles	Hoese (1960)
(Drought/Freshwater Inflow)	White, et al (1983), Eleuterius (1987)
2. Anthropogenic Processes	
a. Physical/Mechanical Disturbances	Pulich, et al (1997)
Dredging/Channel Construction	Odum (1963), Phillips (1980), Pulich, et al (1997), Onuf (1994)
Hydrocarbon/Mineral Exploration	Cobb (1987)
(Pipelines, drill pads, seismic)	
Shoreline Developments	Pulich and White (1991)
(Bulkheads, piers, etc.)	
Motorboat Impacts	Sargent, et al (1995), Zieman (1976), Eleuterius (1987), Dunton (1998)
b. Water Quality Conditions	
Algal Blooms and/or Nutrient Loading	Dennison, et al (1993), Onuf (1996), Tomasko, et al (1996)
Light Attenuation Caused by Suspended Solids	Onuf (1994), Dunton (1996), Kenworthy and Haunert (1991)
Anoxia and H_2S Effects	Carlson, et al (1995)
Macroalgae/Epiphyte Accumulations	Pulich, et al (1997)

seagrass areas will effectively contribute? This document outlines a basic coordinated planning process to achieve such goals. The main intent of this planning effort is to bring concerned parties together, identify and review seagrass issues, and develop recommendations to guide concerted action on them.

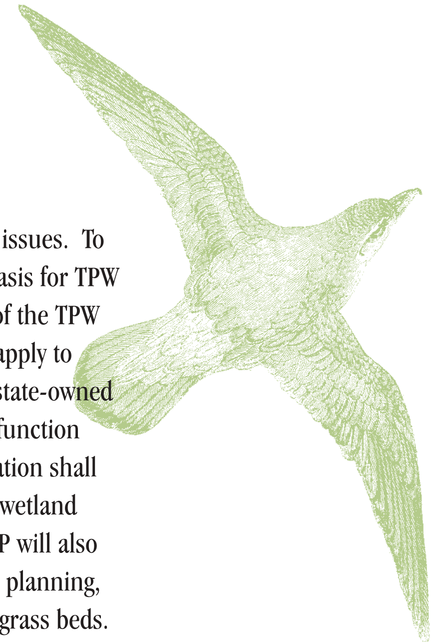
Large-scale multiple stakeholder programs from other states serve as models for this type of planning action to be effective. The Chesapeake Bay Program (1995) was one of the first system-wide efforts to develop and adopt a guidance plan for protecting submerged aquatic vegetation (SAV) from degradation and restoring lost habitat. This plan has focused on improving water quality over the bay system to achieve standards which correlate with healthy submerged aquatic vegetation (Dennison et al. 1993). In Florida, the state Department of Environmental Protection (1996) has sponsored the development of a similar Seagrass Ecosystem Management and Implementation Plan with regional and local governmental and scientific input. This will comprise a formalized statewide guidance plan with recommendations and strategies for protecting and restoring seagrass beds (Kenneth Haddad, personal communication, Department of Environmental Protection, Florida Marine Research Institute). One such strategy will target water quality degradation problems which have seriously impacted Florida's seagrass beds. Another strategy specifically identifies the issue of boater awareness of seagrass habitat as a way to reduce boat propeller scarring, a major impact in Florida grassbeds (Sargent et al. 1995). On the Pacific coast, resource analysts in Washington State have suggested a prioritized sequence of steps and criteria which coastal zone decision-makers should follow and evaluate in designing and implementing seagrass science and management policies (Hershman and Lind 1994).

This proposed planning process does not aim to directly develop seagrass policies or regulations for Texas coastal management. Rather, the intended result will be a planning document outlining an organized process for implementing key strategies and actions for research projects, management issues, and information dissemination. Implementation of the plan's strategies will be the responsibility of any number of organizations or individuals. If development of management policy or regulations is warranted, then these would be developed and implemented later by the appropriate entities authorized to do so. As a first step in an organized planning process, however, it is important that the ideas and proposals represent the input of the necessary participants in the management effort. Input from stakeholders gives the plan the proper statewide foundation and support.





HISTORY OF TEXAS SEAGRASS CONSERVATION



Regulatory Authority

Legislative mandates exist for Federal/State groups to address specific seagrass-related issues. To a major extent, the State-owned Wetland Conservation Plan (SOWCP) represents the basis for TPW and TGLO initiating a statewide Seagrass coordination effort. Under Chap.14.002 (3) of the TPW Code, TPW and TGLO are charged with implementing provisions of the SOWCP which apply to seagrass habitat in coastal regions. This section contains "provisions for inventory of state-owned coastal wetlands to determine gains and losses in areal extent, wetland types, wetland function and causes of wetland alteration." In Chap. 14.002 (9), planning for seagrass conservation shall include "scientific studies which examine the effects of boat traffic in sensitive coastal wetland areas and for education of the public with regard to the effects of boating." The SOWCP will also include provisions for freshwater inflow protection, navigational dredging and disposal planning, and non-point source pollution prevention, processes that may affect the health of seagrass beds.

TGLO has jurisdiction over management of coastal submerged lands where seagrasses occur. The TGLO routinely considers potential seagrass impacts during its evaluation of proposed contracts with private, public, and governmental entities requesting to use these state-owned lands. As a standard practice, this is done in cooperation with TPW which is the designated fish and wildlife resource agency of the State. TPW and TGLO routinely coordinate with USACOE, USFWS, and NMFS on environmental impact assessment of seagrass beds due to dredging or other CWA Sec. 404 project permits. There is currently an official multiagency coordination committee (the ICT or Interagency Coordination Team) which deals with impacts from the GIWW maintenance dredging. This management scheme has established an effective Sec. 404 permit review process between the agencies and has been the basis for developing policies applicable to seagrass protection.

Seagrasses are the cornerstone of a healthy bay-estuarine system.

TNRCC, the official State regulatory authority for water quality management, plays an important role in coastal seagrass protection. TNRCC jurisdiction includes water quality standards, Total Maximum Daily Loads (TMDL's) and wastewater allocations, watershed planning, wastewater permitting and enforcement, nonpoint source pollution controls, and 401 certification of Federal permits. In addition, the Texas State Soil and Water Conservation Board cooperates with TNRCC in nonpoint source management, specifically in those situations associated with agricultural sources.

The Texas Coastal Management Program (TCMP) represents another vehicle for coordinating seagrass conservation. The Coastal Coordination Council (CCC) of the CMP can formally review coastal zone projects for impacts on seagrass resources if the impact exceeds established thresholds. This Council review provides a mechanism to ensure consistency in seagrass protection policies across agency boundaries. The Federal Consistency review authority of the CCC also should be a significant mechanism to protect and restore seagrasses, especially in National Estuary Program Study areas. If standardized, science-based measures are adopted and promulgated, developers, coastal zone users, and resource agencies will be able to plan environmentally sensitive projects together with minimal impact to seagrass habitats.

Research and Conservation Programs

Estuary Programs in other States (ie. Virginia, Maryland, Florida) have served as focal points to identify issues and prioritize objectives for seagrass conservation, as well as develop action plans to accomplish this. Necessary information has been synthesized and integrated for these states, and a working management process established. In Texas, the Galveston Bay and the more recent Coastal Bend Bays and Estuaries Program have both recognized and promoted the need to direct special attention to seagrass problems, which they consider a unique, high quality coastal resource. Although Galveston Bay has limited seagrass beds, the Coastal Bend area is dominated by this habitat type, and both Programs have concluded that there is urgency and necessity for coordinated seagrass protection in those systems. For the future, they offer an excellent research/outreach framework to plan and implement seagrass conservation measures at the local estuary level in Texas.

The University of Texas Marine Science Institute (UTMSI) and Texas A&M University, as well as resource agencies (eg. NMFS, NBS/USFWS, TPW), have long-standing histories of actively conducting ecological and environmental research on seagrass. Research activities are ongoing in several areas: Status and Trends Monitoring; Landscape Dynamics and Seagrass Community Succession in Texas; Ecological Studies of Light and Turbidity Effects on Seagrass Productivity; and Assessment of Physiological Seagrass Responses to Environmental Factors. Seagrass restoration studies have been conducted to determine feasibility of transplanting seagrasses into areas where they have disappeared, such as Galveston Bay (Sheridan et al. 1995). Other studies are developing productivity models to predict impacts of dredge material disposal from the GIWW on seagrass beds in Laguna Madre (Dunton and Eldridge 1996). Studies by Onuf at NBS/USFWS and Dunton at UTMSI have provided recent documentation of impacts to seagrasses in the Laguna Madre due to dredging effects and the brown tide bloom (Onuf 1994, 1996; Dunton 1993, 1995). Two recent resource agency-sponsored programs, the Natural Resources Inventory Program and the Corpus Christi Bay National Estuary Program, have enabled the completion of seagrass mapping inventories by TPW for much of the central Texas coast (Pulich et al. 1997).

PROCESS FOR DEVELOPING THE SEAGRASS CONSERVATION PLAN

In 1995, efforts were initiated by TPW to coordinate with research scientists, resource managers, and boating interests to address motorboat impacts to seagrass beds. These discussions led to recognition that other, perhaps more severe, problems exist in Texas seagrass beds (e.g. impacts from water quality degradation or dredging). Another meeting was later held in September 1995 at TAMU-Corpus Christi with a diverse planning group of *ca* 30 persons, including interests from environmental science, marine biology, navigation, industry, water-borne recreation, fishing groups, and waterfront development. Many ideas were raised, and the major outcome was the decision to develop a comprehensive Seagrass Conservation Plan for Texas. The approach envisioned a two part process.

Seagrass Planning Symposium

The first step consisted of drafting a Conceptual Plan which outlined Issues, Goals and Objectives for Seagrass Conservation in Texas. This working document was presented for public review, discussion, and further input by attendees at the Seagrass Conservation Symposium held in the fall of 1996 in Corpus Christi, Texas. About one hundred scientists, resource managers, business people, and environmentally-concerned citizens gathered for the two day Symposium/Workshop to hear presentations, exchange information, and evaluate ideas on seagrass conservation. Attached at the end of this section, the program for the Symposium illustrates the workshop process and scope of topics covered. The list of Symposium participants is also included.

The draft document outlining the Texas Seagrass Conservation Plan identified three major theme areas where strategic planning was needed:

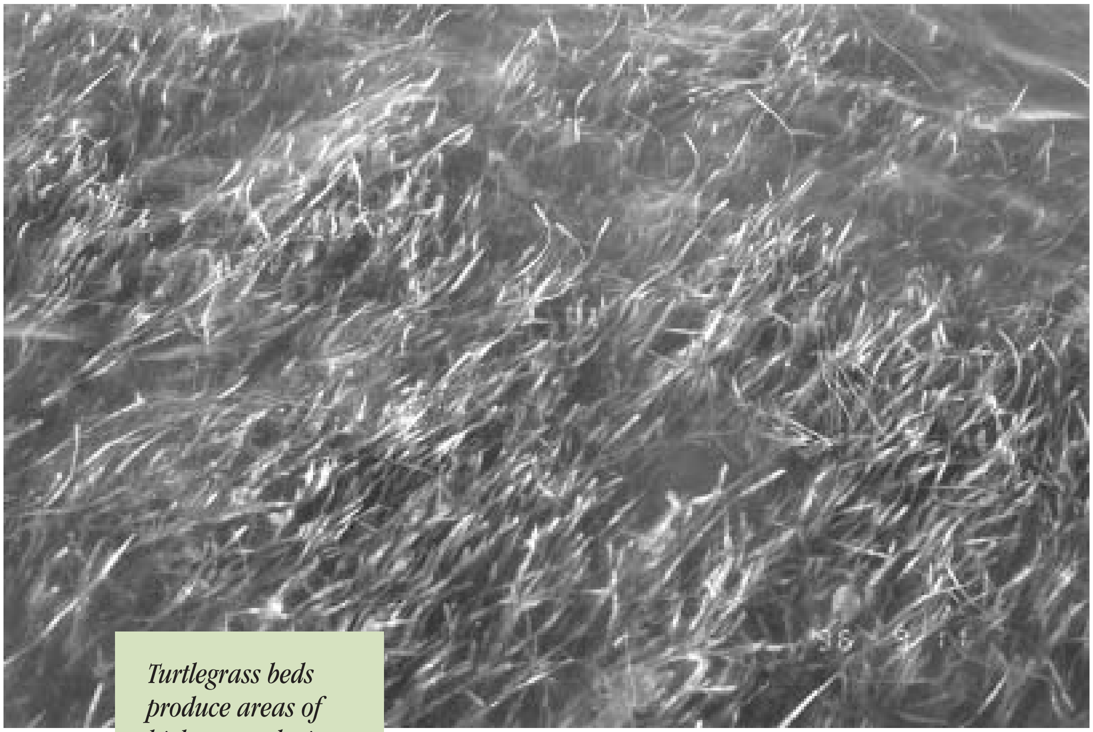
Seagrass Science and Research
Seagrass Policy and Management
Environmental Education and Outreach

These three topics were considered to relate quality and health of seagrass beds to ecological processes, socioeconomic issues, and environmental management issues. For each theme area, separate Goals, Objectives, and Actions were then developed, discussed, and integrated into the formal seagrass conservation document.

Formal Seagrass Conservation Plan Document

A brief description of the process used to produce this final written document is in order. The original sponsors of this planning effort consisted of the three state agencies: TPW, TGLO, and TNRCC, as well as the TNRCC's affiliate National Estuary Programs in Galveston and Corpus Christi. These primary sponsors, recognizing that issues involved were sufficiently complex, assembled three steering committees or focus workgroups of recognized experts, to develop the Research, Management, or Education Agendas. The steering committees met and brainstormed during the summer of 1996, and collectively developed the preliminary problem statements, objectives and actions discussed at the fall 1996 Symposium. This conceptual outline was also a starting point to draft the formal Plan document after the symposium.

After reviewing and compiling the proposed recommendations from the open symposium forum, the sponsors continued to work with the three designated committees (focus groups) to revise and expand the document into a formal plan. This synthesis and organization was directed by the steering committee and a designated Chairperson for each Theme (or Issue) Area. The resulting product was the three chapters on Research, Management, and Education. Although each chapter was written primarily by the respective Committee Chairperson, the concepts and issues were a synthesis of the entire planning process. The basic format for these chapters was to formulate problem statements and corresponding solutions in the form of action items. The formal plan attempts to integrate these three Issue Areas as presented in the last chapter on "Implementation of Objectives and Actions." It is anticipated that the strategies and recommendations will be implemented by the appropriate agencies, universities, and non-governmental organizations over a 5 to 10 year horizon.



BETSI BLAIR

Turtlegrass beds produce areas of high water clarity due to the baffling effect of wide leaves.

Symposium on Texas Seagrasses

November 4-5, 1996
Corpus Christi, Texas

Seagrasses are unique, vital components of estuarine ecosystems along the Texas coast, especially the middle and southern portion. Although seagrasses have historically fluctuated in their distribution, recent environmental conditions may pose special threats to the lush seagrass meadows of Texas. An integrated, organized approach is suggested to address seagrass problems over the next 10 years. The first step is to develop a formal plan that coordinates the efforts of seagrass researchers, coastal resource managers and concerned citizens to work toward mutually accepted conservation goals.

Agenda: Development of a Seagrass Conservation Plan

November 4

Plenary Session

Introduction to Meeting

Welcome –
Andrew Sansom, Executive Director, Texas Parks and Wildlife

Keynote Overview –
Larry D. McKinney, Ph.D., Texas Parks and Wildlife

Status and Trends in Texas Seagrasses –
Warren Pulich, Ph.D., Texas Parks and Wildlife

Ecology of Seagrasses –
Ken Dunton, Ph.D., University of Texas Marine Science Institute

Function and Values of Seagrass Habitat –
Pete Sheridan, Ph.D., National Marine Fisheries Service

Developing a Management Plan for Coastal Resources of the Coastal Bend –
Richard Volk, Corpus Christi Bay National Estuary Program

A Management Plan for Coastal Resources of Galveston Bay –
Marilyn Browning, Galveston Bay Estuary Program

Science and Management Issues from Florida Seagrass Systems –
Ken Haddad, Director, Florida Marine Research Institute

Conservation and Environmental Awareness through Education and Public Outreach –
Jim Lester, Ph.D., University of Houston

The Texas Coastal Management Program –
Tom Nuckols, Director, Coastal Division, Texas General Land Office

Breakout Sessions

Development of Strawman Plan and Organization of Three Breakout Sessions –
Larry D. McKinney

Breakout Sessions –
Facilitated Group Discussion of Planning Issues

November 5

Breakout Sessions (continued) –
Development of Specific Objectives and Strategies

Breakout Sessions (conclusions) –
Formulate Recommendations and Form Core Groups to Assist with Final Plan

Prepare Summary of each Breakout Session –
Breakout Leaders and Facilitators

Reports by each Breakout Moderator

What Happens Now?
Larry D. McKinney

List of Attendees at Seagrass Symposium
Corpus Christi, Texas
November 4-5, 1996

Research Issues Workgroup

Kenneth Dunton - co-chairman	Christopher Onuf - co-chairman
Peter Sheridan	Scott Holt
Warren Pulich Jr.	Steven Anderson
Paul Montagna	Terry Cook
Tom Minello	Hudson DeYoe
Peter Eldridge	Billy Fuls
Jim Bergorn	Don Hockaday
Randy Blankinship	Raul Cantu
William Longley	Larry McEachron
Todd Merendino	Jimmy Shiveley
Bryan Pridgeon	Kyle Spiller
Jim Sutherlin	Tom Warren
William White	Terry Whitledge
Brian Banks	Sara Black
Paul Choucair	James Kaldy
Joseph Kowalski	Terry Roberts
Norman Sears	Liz Smith
Kim Withers	Terry Cody
Sandra Alvarado	Edward Sutherland

Management Issues Workgroup

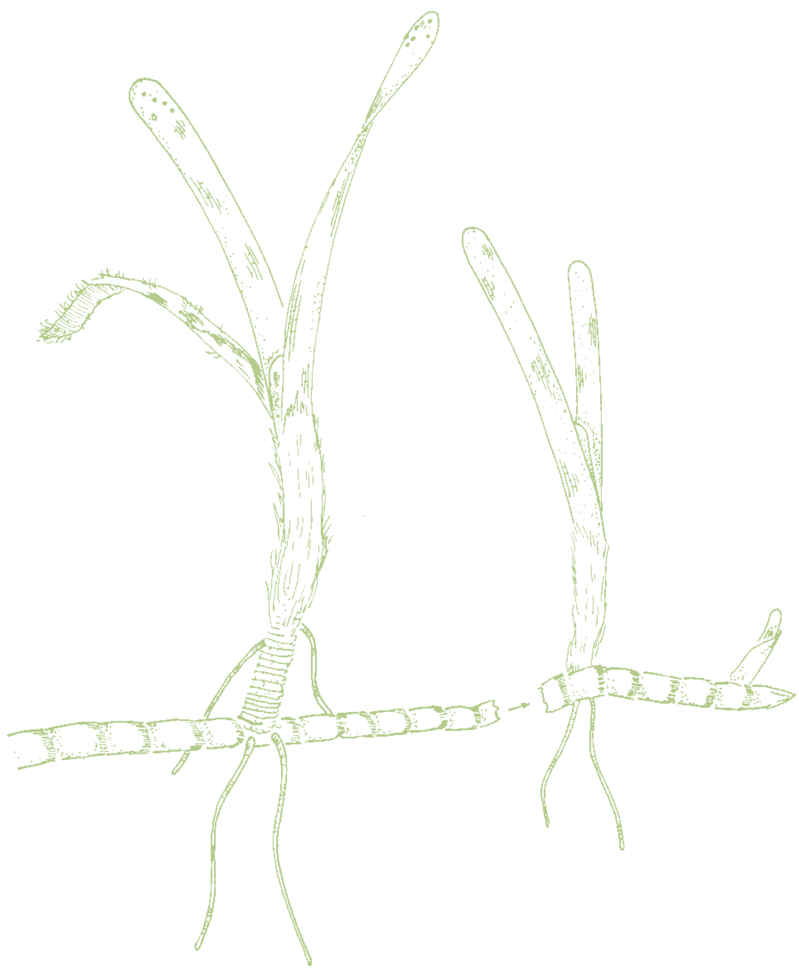
Larry McKinney - co-chairman	Leland Roberts - co-chairman
Kenneth Haddad	Tom Calnan
Deyaun Boudreaux	Robyn Cobb
Paul Carangelo	Jim Ehman
Ray Allen	Charles Belaire
Dave Buzan	Albert Green
Mark Fisher	Richard Harrington
Lynnda Kahn	Rollin MacRae
Russ Miget	Don Petty
Tom Nuckols	Rusty Swafford
Bob Spain	Wes Tunnell
Lee Sutton	Eddy Seidensticker
Bill Hood	Cherie O'Brien
Louis Hamper	Mary Ellen Vega
Lloyd Mullins	

Education/Public Outreach Workgroup

Jim Lester - chairman

Nancy Webb
Bob Murphy
Thomas Linton
Bob Nailon
Tony Reisinger
Christine Garcia-Conner
Scott Hedges
Rebecca Hensley
Kay Jenkins
Susan Cox
C. R. (Rob) Youker

Richard Volk
Rick Tinnin
Chris Christensen
Cathy Porter
Nancy Herron
Ed Hegen
Pat Bacak-Clements
Terri Wood
Carole Hemby
Tim Spice



KEN DUNTON

Scuba or snorkeling techniques are often necessary to perform seagrass research.

CHAPTER 2.
RESEARCH ISSUES FOR TEXAS

Ken Dunton
The University of Texas at Austin
Marine Science Institute

INTRODUCTION

The role of seagrass in supporting coastal food webs and the effects of both natural and anthropogenic disturbances on seagrass health require a comprehensive understanding of the mechanisms controlling seagrass growth. The relative importance of these factors can vary significantly among estuarine systems on the Texas coast, complicating management policies in response to human induced impacts.

In this chapter, we present the recommendations of over 50 researchers, state and federal regulators, and environmental managers on the research needs, strategies for monitoring, and management policies required to increase our basic knowledge of this valuable resource. The following four major objectives were identified in our discussion of research issues related to seagrass distribution, productivity and ecology:

- **Regularly assess status and trends of seagrass distribution on a coast wide basis.** This includes the development of long-term monitoring plans for mapping and measurement of key parameters to assess both changes in water quality and seagrass health.

- **Determine causes of changes in seagrass species composition and coverage (acreage), including areal losses and gains.** Basic research topics under this goal include studies of plant physiology, demography, landscape ecology, process oriented work with respect to sediment or water column factors and interactions, and experimental studies on the creation and restoration of seagrass beds.

- **Identify habitat functions and productivity of natural seagrass community types and identify linkages with other habitats to support habitat conservation, creation, enhancement and restoration.** This goal is directed toward ecologically oriented concerns related to functional differences in seagrass habitats with respect to species, plant age and population structure, patch formation, epiphyte loading and evaluation of transplanting projects.

- **Provide data for development of management policies in response to human induced impacts.** Review of existing information on seagrasses, the development of a data clearing-house, and the application of applied studies to specific management questions are the major components of this goal, which builds on the foundation of knowledge provided by monitoring and basic research.

About 80% of the seagrass habitat in Texas is located in the Laguna Madre System.

VALUE OF SEAGRASS BEDS

Seagrass beds are among the most productive of marine plant communities. They are important as producers of food (or carbon) for complex food webs that range from bacteria to turtles as well as providing habitat and nursery ground for numerous species, including commercially and recreationally valuable shrimp, fish, crabs and their prey (see review by Zieman, 1982; Phillips, 1984; Thayer *et al*., 1984; Kenworthy *et al*., 1988; Zieman and Zieman, 1989). Nearly all of these organisms depend on seagrass beds as a refuge or habitat for at least part of their life cycle; Chambers (1992) estimated that 98% of the commercial landings in the Gulf of Mexico were estuarine-dependent.

A comparison of macrofaunal abundance in vegetated (seagrass) and non-vegetated (bare bottom) habitats from around the world is shown in Table 1. These data clearly show that habitat value of seagrass beds to estuarine fauna; animal abundances in seagrass beds can be 2 to 25 times greater than in adjacent unvegetated areas.

Table 2-1. Comparison of densities (no. per m^{-2}) of animal communities associated with vegetated and unvegetated habitats. Adapted from Orth *et al*. (1984).

Location	Seagrass	Vegetated	Unvegetated	Source
		Infauna		
Bermuda	*Thalassia testudinum*	13,580	3,145	Orth, 1971
		Polychaetes		
Florida	*Thalassia testudinum*	33,485	17,220	Santos and Simon, 1974
		Macrofauna		
North Carolina	*Zostera marina*	923	170	Thayer *et al*., 1975
		Infauna		
Virginia	*Zostera marina*	51,343	1,771	Orth, 1977
		Infauna		
North Sea	*Zostera noltii*	5,088	1,043	Reise, 1978
		Infauna		
Australia	*Zostera muelleri*	1,039	156	Poore, 1982
		Macrofauna		
Belize	*Thalassia testudinum*	12,167	16,750	Young and Young, 1982
		Macrofauna		
Florida	*Thalassia testudinum*	17,479	5,844	Virnstein *et al*., 1983

WARREN PULICH

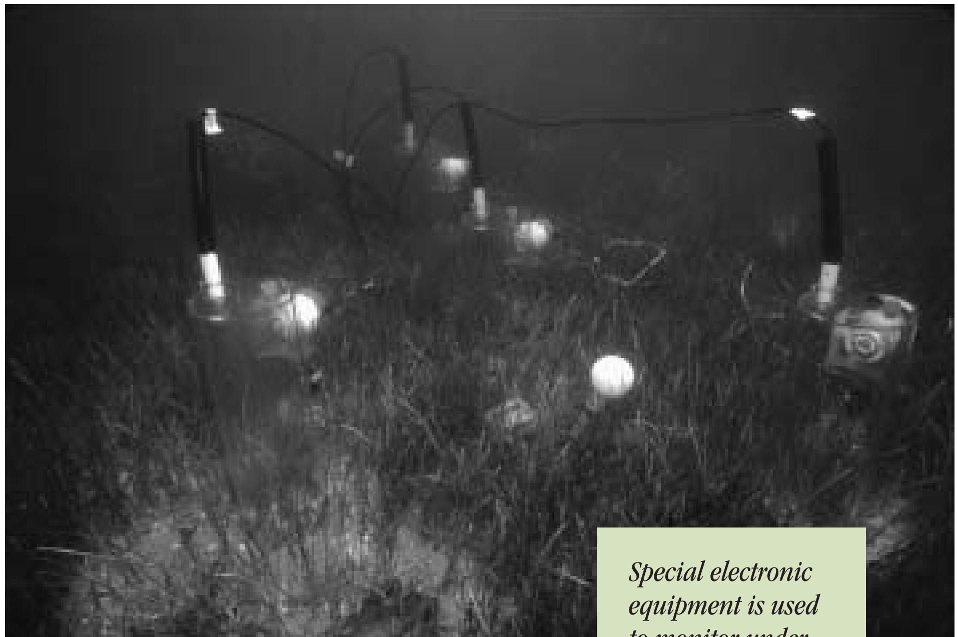
Benthic animals like sea cucumbers are more abundant in grassbeds compared to bare sediments.

In addition to providing habitat for invertebrate fauna and fishes, seagrasses also provide habitat for other wildlife. These include migratory waterfowl, sea turtles, and a variety of wading and diving birds (mergansers, loons, cormorants, pelicans). Some of these animals consume seagrasses directly: redhead ducks feed on seagrass rhizomes; sea turtles and manatees eat seagrass leaves.

The benefits of seagrass habitats to local and regional economies along the Gulf coast are considerable. The gross economic contribution associated with wetlands along the Gulf coast can be determined based on their potential to produce economically useful products as well as their recreational value. In 1989, the commercial value of finfish and shellfish harvested along the U.S. Gulf coast was about 648 million dollars (NOAA, 1990). Using these data and estimates of values for recreation and storm protection, per-acre values of seagrass habitats likely range from $9,000 to $28,000 based on a recent evaluation of wetland habitats in the Gulf (Lipton *et al*., 1995). In Texas, the total value of seagrass habitat based on current estimates of seagrass distribution, recreational value, and commercial fishery harvests, is at least 12.6 million dollars annually (Dunton, unpub. data). These conservative estimates clearly denote the importance of conservation measures to protect this extremely valuable resource in Texas.

ENVIRONMENTAL STATUS

Status and Trends



KEN DUNTON

Special electronic equipment is used to monitor underwater conditions in seagrass beds.

The total area of seagrass habitat in Texas was estimated to be about 833 km^2 in 1988, and 79% of this is located in the Laguna Madre (See Pulich, Introduction). A decline of 150 km^2 in seagrass habitat has occurred over a twenty-year period in the lower Laguna Madre, equivalent to about 25% of the mid 1980s habitat (Quammen and Onuf, 1993). This loss has been attributed to increased turbidity caused by maintenance dredging (Onuf, 1994). Loss of habitat in the lower Laguna was balanced by an increase in seagrasses in the upper Laguna during the same period (mid 1960s to mid 1980s), however, the trend of increased seagrass cover in the upper Laguna started to reverse in the early 1990s as a consequence of the persistent brown tide algal bloom (Onuf, 1996). Light levels were reduced as much as 50% in response to the high, water column chlorophyll concentrations (Dunton, 1994). Light limitation, either as a consequence of increased levels of suspended solids or chlorophyll concentrations, is therefore a serious problem facing seagrass communities along the Texas coast.

CAUSES OF SEAGRASS LOSSES

Natural Disturbances

Storms, floods, and droughts, are examples of natural disturbances that can affect estuarine biota. Disturbances by large storms can result from potentially massive sediment redistribution. But, natural storm events often have variable impacts on estuarine and coastal biotic communities (Conner et al. 1990). For example, Hurricane Andrew had no significant impact on seagrass beds in South Florida (Tilmant *et al*., 1994), but van Tussenbroek (1994) reported that Hurricane Gilbert impacted *Thalassia testudinum* (turtlegrass) communities in Puerto Morelos, Mexico. Thus, the effect of large scale disturbances on benthic plant communities can be quite different depending on a number of factors, e.g., storm frequency, intensity, and the nature and composition of the submerged aquatic plant community. Storms are stochastic events that can not be predicted. However, a changing climate may also effect storm frequency and intensity.

Turbidity, sedimentation and bioturbation are other natural disturbances. Shading due to high turbidity can limit photosynthesis, and hence primary production (Fig. 2-1). Sediment carried by fresh water flowing into bays and estuaries may be kept in suspension by wind driven water turbulence, ultimately being deposited in areas of quiet water. In extreme cases, seagrass burial can result from high sedimentation events.

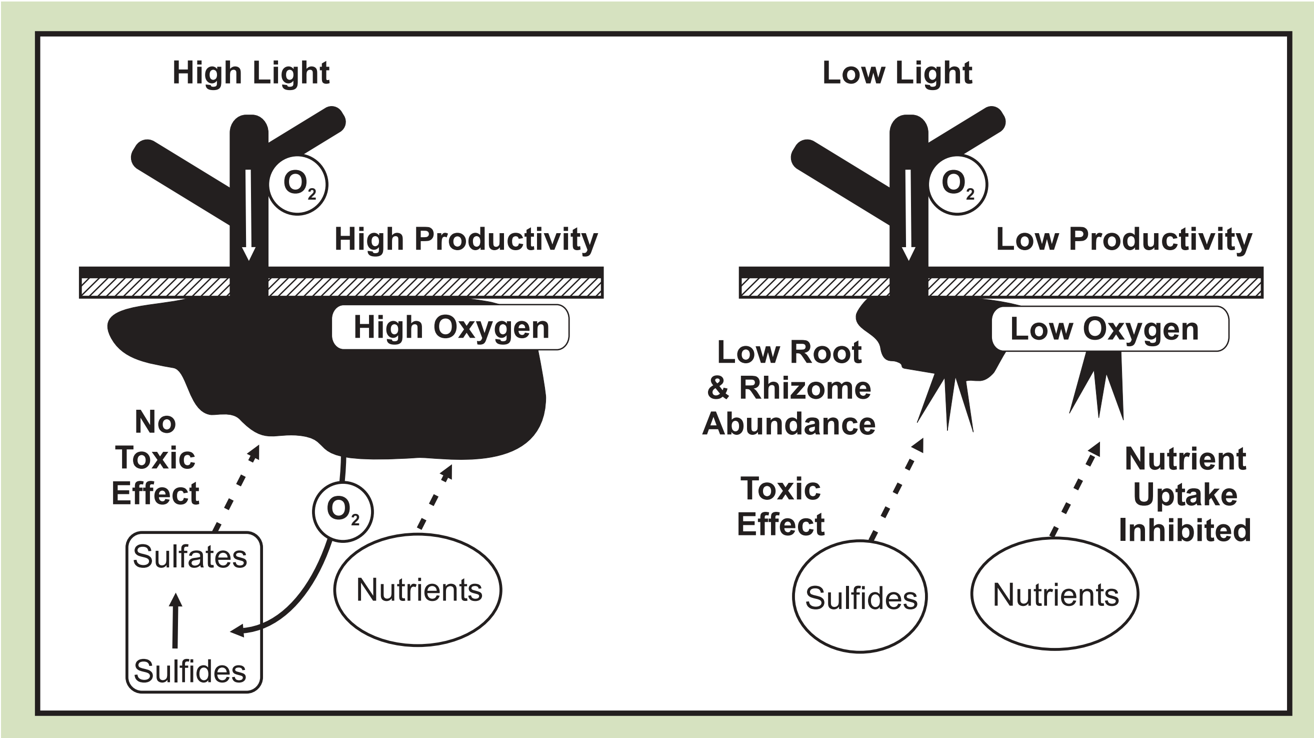


Figure 2-1. A conceptual model of seagrass productivity depicting the effects of reduced light on seagrass production. Under low light conditions, less oxygen is produced in photosynthesis, resulting in lower oxygen availability to roots and rhizomes, which causes death of tissues from sulfide toxicity.

High turbidities are often associated with freshwater sediment loads and sediment resuspension by winds and tidal mixing. Bioturbation results from the activities (e.g., burrowing, locomotion, and feeding) of benthic animals but is probably not a significant factor that promotes turbidity in seagrass beds. Storms, however, can contribute both to the timing and intensity of resuspension events, because high winds are often associated with storms.

Anthropogenic Disturbances

Humans have the potential to greatly disrupt seagrass ecosystems. Generally, these ecosystems are adapted to cyclic natural phenomenon such as changes in temperature, light, and nutrients. In contrast, human activities may be continuous or episodic events, for which organisms are not adapted, e.g., trawling, dredging, and nutrient inputs.

Anthropogenic disturbances include a variety of activities that impact seagrass habitats (Fig. 2-2). The frequency of all anthropogenic activities increases with increasing human populations and use of the ecosystem. The activities are a direct result of marine transportation, commercial fishing, tourism, recreational boating, and agricultural practices.

Marine transportation is a dominant industry in Texas, because the Port of Corpus Christi and the Port of Houston are among the six largest ports in the United States. Commercial maritime traffic includes tankers, container ships, grain ships, barges, and associated tugboats which rely on channels that must be maintained at 15 m depths in bays that commonly range only from 1 to 4 m deep. Dredging disrupts benthic communities during the removal, deposition and re-distribution of fine materials; these activities ultimately result in higher turbidity.

Of the major commercial fisheries in Texas, shrimping is by far the largest, with harvesting accomplished by dragging bottom trawls. Trawls disturb the bay bottom, leading to sediment resuspension and release of nutrients into the water column. Nutrient release can result in decreased light penetration of the water column through the promotion of algal blooms; therefore both processes can have negative impacts on seagrass distribution and productivity. Similarly, run-off from agricultural and municipal areas is often characterized by high concentrations of inorganic nutrients, particularly nitrogen. These loadings, together with point source discharges, are largely responsible for the eutrophication of our coastal waters.

Tourism and recreational boating have been increasing during the last ten years as coastal populations have doubled. The main effects of this industry are related to boat operations, marina construction, and small localized oil spills in marinas. Recreational boating can have a distinct impact on shallow seagrass beds through propeller scarring.

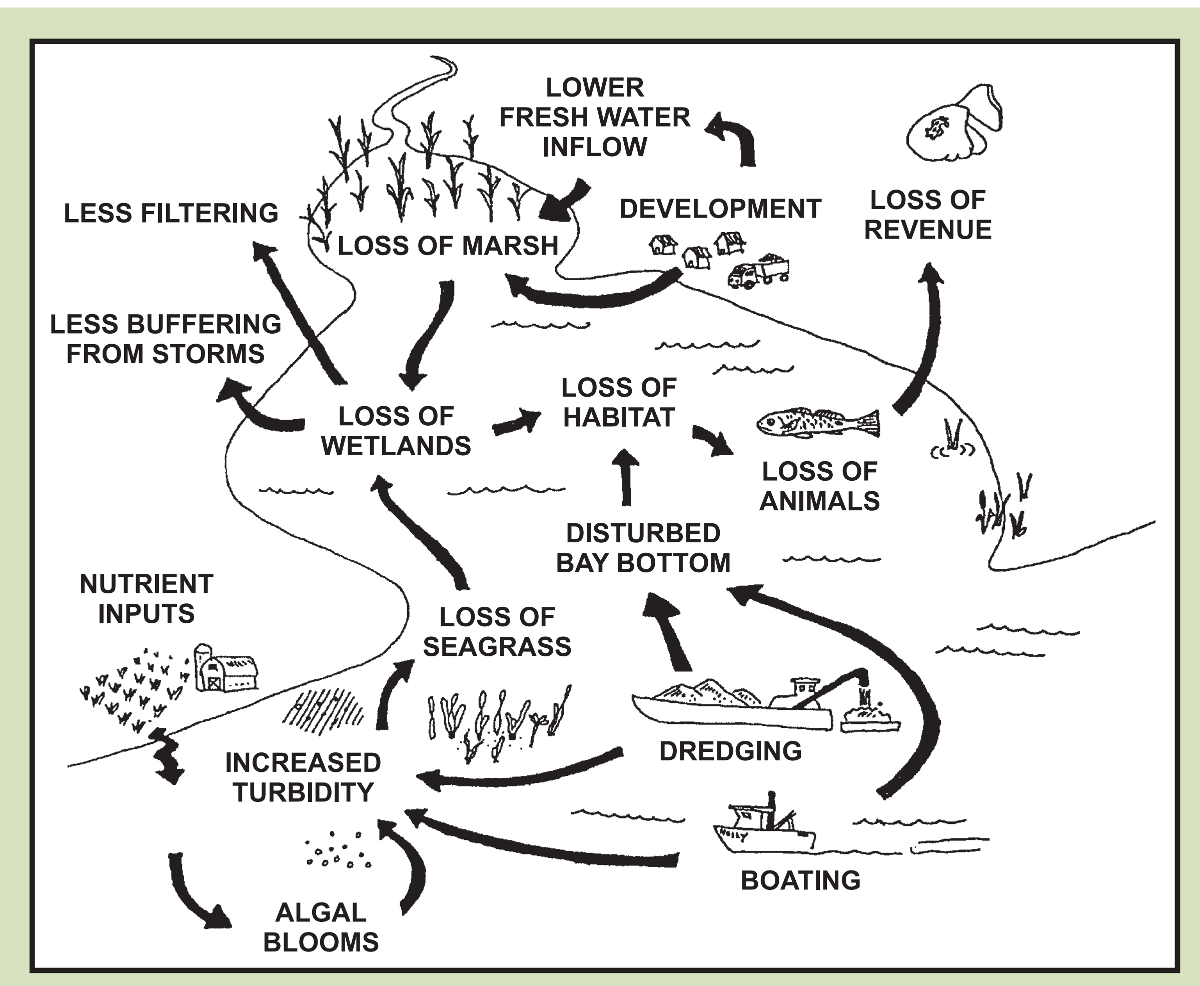


Figure 2-2. The major factors that contribute to loss of seagrass habitat are primarily from human induced impacts and include dredging, excessive nutrient inputs, and boating activities (adapted from Montagna, 1996).

Dredging Effects. Dredging and filling activities have been widely recognized as one of the major anthropogenic disturbances contributing to the destruction of seagrass meadows. The direct and immediate effect of dredging on submerged aquatic vegetation (SAV) is seagrass mortality due to burial. In addition, there are indirect losses resulting from the disturbance of sediments during dredging operations. Seagrasses have high light requirements (Dunton, 1994), and the decreased light availability associated with sediment resuspension has been closely associated with losses of areal coverage in the Laguna Madre (Onuf, 1994). Furthermore, dredged material disposal areas are not always suitable for the colonization and growth of seagrasses (Zieman, 1975). Dredging may also result in hypoxia by increasing biological oxygen demand as organic material exposed by dredging operations undergoes decomposition, which in turn can lead to changes in the redox potential of sediments within meadows (Zieman, 1975; Nessmith, 1980). As a result of changes in hydrologic conditions occurring due to dredging of navigational channels, seagrass meadows can also undergo erosion.

There is evidence that suggests dredging is a causative factor of seagrass loss in Texas. Odum (1963) found that *Thalassia testudinum* beds in the proximity of a dredged area in Redfish Bay had low productivity and an imbalance of respiration over photosynthesis in the spring and summer following the initiation of dredging operations in 1959 (Fig. 2-2). He attributed the low productivity to decreased light penetration. Direct losses of areal coverage as a result of burial were also reported. In addition, increased chlorophyll *a* concentrations in blade tissues, which are indicative of light stress, were clearly higher in plants closest to the channel where dredging occurred (Table 2-2). One year later, in the summer following the dredging event (1960), gross photosynthesis increased four-fold, presumably in response to increased light levels.

Table 2-2. Chlorophyll *a* in *Thalassia testudinum* leaf tissue before (1959) and following (1960) the dredging of a navigational channel in Redfish Bay, Texas. Values represent averages of measurements presented in Odum (1963).

Distance from new channel	Chlorophyll *a* (g per m^2)	
	Summer 1959	Summer 1960
0	0.003	Station out of water as spoil island
0.25 miles east	0.011	Beds covered with 30cm of silt; no plants
0.50 miles east	0.058	1.35
0.75 miles east	0.045	0.41
1.00 miles east	0.031	0.25

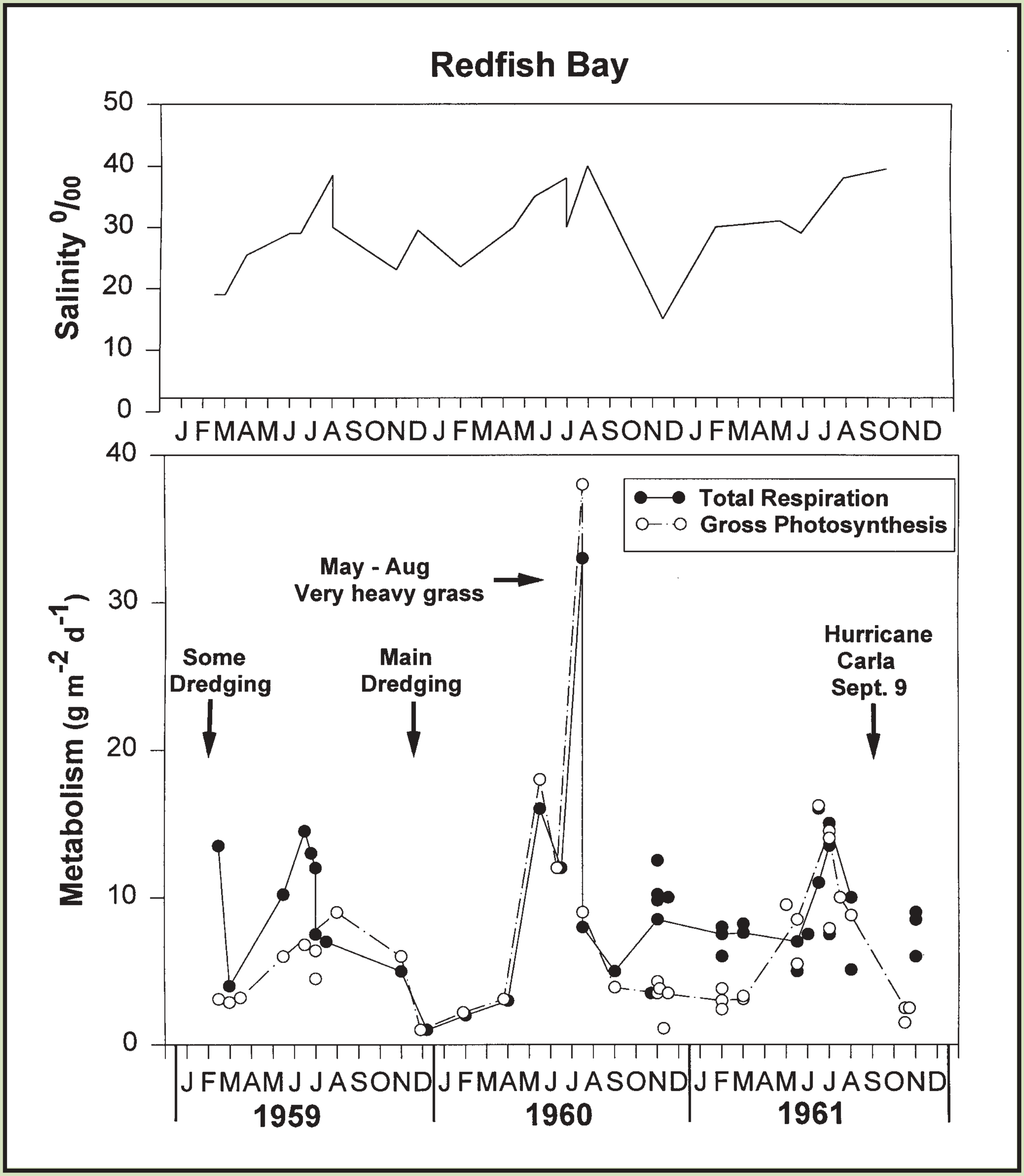
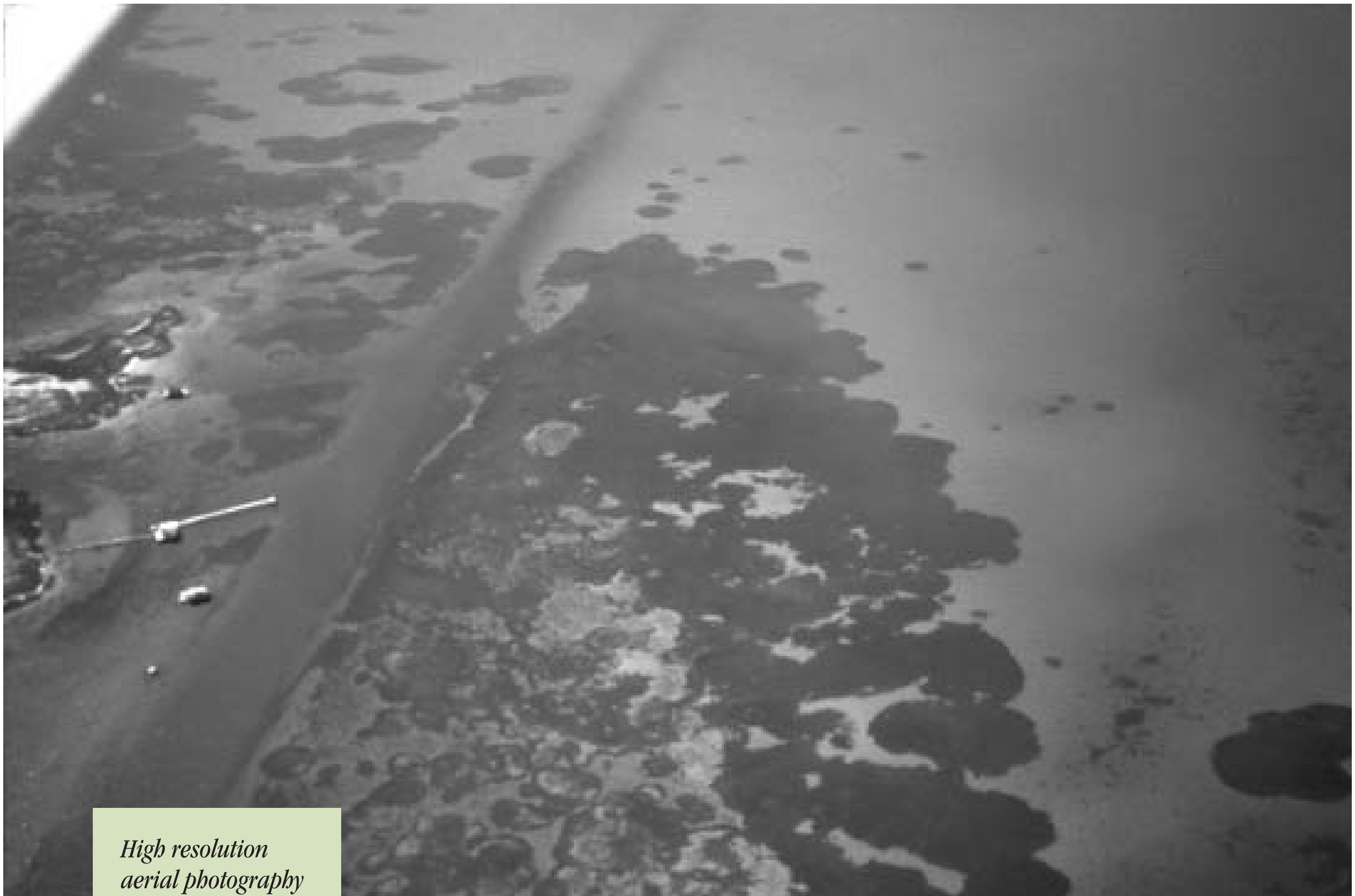


Figure 2-3. Record of water salinity, gross photosynthesis and total respiration in turtlegrass, *Thalassia testudinum,* in relation to dredging in Redfish Bay, Texas. Adapted from Odum, 1963.



KEN DUNTON

High resolution aerial photography reveals striking patterns in seagrass bed landscapes indicative of growth responses to both natural and human disturbances.

There is a relationship between changes in seagrass distribution and the location of dredging operations in the Laguna Madre (Onuf, 1994). Increased turbidity results from the resuspension of dredged sediments from spoil banks by wind-generated waves. Wind-induced wave action is prevalent in south Texas due to the prevailing southeasterly winds and to northerly frontal passages that are characteristic of the area. Consequently, Onuf (1994) found that open bay disposal of dredged sediment led to decreased light availability to seagrass meadows and was greatest in the 1-3 month period following dredging operations. In addition, attenuation coefficients were above predicted values for up to 15 months following the disturbance. Although the effects of dredging on light attenuation were most pronounced in the vicinity of dredged areas, increased turbidity was evident up to 1.2 km away (Onuf, 1994).

Boating Effects. In 1986, there were over 6 million person trips to the Texas coast for recreational fishing and boating activities (Fesenmaier *et al*., 1987). The negative impact of recreational boating activities on seagrass habitat has long been recognized (Phillips, 1960; Zieman, 1976; Eleuterius, 1987). Recreational boating activity causes direct damage to seagrasses through the physical destruction of seagrass leaves and below-ground tissues (roots and rhizomes) by boat propellers. Prop scars tend to occur in areas less than 1 m deep at low tide (Zieman, 1976), and are readily visible in seagrass beds from the water surface itself and through low altitude aerial photography. Eleuterius (1987) indicated that once a propeller scar is created, wave action leads to erosion within the channel resulting in scouring and deepening of the disturbed area. Similarly, Zieman (1976) reported a reduced proportion of fine sediments within propeller scars.

Dredging, propeller scarring, and nutrient loading are among the most potentially destructive activities that impact seagrass communities.

There are few data regarding the extent of prop scarring of seagrass beds in Texas. Likewise, the areas of greatest impact have not been identified. However, a preliminary study of the areal extent of seagrass coverage and propeller scarring in the Corpus Christi Bay National Estuary Program study area was conducted in the winter of 1996-1997 (Dunton, 1998). Analysis of propeller scarring was determined from aerial photography for 8 areas of the Coastal Bend Bay System. Prop scar impact ranged from ca 16% in the Harbor Island area to more than 97% in Estes Flats of Aransas Bay.

Nutrient Loading Effects. Eutrophication from nutrient loading in coastal and estuarine systems is rapidly becoming a major problem as human population and development continues to soar in coastal areas (Hinga *et al*., 1991). Frequently cited examples of nutrient loading in shallow coastal estuaries include nitrate-enriched groundwater from septic systems (Lee and Olsen, 1985; Valiela *et al*., 1992) and agricultural inputs of N which are flushed into estuaries through run-off or riverine inputs (Stevenson *et al.*, 1993). In Texas coastal systems, agricultural and urban contributions are the largest potential (but unquantified) sources of N loading (TSSWCB, 1991), but other inputs, including waste from shrimp and fish mariculture industries are becoming increasingly important (Whitledge, 1995). It is well recognized however, that although the magnitude of nonpoint source nutrient loading to nearshore systems is largely unknown for most of the Nation's estuaries, continued increases in N loading will lead to long-term or irreversible damage to estuarine living resources (Dennison *et al*., 1993; Burkholder *et al*., 1995; Glasgow *et al.*, 1995; Nixon, 1995).


KEN DUNTON

Macroalgae (seaweeds) can become overly abundant in seagrass beds when excess nutrients are present.

The impact of eutrophication on seagrasses has been associated with the growth of both epiphytic and drift macroalgal stimulated by excess nutrients (Valiella *et al*., 1992). Descriptive field studies have found that epiphytic algae appeared to inhibit or eliminate seagrasses entirely (e.g., Dennison *et al.*, 1993) and experimental work has demonstrated that nutrient loading can reduce seagrass productivity and health by stimulating algal competition (Short *et al*., 1995) and by direct nitrate toxicity (Burkholder *et al*., 1994). Recently, Short and Burdick (1996) related housing development and nitrogen loading rates to eelgrass habitat loss in a New England estuary. In Texas, seasonal increases in water column inorganic-N levels have been correlated with significant increases in algal epiphytes and temporary loss of seagrass vegetation (Dunton, 1990). The long term persistence of the brown tide algal bloom, which may be related to anthropogenic changes in nutrient levels in the Laguna Madre, has resulted in seagrass loss in the upper Laguna Madre (Onuf, 1996). In summary, the well documented and negative responses of seagrasses to nutrient enrichment warrant immediate action to restrict the release of nutrients from point and nonpoint sources to Texas coastal waters.

SEAGRASS RESEARCH PLAN

PRIORITY GOAL: To gain a better understanding of seagrass biology and the effects of dredging and filling activities, boat and ship traffic, and nutrient loading through sound scientific research.

OBJECTIVE I: Regularly assess status and trends of seagrass distribution on a coast wide basis.

1. Strategy: Develop a strategic long-term monitoring plan that includes seagrass biological parameters as well as sediment and water quality indicators.

2. Strategy: Perform coordinated, standardized mapping of seagrass beds at appropriate temporal and spatial scales.

    - Action: Integrate mapping and ground truth information on composition, productivity, indicators, etc.

    - Action: Specify data standards of mapping efforts

    - Action: Archive mapped data into a GIS or equivalent database using standard protocols

OBJECTIVE II: Determine causes of changes in seagrass species composition and coverage (acreage), including areal losses and gains.

1. Strategy: Conduct process-oriented (basic) research on seagrass autecology including: physiology, production ecology, reproduction, indicator development, landscape ecology, and demography.

    - Action: Physiological studies should include photosynthesis, nutrient acquisition by leaves vs. below ground tissues, C:N:P ratios, carbohydrate concentrations and stress responses

    - Action: Studies of reproductive biology should include genetic diversity, seed production/survival, and vegetative vs. sexual trigger factors

    - Action: Research in landscape ecology should address population changes due to drift algae, episodic loading events, physical factors, and large scale disturbance events (e.g., hurricanes)

    - Action: Indicator development should address rapid morphological and/or physiological changes in plant tissues and associated fauna that readily reflect degradation of seagrass habitat

    - Action: Apply information on seagrass research outside of Texas

- Action: Conduct research on population ecology and assess susceptibility of seagrasses to diseases based on exposure to environmental stressors

2. Strategy: Conduct process-oriented research on water column and sediment factors that affect seagrasses.

   - Action: Assess specific physico-chemical parameters required to maintain the current health and distribution of seagrasses

   - Action: Assess changes in light quality and quantity as they affect seagrass health, and relate them to nutrient loading and stimulation of phytoplankton blooms (brown tide), epiphytes, and drift macroalgae

   - Action: Assess the biogeochemical environments occupied by below-ground tissues, such as:

     – pore water composition (NH_4, FeS, DIN, P, H_2S, etc.),
     – sediment physical characteristics (grain size, composition, porosity, organic carbon),
     – benthic nutrient flux,
     – microbially mediated processes, and
     – seagrass-sediment pore water interactions as they affect the density and distribution of seagrasses.

3. Strategy: Conduct experimental research on seagrass bed creation and restoration.

   - Action: Determine how donor stocks should be chosen to achieve maximum success

   - Action: Determine if there are methods to accelerate natural recruitment of seagrasses

   - Action: Develop methods for evaluting ecological functioning of restored seagrass beds

OBJECTIVE III: Identify habitat functions and productivity of natural seagrass community types and identify linkages with other habitats to support habitat conservation, creation, enhancement and restoration.

1. Strategy: Conduct process-oriented research on habitat and community ecology of grassbeds.

   - Action: Studies should investigate:

     – Importance of linkages with other habitats on seagrass community composition and productivity

– Relation to more pristine systems (e.g., Mexican Laguna)
– Economic value of seagrass beds
– Functional difference of seagrass bed types
– Seagrass diseases and interactions with environmental stressors
– Population genetics
– Secondary production as a function of epiphyte loading
– The size of habitat patches in relation to secondary production
– The effect of habitat fragmentation on function

2. Strategy: Evaluation of success of mitigation through examination of existing projects (apply adaptive resource management to seagrass restoration and enhancement).

- Action: Develop GIS database of all seagrass creation/mitigation/restoration projects in state and private waters

- Action: Establish functional equivalence/maturity as a function of age

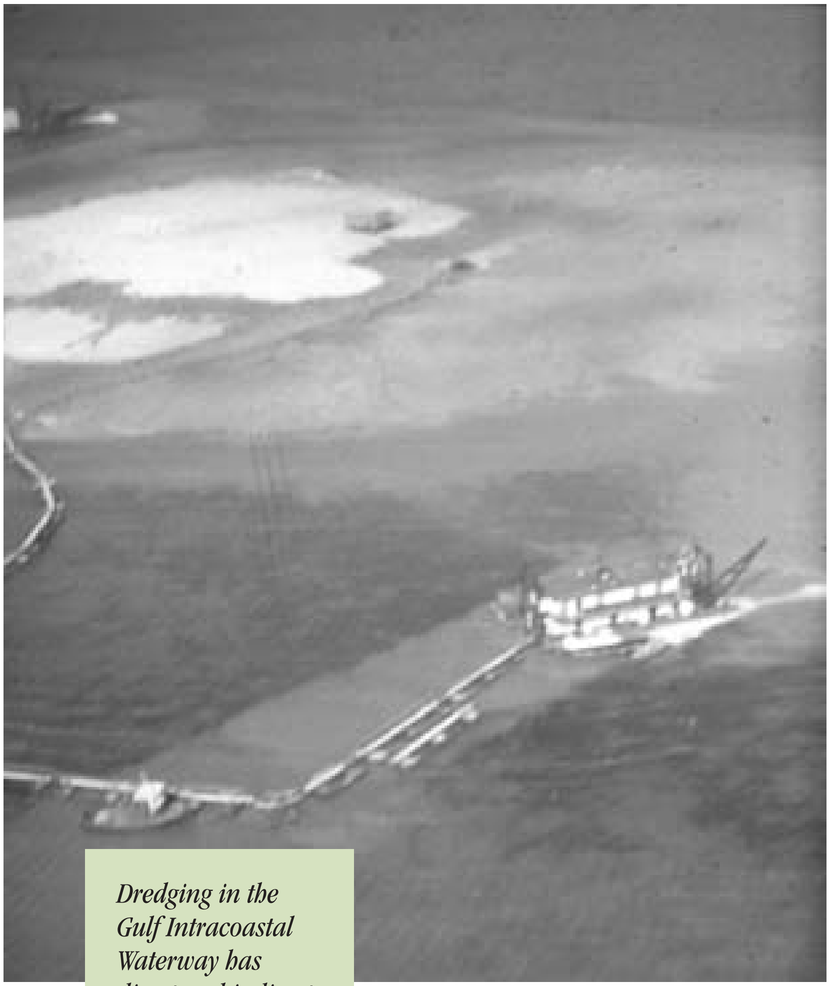
OBJECTIVE IV. Provide data for development of management policies in response to human induced impacts.

1. Strategy: Review of existing information on seagrasses in Texas and establishment of a data clearing-house.

2. Strategy: Conduct applied studies to provide science-based answers to specific management questions.

- Action: Studies should address:

– Effects of boating impacts (trawling, boat traffic [sailboats, jet skis, motor boats])
– Effects of municipal and industrial discharges on seagrass beds
– Effects of aquaculture discharges on seagrass beds
– Socioeconomic values and impacts of management on users
– Effects of the increase of human population (e.g., non-point nutrient loading, user impacts)
– Effects of oil, gas and mineral exploration and development
– Global climate change: increases in mean sea level
– Repairing prop scar damage
– Dredging effects on light attenuation
– Stabilization of dredged disposal material
– Indirect effects of dredged materials
– Development and verification of seagrass models
– Watershed contributions to nonpoint source nutrient and toxin loadings



LARRY McKINNEY

Dredging in the Gulf Intracoastal Waterway has direct and indirect impacts on seagrass beds.

CHAPTER 3.
MANAGEMENT ISSUES FOR TEXAS

Leland R. Roberts
Texas Parks and Wildlife
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INTRODUCTION

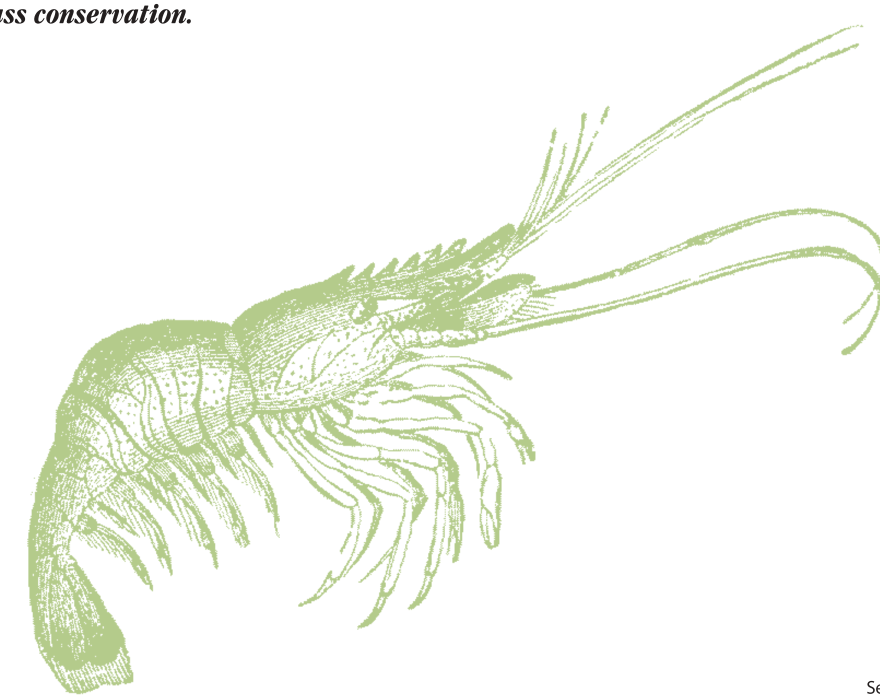
Coastal waters are subject to increasing change due to the burgeoning population of Texas. Of the state's 17 million people, one-third of them are living in the coastal area [Texas Coastal Management Program (TCMP), 1996], and a diversified growth for the state is expected to continue (Texas Almanac, 1992-93). Although population growth is heaviest in urban areas such as Houston, Corpus Christi, and the Rio Grande Valley, population is growing throughout the Texas coastal area, with a projected growth of at least 2-3 percent statewide. Population growth brings more competition for the resources provided by coastal waters and wetlands.

The 1990 Texas Outdoor Recreation Plan (TORP) discusses the potential degradation of coastal resources. Littered beaches, spills or other discharges of oil, loss of habitats from development, and dredging of navigational channels, are only a few of the problems which affect management of natural resources such as seagrasses. Protection of natural resources and the need to plan for coastal economic development have resulted in the preparation of the TCMP, which establishes goals and policies for protection of coastal natural resources and requires that agency actions be consistent with those goals and policies. The TCMP broadly addresses many threats to seagrasses. It is anticipated that this Seagrass Conservation Plan for Texas (SCPT) will provide specific coastal planning needed for seagrass protection.

Four problem areas involving management issues are addressed by the SCPT: (1) Seagrass beds are being lost or degraded, and/or species composition is changing. Seagrass beds need to be protected and restored through effective water quality standards, mitigation, and restoration. In addition, dredging, shoreline development, and competing uses, such as boating, need to be effectively managed; (2) Conflicting agency authority may prevent effective management. Consistent and coordinated policies and regulations between agencies need to be developed; (3) Data synthesis and monitoring are insufficient for management decisions and need to be focused on management needs; and (4) Public outreach is presently too limited to achieve the goal of public awareness.

The SCPT contains one management goal and eight objectives identified through preliminary drafts prepared by the SCPT steering committee, and refinements made by those attending the Symposium on Texas Seagrasses in Corpus Christi on November 4-5, 1996. The following goal was identified in discussions on management issues related to agency coordination, research, and education:

To develop a sound management process that coordinates agency policies, public concern, and existing knowledge from research, to achieve effective seagrass conservation.



The SCPT addresses three primary areas for policy development – regulatory, management, and education. Objectives are listed for each policy area.

The Texas Seagrass Conservation Plan outlines a framework to guide the development of future management policies.

REGULATORY

- **Ensure water and sediment quality beneficial to the seagrass community**. High water quality is essential to the health of seagrasses, as it prevents problems such as phytoplankton blooms or macroalgae accumulations. Conversely, degraded water quality may promote eutrophication. Water Quality Criteria are needed for biodiversity, pollutants, nutrients, turbidity, dissolved oxygen, and salinity. Criteria should represent ambient environmental limits promoting optimum seagrass health.

- **Protect seagrass beds through effective application of the mitigation sequence: avoidance, minimization, compensation**. The federal Section 404/401 permitting process has been effective but improvements are needed in interagency coordination. Guidelines for avoidance of seagrass bed impacts should be emphasized, since restoration of seagrasses is usually difficult and expensive.

MANAGEMENT

- **Restore/enhance/create lost functions and values of seagrasses on a system-wide level, where feasible**. Many attempts to restore, enhance, or create seagrass beds have not been successful. Therefore, applied research is needed to develop guidelines for site selection, planting methods, and survival monitoring after planting.

- **Design dredging or shoreline development projects to effectively reduce impacts upon seagrasses**. Dredging of canals through or near seagrass beds, maintenance dredging of channels, and dredge material disposal can destroy seagrasses or inhibit growth through dredging-caused turbidity. Development along bay/estuary shorelines may affect conditions of depth, currents, etc., that cause loss of seagrass. Best Management Practices should be followed to protect seagrasses while allowing economic development of coastal resources.

- **Develop consensus agreements or plans among users of the seagrass resource.** No one agency or group can institute unilateral plans or actions for use of coastal resources in today's open government. Therefore, "consensus agreements" must be developed among competing user groups to provide workable plans. An example of this would be solutions to reduce the impacts from propeller scarring and boat traffic on seagrasses.

- **Provide agency policy coordination that will assist management of seagrasses by all agencies**. Policies of agencies which regulate or impact natural resources must be reviewed to prevent unintentional or unnecessary blocking of plans/actions by another agency.

- **Conduct research and on-going data acquisition and analysis to provide a sound technical basis for management actions and policies**. Existing data will be made readily available to managers and stakeholders, and monitoring of seagrasses will be optimized for cost-effectiveness. A clearinghouse for data needs to be established (see also Research Objective IV, Strategy 1).

OUTREACH

- **Develop a sense of community stewardship and individual responsibility for the conservation of seagrass.** Seagrasses and other natural resources can be used, but must be protected under a sense of community stewardship and individual responsibility. All stakeholders must be cooperatively involved in developing this message.

Status and Trends: A Management Perspective

In 1994, seagrass acreage was approximately 235,000 acres coastwide (Pulich and Roberts, 1996). Trend data within the last 40 to 50 years, however, indicates that considerable change has occurred coastwide in Texas, with seagrass becoming scarce in some areas and more abundant in others. Change has occurred from natural causes, such as hurricanes, water (sea) level change, and climatic cycles. Anthropogenic causes have included both indirect and direct destruction and/or degradation from over 770 miles of federally maintained navigation channels and over 500 "designated" disposal sites, shoreline developments, commercial and recreational boating, nutrient loading, inadequate policies, a lack of unified planning, and a lack of education/outreach to the general public. Regulatory authorities have attempted to maintain or restore seagrass beds by using the mitigation process; while helpful, the standards in the process may not be sufficient. The goals, objectives, and actions proposed below will hopefully contribute to improvement of seagrass conservation in Texas.

REGULATORY ISSUES

Water and Sediment Quality

To ensure water and sediment quality beneficial to the seagrass community, a series of objectives will need to be accomplished, including: 1) consideration of seagrasses as a beneficial aquatic life use; 2) developing specific water quality guidelines and criteria to protect seagrass beds; and 3) developing Best Management Practices (BMPs) which protect seagrasses.

The Texas Surface Water Quality Standards designate water-quality related uses and numerical criteria to support those uses. Examples of designated uses include "contact recreation," various levels of "aquatic life," "public water supply," and in a few cases "waterfowl habitat" and "aquifer protection." Seagrass habitat should be evaluated as an additional designated use to be considered in these standards. The initial step would be to consider establishing "seagrass habitat" as a specific use during triennial public revisions of the Water Quality Standards.

Criteria to specify water quality goals in support of designated uses can be narrative or numerical. For some parameters, criteria are not specified numerically in the standards, but numerical screening levels are used in the Texas Water Quality Inventory to assess whether designated uses are being adequately maintained. Additional evaluation would be needed to develop criteria or screening levels for seagrass protection. Potential criteria or screening levels to assess seagrass protection include suspended sediment, nutrient concentrations, turbidity, salinity, and indicators of seagrass diversity and health. These criteria and screening levels would establish water quality goals and encourage the protection of seagrass communities. A substantial amount of new information will be needed to establish these criteria and to develop policies on how to implement realistic protective measures for seagrasses. Therefore, this objective must also be addressed through directed research projects and public participation in policy formulation.

Watershed management programs can play an important role in ensuring water and sediment quality beneficial to seagrass communities. Incorporating seagrass ecosystems into watershed assessments can help identify areas needing additional management. Watershed management

WARREN PULICH

Turbidity plumes resulting from dredging or trawling activity may reduce underwater light available to seagrasses.

programs can also help protect water and sediment quality by promoting non-regulatory management activities. Watershed management programs can assist in the development and implementation of BMPs for reducing seagrass impacts. BMPs are an important action under this objective since they protect water and sediment quality.

Implementation of a variety of BMPs are needed to address impacts from runoff. Some impacts may require the development of new BMPs. Special emphasis should be given to development of water-based BMPs that protect seagrass beds. These BMPs should focus on reducing turbidity impacts associated with dredging near grassbeds, and avoiding impacting seagrass with new channels and recreational access.

Accomplishing these objectives will make significant strides towards ensuring water and sediment quality beneficial to seagrass communities.

Effective Application of the Mitigation Sequence

Federal Section 404 Permits and state Section 401 Water-quality Certifications have been somewhat effective in protecting seagrasses, but improvement is needed in interagency coordination. In addition, mitigation guidelines need to be strengthened and made consistent.

The economic viability of the coast is directly linked to the ecological health of our bays and estuaries. With increasing populations in the coastal area, development will occur at an increasing rate, resulting in additional degradation and loss of coastal natural resources, including seagrasses. Effective federal and state regulatory programs are needed to protect these valuable coastal natural resources.

Federal and state regulations and programs that help protect seagrasses in Texas are primarily the Section 404 and 401 Permits of the Clean Water Act (CWA) and the TCMP. The day-to-day activities of the Section 404 program for the Texas coastal region are administered by the Corps of Engineers (Corps), Galveston District. Permit applications for Section 404 Permits are reviewed not only by the Corps but also by the Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), Texas Parks and Wildlife (TPW), the Texas Natural Resource Conservation Commission (TNRCC), and the General Land Office (GLO). The Corps schedules bi-monthly joint evaluation meetings with federal and state agencies to discuss permit application, schedule possible on-site field inspections with applicants, and determine any mitigation requirements.

State and federal entities must work together to adopt goals and policies for the successful management of seagrass in Texas.

Section 404 applies to discharges of dredged or fill material in waters of the United States. The Section 404 (b)(1) Guidelines (40 CFR Part 230) are the substantive environmental standards by which all Section 404 permit applications are evaluated. The Guidelines apply to wetlands and special aquatic sites, including seagrasses. They state that "no discharge of dredged or fill material shall be permitted unless appropriate and practicable steps have been taken which will minimize potential adverse impacts of the discharge on the aquatic ecosystem" (40 CFR 230.10(d)). Compliance with Part 230.10(d) requires application of a sequence of mitigation: (1) avoidance; (2) minimization; and (3) compensation. Avoidance is primarily addressed through compliance with an alternative analysis which determines whether there is "a practicable alternative to a proposed discharge which would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences." Minimization includes all reasonable actions to reduce the adverse impacts of a proposed discharge. Appropriate and practicable compensatory mitigation is required to offset unavoidable seagrass impacts that remain after all appropriate and practicable minimization has been required. Compensatory mitigation may include restoration and enhancement of degraded seagrasses and creation of seagrasses from uplands. Restoration is preferred over creation, because there is greater likelihood of success. Compensatory mitigation in areas adjacent or contiguous to seagrass impact is the preferred approach. In certain cases, it might not be practicable to conduct mitigation on-site, and might be necessary to mitigate off-site but within the same estuarine system.

Another mechanism for state regulation of seagrasses is water quality certification under Section 401. This process essentially allows the state to determine whether federal permits for discharges into the surface waters of the state will be granted, denied, or conditionally granted. The TNRCC rules for Section 401 Certification (30 TAC Chapter 279) incorporate key components of the federal Section 404 (b)(1) Guidelines, including the mitigation sequence. Most actions of the Section 401 Water Quality Certification program are under the jurisdiction of the TNRCC, but oil and gas production activities covered by Section 404 are certified by the Railroad Commission of Texas (RRC).

Management of the TCMP is overseen by the Coastal Coordination Council (CCC), which is chaired by the commissioner of the TGLO. The other members of the CCC are the chair of the Parks and Wildlife Commission; the chair of the Texas Transportation Commission; the chair of the TNRCC;

the chair of the Texas Water Development Board; a member of the Texas State Soil and Water Conservation Board; a member of the RRC; and four gubernatorial appointees. The CCC is charged with adopting uniform goals and policies to guide decision-making by all entities regulating or managing seagrass use within the Texas coastal zone, and to formally review significant actions exceeding established thresholds taken or authorized by state agencies and subdivisions that may adversely affect seagrasses.

The CMP policies in 31 TAC Section 501.14(h) apply to the construction of structures in and the filling of critical areas, including seagrasses. These policies basically mimic the Section 404 (b)(1) Guidelines. Other applicable TCMP policies are policies on dredging and the disposal and placement of dredged material (31 TAC Section 501.14(j)) and policies on development on state-owned submerged lands (31 TAC Section 501.14(i)).

MANAGEMENT ISSUES

Restoration, Enhancement, and Creation

Success in restoring and enhancing seagrass beds was originally reported as minimal (Cobb 1987). Over the last ten years, however, techniques have been developed for restoring some seagrasses in Texas where they have grown in the past. Restoration of shoalgrass beds (*Halodule wrightii*) is routinely attempted, and creation of shoalgrass beds in previous coastal upland areas is now considered feasible. Since 1987, one restoration contractor (Belaire Environmental, Inc.) has planted more than 200 acres with seagrass plugs at approximately 30 sites in Texas (Charles Belaire, pers. communication). These projects, ranging from Galveston Bay to the lower Laguna Madre, have involved primarily shoalgrass (20 out of 25 sites) and widgeongrass (6 out of 25 sites). One site each attempted to establish turtlegrass (failed) and manateegrass (2-year survival). In summary, Belaire documents that 182 acres out of 201 acres total (88 %) have been established successfully and survived for at least two years.

Of the four species of seagrasses in Texas, shoalgrass is the preferred transplanting species as success is higher and it provides excellent habitat for numerous trophic levels. Turtle grass (*Thalassia testudinum*) also provides excellent habitat, but its slow growth makes it very difficult to propagate and restoration in Texas is rarely attempted. Widgeon grass (*Ruppia maritima*) is excellent in less saline waters for aquatic organisms and is good for waterfowl. However because restoration success cannot be guaranteed, state and federal resource agencies often ask that any attempts to mitigate losses or damage be at least a ratio of three acres of seagrass planting for each one acre of seagrass destroyed (3:1 ratio). This merely increases the chance that the same acreage of seagrass will exist after restoration as before. In addition, replanting is often requested if planting success is less than 70 percent.

Management efforts should be directed several ways. Increased research on successful planting techniques is needed. In addition, standard methods for removal of donor plants are needed so that seagrass beds in public waters are not damaged by removing plants. The current GLO and TPW procedures which cover such "borrowing" activity in donor grassbeds are considered reasonably protective. However, one technique not currently specified in these guidelines would be to recommend replacing sediment to the "borrow holes" in the donor bed. A seagrass nursery could also be advantageous for providing suitable genetic stocks, but sites would have to be found and techniques for intensive propagation developed. Sites acceptable for replacement or enhancement should be located. Finally, since plantings are occasionally unsuccessful, the proper ratios for various situations should be determined on a watershed or system level.

Management needs should be addressed in the context of the historical description of a given habitat. Current management tends to require restoration, enhancement, and creation to maintain the current status quo at the expense of other habitat types that may have been at higher or lower levels at other times in history. Therefore, policies involving in-kind and in-system mitigation should be reviewed for current application by both management and research teams.

Current management practices often result in a large number of individually small compensatory mitigation sites. Should policy, instead, be flexible enough to allow the development of larger individual mitigation areas which would allow additional benefits due to economy of scale? Various approaches could include one mitigation effort providing site preparation, with following efforts providing the source of plant material, the actual planting process, and so forth. This would require the development of a watershed or system-wide plan for habitat needs and the identification of mitigation opportunities. Perhaps, in this "pooled resources" approach, cash mitigation could be accepted until enough funds are collected to purchase and develop a meaningful site. This type of program could have potential for privatization with regulatory oversight.

Dredging and Shoreline Development

Dredging of new channels through or near seagrasses, and maintenance dredging of existing channels, may cause mortality from burial or may inhibit growth from turbidity and light reduction. Development along bay and estuary shorelines may create conditions of depth and currents that cause seagrass loss. Best Management Practices are needed to protect seagrasses while allowing economic development.

Dredging. Texas bays and estuaries are crisscrossed by over 770 miles of federally maintained dredged channels and an unquantified number of private and commercial channels. Material excavated from federally maintained channels is placed in more than 500 designated disposal sites, including the following types: typically upland confined, open-water confined, upland and open-water partially confined, open-water unconfined in bays and estuaries, and open-water unconfined in federally approved Ocean Dredged Material Disposal Sites located in the Gulf of Mexico. The disposal sites in the bay and estuary environments and adjacent uplands encumber about 72,000 acres of upland, intertidal, and submerged lands.

The most significant environmental impacts of dredged material disposal are related to the historic preference for use of partially confined or unconfined open-water disposal sites. Material placed in these sites typically disperses by mud flow or siltation during or immediately following the disposal operation, commonly beyond the authorized limits of the disposal site. Onuf (1994) reported that light reduction from maintenance dredging of the GIWW was the suspected cause of large-scale loss of seagrass cover in deep parts of the Laguna Madre between surveys conducted in 1965 and 1974. Dredged material also displaced many acres of seagrasses in West Bay between 1956 and 1975 (Pulich and White, 1991).

Shoreline Development. Many bay-estuary-lagoon shorelines have been artificially stabilized by bulkheads, rip-rap, and other erosion control measures. In some areas, for example in areas of rapid subsidence, these stabilizing features also contribute to deeper-water conditions near shore by inhibiting the natural development of a broad, shallow, and gently-sloping bay margin profile (Pulich and White, 1991). Shoreline stabilization practices, especially bulkheading, may significantly increase local physical energy regimes by preventing dissipation of natural wave energies. This may result in loss of seagrasses or may prevent recovery of seagrasses with improving water conditions (Chesapeake Bay Program, 1995). Nonstructural methods for shoreline stabilization, such as planting of marsh vegetation, are generally preferred over structural methods.

Shoreline development can cause indirect impacts to adjacent seagrass beds from water quality degradation.

When improperly designed, piers and over-water structures present special problems to seagrass habitats. The reduced amount of surface light can pose a severe stress to the underlying seagrass beds. Although few guidelines presently exist, there is a need to establish pier construction guidelines which address both environmental issues and the public's desire to utilize coastal bay shorelines. Larger, over-water structures, which generally reduce light over much larger areas (and also can be a source of point-source discharges), should be discouraged in seagrass areas.

Consensus Agreements or Plans Among Users

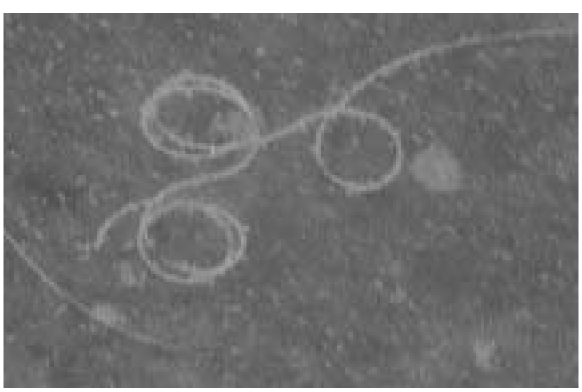
Beneficial Uses Plans. Users of natural resources, such as seagrass beds, seek consensus over controversial issues involving resource use. However, consensus is often difficult to achieve. An example of a model plan for a controversial issue involving coastal natural resources is the 1994 Beneficial Uses Group (BUG) Plan for the Houston Ship Channel deep-draft navigation project. The Plan is a consensus agreement that attempts to minimize the ecological and sociological impacts of dredging by maximizing the beneficial uses of dredged material.

The BUG was created in the early 1990s as a subcommittee of the Interagency Coordination Team (ICT) established by the Corps for addressing various environmental issues associated with the two-phase Houston Ship Channel Modernization Project. The BUG's membership included the USFWS, EPA, Corps, NMFS, Natural Resource Conservation Service, and the TPW, TGLO, and Port of Houston Authority. The purpose of the BUG was "to develop a disposal plan that utilizes dredged materials in an environmentally sound and economically acceptable manner that incorporates, to the extent possible, other public benefits into its design." The BUG was committed "to the objective that the final plan would have a net positive environmental effect over the 50-year life of the project." The BUG actively solicited beneficial use suggestions from all bay stakeholder groups.

Features of the BUG Plan include the construction of 4,250 acres of intertidal marsh in the Galveston Bay system, the construction of boater access channels and anchorages in mid and lower Galveston Bay, and the construction and restoration of islands in the Galveston Bay system. Among the benefits derived from the Plan are: (1) the creation and restoration of wetland habitat in the Galveston Bay system, a priority problem for the Galveston Bay National Estuary Program; (2) the minimization of impacts to productive bay habitats through the placement of beneficial use sites within areas presently used as unconfined disposal areas; and (3) others, including shoreline protection and the creation of avian habitat.

The Plan was an evolving process with particular emphasis on public involvement, evaluation criteria, and field testing and verification. The Plan is currently being implemented in the Galveston Bay system. Other similar plans could be developed for estuarine systems, such as Laguna Madre, where seagrasses are dominant.

LELAND ROBERTS



LELAND ROBERTS

Damage to seagrass beds from motor-boat propeller scarring is becoming increasingly evident.

Boating Impacts. It has become increasingly apparent that boating activities cause noticeable impacts to seagrass beds in several ways. Propeller-scarring has been documented in both Florida (Sargent et al. 1995) and Texas (Pulich et al. 1997, Dunton et al. 1998) seagrass beds. This activity can cause significant disturbance and even fragmentation of the shallow grassbed habitat. Such scarring is frequently observed near developed, urban bay areas, with high populations of boaters. While the long-term results of such scarring are not definitely established, the consensus of scientists and resource managers calls for protective measures to reduce boat traffic through these shallow grassbeds. Anchoring of boats (especially houseboats) for extended time periods can also cause significant damage to grassbeds. The tell-tale circular scars left from boats swinging on anchor are often seen in the Laguna Madre. The first approach to dealing with these problems should employ consensus-building among boaters, fishermen, and other users of the bay resources. Appropriate, non-regulatory actions are described in the Chapter on Education and Outreach Issues. These approaches are designed to help change people's attitudes and behavior when boating in or near seagrass areas.

Policy Coordination

Policies affecting seagrasses are present in many agencies including: water quality policies in the TNRCC and RRC; use of shrimp trawls and oyster dredges in the TPW; habitat damage assessment policies for oil and chemical spills in the TPW, NMFS, TNRCC, TGLO, and USFWS, with related components, including involvement from the Corps, EPA, federal courts and the Department of Justice; bottom disturbances, mitigation, and TCMP planning in the TGLO; shellfish sanitation for oyster harvesting in the State Department of Health; and others. Each of these policies may be written with only one agency and its specific regulatory authority in mind. Such policies may, therefore, be more restrictive on other uses of the resource than is necessary. Policies should be prepared in a holistic framework to deal with the primary subject, but not be so restrictive that the uses of resources by others are unnecessarily impaired. Therefore, the objective of examining written and unwritten policies to ensure that goals can be achieved is offered as part of this plan.

The objective includes developing policies and regulations which provide for "planned achievements" for seagrasses. The goals and objectives for this action need to be prepared without the constraints which may now be restricting desired "achievements," and these may need their own set of goals and objectives to reach the desired outcome. Efforts should also focus on practical and applied science, both for management and for research. Finally, existing policies should be reviewed not only for flexibility, but also for unnecessary restriction of applications which may come from outside sources.

Monitoring programs are needed for status and trends information and to help evaluate management actions.

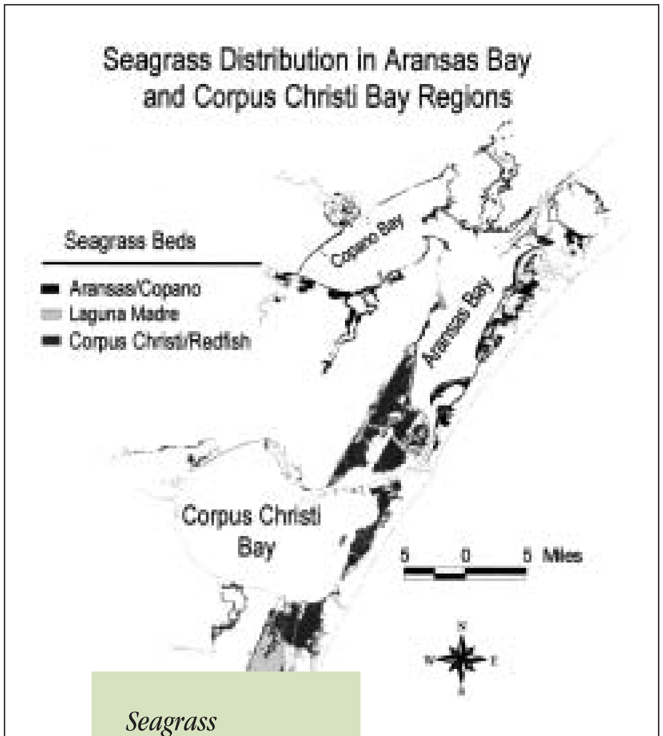
Agencies should provide a brief, concise summary of applicable, existing written and unwritten policies, including footnotes and full summaries and text of enabling legislation, regulation, pertinent case law and administrative histories. These could be categorized as policies applied to routine versus non-routine policy applications. This would not be duplication with the TCMP, but would be a "nuts and bolts" review of the policies and their application to seagrass management.

To measure policy effectiveness, an updated data base on seagrass loss/damage, the amount of compensatory mitigation, and mitigation success rates needs to be developed. The primary focus would be to determine how rational these policies are in the context of ecological, social, and financial management (holistic) paradigms.

Research, Data Acquisition, and Monitoring

Although seagrasses provide a high quality, unique habitat for coastal fishes, shellfishes, and some aquatic mammals, the science base is not complete upon which to base management decisions relating to seagrasses. Needed information would include the identification of data gaps to guide management and research priorities. Monitoring programs are still needed for status and trends information and to help evaluate management actions.

Seagrass Ecology. Research has provided some information on the basic biology of growth, light and depth requirements, and sediment conditions. However, management oriented research is badly needed in many cases, e.g., on water quality requirements of seagrasses. For example, it is suspected that excess nutrients may promote the growth of phytoplankton, which then reduces the penetration of light and effectively causes loss of seagrasses in waters over 5 feet deep. Turbidity from dredging is also suspected as being responsible for minimizing the penetration of light to seagrasses. Management efforts will depend upon the development of new approaches that utilize a watershed approach to water quality parameters to control input of nutrients into estuaries. Ecological studies are also needed to develop dependable techniques for restoration and creation of seagrasses as part of a mitigation plan when seagrasses have been damaged or destroyed. Techniques for producing nursery stocks for restoration are needed, as are the methods of using existing seagrass beds for transplant stock.



Seagrass distributions should be mapped every 2 to 5 years to provide accurate trend data

Monitoring. Adequate status and trends information is critical for managing the estimated 951 km^2 of seagrass habitat in Texas. Unfortunately, many efforts to monitor or map biological resources have not included seagrasses due to the special photographic procedures required. However, studies on limited areas have determined that areal coverage is decreasing in areas and expanding in others. Also, species composition is changing in certain areas. Understanding the reasons for change requires good monitoring data, although, with the broad expanses of seagrass meadows existing from San Antonio Bay through South Bay, monitoring efforts may need to be focused on strategic areas because of costs.

Summary. Sound, scientific data are needed to provide reliable information for application to management. Currently, there is minimal planning to guide this data compilation effort. The SCPT should help guide the development of such an organized database.

EDUCATION/OUTREACH

Community Stewardship and Individual Responsibility

The basic questions are: (1) why do people adopt certain attitudes and make them part of their philosophy; and (2) how can information be presented to correctly change people's attitudes? Examples of attempts to provide choices in attitudes exist within Texas. The "Don't Mess with Texas" program by Texas Department of Transportation was designed to reduce litter on Texas highways by getting people to adopt sections of highways and pick up the litter at least three times each year. Another example is a TPW program entitled "Don't be a Pain in the Boat" designed to reduce boat accidents by encouraging less use of alcoholic drinks while boating. The TPW also initially gathered representatives of boating trades, fishing guides, marine dealers, outdoor educators, seagrass scientists, etc., to develop a list of actions regarding seagrass protection. Success seems to lie with getting people involved in positive actions to protect or preserve quality of life.

SEAGRASS MANAGEMENT ISSUES PLAN

PRIORITY GOAL: **To develop a sound management process that coordinates agency policies, public concern, and existing knowledge from research, to achieve effective seagrass conservation.**

Priority Problem I

Seagrass beds are being lost or degraded, and/or species composition is changing.

Objective 1: Ensure water and sediment quality beneficial to the seagrass community.

- Strategy: Designate seagrass as a high or exceptional Aquatic Life Use in Texas Surface Water Quality Standards.
- Strategy: Designate water quality criteria for seagrasses in Texas Surface Water Quality Standards.
- Strategy: Develop and implement water-based Best Management Practices.

Objective 2: Protect seagrass beds through effective application of the mitigation sequence: avoidance, minimization, compensation.

- Strategy: Develop consistent and effective mitigation guidelines.

Objective 3: Restore/enhance/create lost functions and values of seagrasses at a watershed/system-wide level, where feasible.

- Strategy: Develop guidelines for site selection on a watershed/system-wide level, planting methods, and monitoring of seagrass restoration projects.

Objective 4: Design dredging or shoreline development projects to effectively reduce impacts upon seagrasses.

- Strategy: Best management practices are needed to protect seagrasses while allowing economic development of coastal resources.

Priority Problem II

Agency coordination or policies may prevent adequate management.

Objective 1: Develop consensus agreements or plans among users of the seagrass resource.

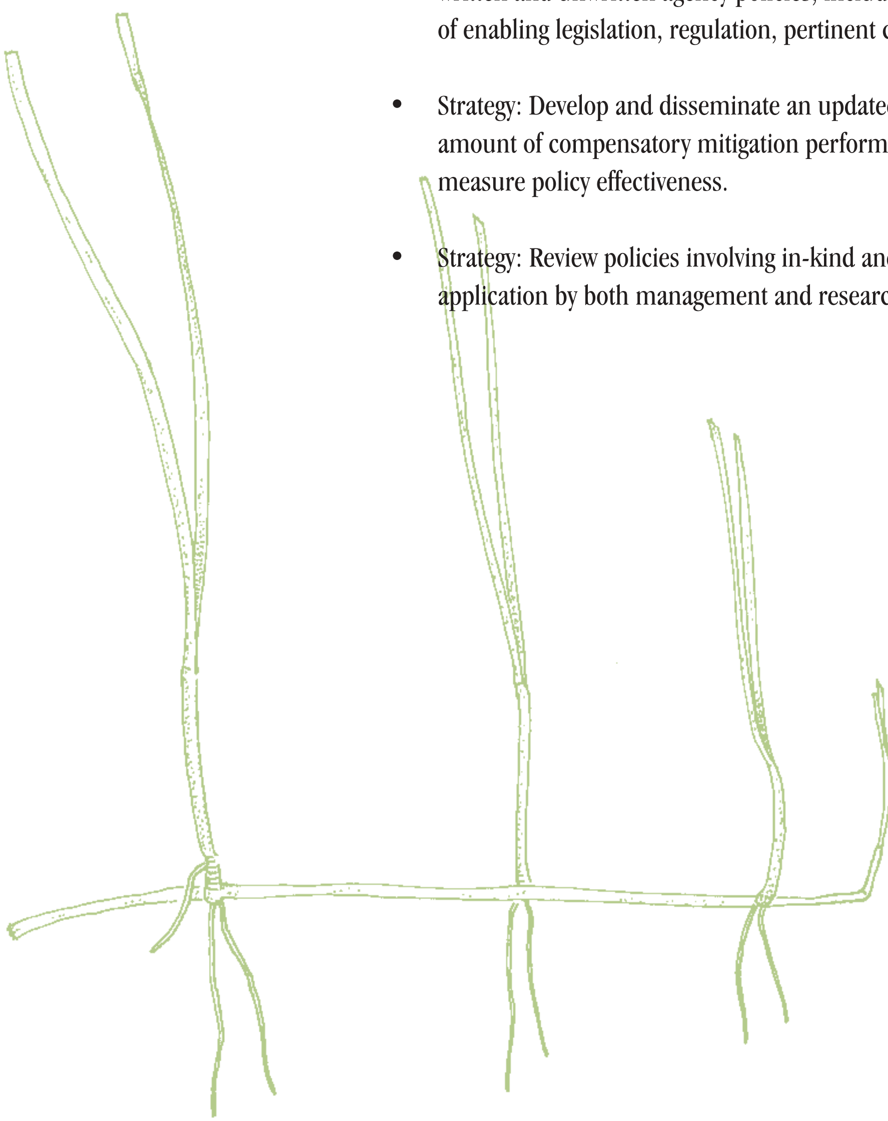
- Strategy: Model consensus agreements or plans after examples such as the successful 1994 Beneficial Uses Group Plan for the Houston Ship Channel deep-draft navigation project.

Objective 2: Facilitate agency policy coordination by improving communication and consistency of actions related to seagrass management.

- Strategy: Develop and disseminate a brief, concise summary of applicable, existing written and unwritten agency policies, including footnotes and full summaries and text of enabling legislation, regulation, pertinent case law and administrative histories.

- Strategy: Develop and disseminate an updated data base on seagrass loss/damage, the amount of compensatory mitigation performed, and mitigation success rates in order to measure policy effectiveness.

- Strategy: Review policies involving in-kind and in-system mitigation for current application by both management and research teams.



Priority Problem III

Data synthesis and monitoring are insufficient for management decisions and need to be focused on management needs.

Objective 1: Conduct research and seagrass resource data acquisition and analysis that provide a sound technical basis for management actions.

- Strategy: Establish a data clearinghouse for seagrass-related information.

- Strategy: Focus research on seagrass management needs for Texas estuarine systems, including such issues as seagrass status and trends, water quality criteria, adequate mitigation ratios, and best mitigation practices.

Priority Problem IV

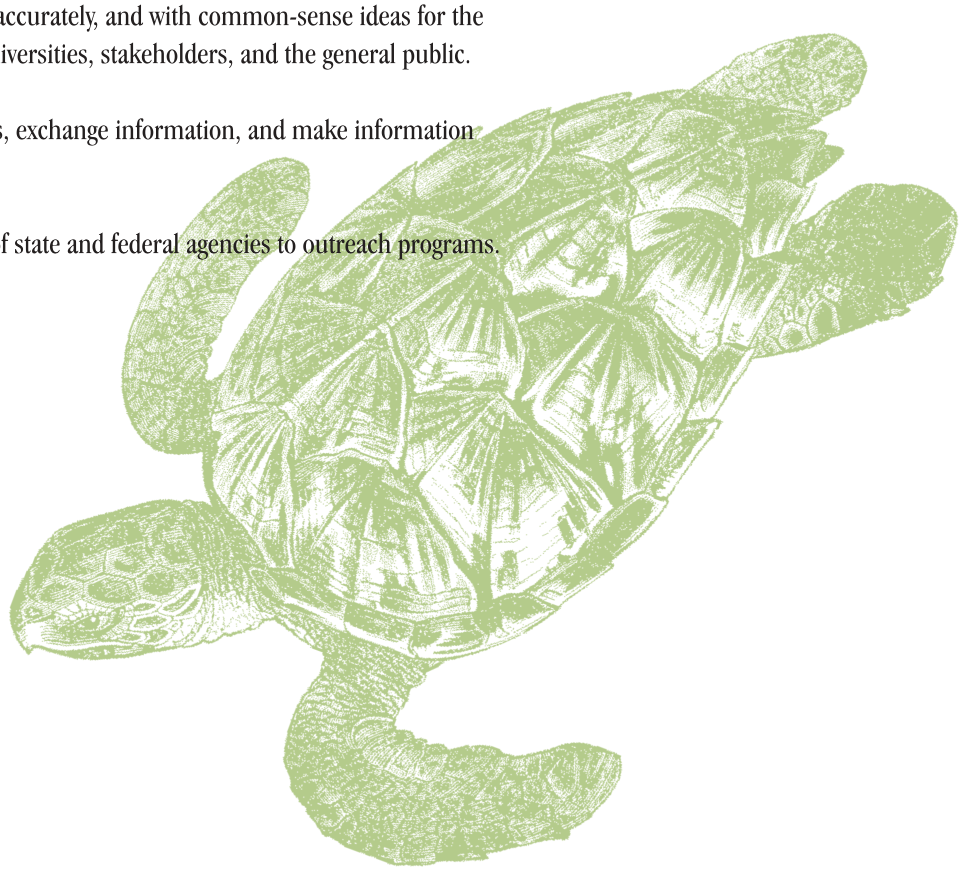
Public outreach is too limited to achieve the goal of public awareness.

Objective 1: Develop a sense of community stewardship and individual responsibility for the conservation of seagrass.

- Strategy: Write information clearly, accurately, and with common-sense ideas for the public sector, including schools, universities, stakeholders, and the general public.

- Strategy: Listen to stakeholder ideas, exchange information, and make information relevant.

- Strategy: Strengthen commitment of state and federal agencies to outreach programs.



PETER SHERIDAN

Seagrass restoration projects are a good method for involving the concerned public in seagrass conservation.

CHAPTER 4.
ENVIRONMENTAL AWARENESS THROUGH EDUCATION AND PUBLIC OUTREACH

Jim Lester
University of Houston - Clear Lake

BACKGROUND

Seagrasses are an important natural resource for the citizens of Texas, but few Texans realize the many benefits from these resources or their impacts on this resource. Education can be the best and most lasting way in which to protect seagrasses because, if done properly, education will lead to behavioral changes that will reduce impacts on this important ecosystem.

Now is the time to educate the public on seagrass habitats and the need for conservation because inaction could result in continuing damage and destruction. Earlier in this century, there were abundant seagrasses in the Galveston Bay complex. Today there is only a relict population of shoalgrass *(Halodule)* in Christmas Bay. Less than 2% of the seagrass acreage observed in 1994 was found along the upper half of the coast. Almost 80% of the seagrass areas are found in the Laguna Madre. Another 19% of the estuarine acreage determined to hold submerged aquatic vegetation was in the Coastal Bend area. The area exhibiting the greatest documented loss of seagrass habitat is the area with the highest coastal population density.

"In the end, we will conserve only what we understand and we will understand only what we are taught."

Baba Dioum

The distributions of seagrasses are consistent with their requirements for warm temperature, moderate to high salinity water and high light penetration. Declines in seagrass abundances are associated with changes in salinity and turbidity. A variety of anthropogenic disturbances can result in increased turbidity which reduces light penetration below tolerable levels for seagrass. These disturbances are the effects of recreational boating, commercial fishing, marine transportation, tourism, and agriculture. Prop scars from motors on recreational boats cause damage to seagrasses. Sediment resuspension occurs from boat traffic and during dredging operations and shrimp trawling. Nutrient loadings arising from agricultural runoff and sewage effluent lead to eutrophication. Phytoplankton blooms and suspended solids reduce light penetration to the seagrasses. Light limitation and direct mechanical damages are the most important causes of seagrass losses today on the Texas coast.

Coastal development, declining water quality, improper use and natural events have all taken their toll on Texas' seagrasses. Education on the value and conservation of seagrasses should begin at the earliest opportunity to encourage responsible actions to compensate for damage and loss of seagrass habitat. If the potential beneficiaries of preserving and restoring seagrass resources will practice responsible behavior and encourage others to refrain from damaging the resource, we can avoid future reductions in this habitat.

SEAGRASS CONSERVATION PLAN: PROCESS AND VISION

This chapter is based on the contributions of representatives of conservation organizations, government agencies, commercial interests and universities who met as an Education Work Group at the Seagrass Conservation Symposium in 1996.

The Vision Statement drafted was:

We envision a Texas where awareness, knowledge, concern, and skills will result in responsible behavior that conserves the seagrasses of our state.

We determined that the objectives and proposed actions related to public education and outreach could be categorized with one simple goal and two objectives.

Goal: To utilize education and outreach to promote stewardship of Texas seagrass habitat.

Objective 1: To educate the public on the status, values, ecology and conservation of seagrasses in Texas. This goal will be achieved by developing and delivering messages through several media for various audiences.

Objective 2: To convince the public to take action to conserve and restore Texas seagrasses. This goal will be obtained through the provision of materials and opportunities which will teach or enhance skills required for seagrass conservation efforts.

THE CONSERVATION EDUCATION PROCESS

Public education to obtain conservation of the seagrass resource is no different from education aimed at getting the public to participate in conservation of other ecosystems. The objective of such educational programs is responsible behavior to avoid harming natural resources. The steps required to reach environmentally responsible behavior are 1) develop awareness, 2) foster understanding, 3) create concern, 4) teach skills, and 5) encourage responsible behavior.

Before the public will adopt different attitudes about the seagrass resource, it must be cognizant of the natural system, i.e., seagrass ecosystems and the processes upon which they depend. This stage of the outreach program focuses on awareness.

After awareness of the resource is achieved, the educational process shifts to producing knowledge of the natural system and its dependence upon certain environmental quality parameters, such as low turbidity levels in the water. The dissemination of knowledge and fostering of values is usually the principal focus of environmental education programs. Awareness, knowledge and concern can be concurrent goals incorporated into the design of educational materials and programs.

Education about conservation issues is based on the delicate balance involved in obtaining sustainable use of the natural resources. Concern for seagrass ecosystems should grow out of the recognition that seafood resources are dependent upon this type of habitat. Also, concern can be generated from the concept that sensitive ecosystems, such as seagrass meadows, are a metaphor for the miner's canary. When the canary dies, it is a strong indication of trouble for nearby humans.

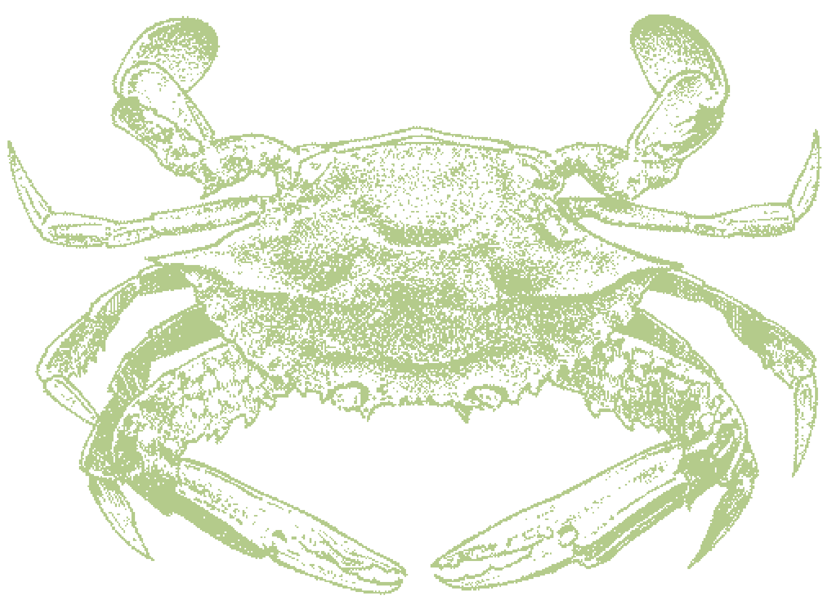
Providing citizens with the skills needed to protect seagrass resources will depend on direct public outreach. Projects must be developed which enlist the public in support of the mission of organizations, such as TPW, which are engaged in the management of the seagrass areas. The public will obtain the necessary skills by participating in actual conservation projects or from training in hands-on methods for seagrass restoration.

CHALLENGES OF CONSERVATION EDUCATION

Teaching about conservation can conflict with deeply held philosophies of traditional western civilization. The pioneers' concept of taming a wild land still exists in Texas. Humans were convinced that they had a mission of domination and exploitation of the Earth. Land has come to be viewed, not as a human homesite, but as a commodity valued only by its price in the marketplace. (Daly and Cobb 1994). Land under seawater in Texas has no sale price and can't be sold in the marketplace; therefore, it is seemingly without value to most citizens. The proposed seagrass education program must convey to Texas citizens an awareness of the value of unexploited seagrass meadows in which fishery resources are nurtured.

Current economic analysis only values a resource after it has been exploited. If we exploit seagrass meadows to extract the fishery resources, such meadows are likely to be damaged to a degree that reduces their productivity and the fisheries yield will decline. There are conditions under which a resource can be rationally exploited to extinction. The world that economic theory normally pictures is one in which individuals all seek their own good and are indifferent to the success or failure of other individuals engaged in the same activity. In such a world, there is no way to conceive of a collective good like preserving seagrass ecosystems for their contribution to biodiversity (Daly and Cobb 1994).

How do we make a decision about when or if to degrade or sacrifice a renewable natural resource? If the resource is in the public domain, like seagrass meadows, that decision is made in the public policy arena. Citizens participate in this policy arena when they vote or express their opinions to government officials. A successful public outreach program will give citizens the knowledge and values necessary to make informed decisions on policy issues related to seagrass conservation, e.g., whether public financing should be used for water treatment capability that will benefit seagrass.



WARREN PULICH

Outreach activities can make use of seagrass habitat as an "outdoor classroom."

Development of a Seagrass Conservation Plan for Texas is one small component of the conservation of biodiversity. The roles of education and outreach in successful conservation of biodiversity have been described in *Global Biodiversity Strategy* (1992). There are three action items specified that deal with education and outreach. First, the education process must build awareness of the importance and values of biodiversity into popular culture. Second, they recommend use of the formal education system to increase awareness about biodiversity and the need for its conservation. Lastly, this strategy suggests that outreach integrate biodiversity concerns into education outside of the classroom.

CONSIDERATION OF MESSAGE, MESSENGER AND RESPONSE

Before developing an education and outreach plan for seagrass conservation the planners need to consider a) the context in which the message will be received, b) the relationship between the messenger and the listener, c) the appropriateness of the content and language of the message, and d) the nature of the desired response.

The context in which the message about conservation of seagrass will be delivered can affect the receptiveness of the listener to the message. If the context will be watching TV with family, then the message might best focus on the welfare of the next generation. If the context is buying a new boat, then the message could dwell on the impact of seagrass loss on personal well-being, such as less seafood and higher prices. If the message is received while taking a fishing trip, then the message might include the potential for regulatory changes, e.g., fishing limits and area restrictions, if seagrass loss becomes severe.

Who will the messengers be? The desired relationship between the receiver and the messenger is one of the student to the teacher. Members of a group with which the listener identifies are best. Representatives of government agencies are problematic because much of the public currently has negative views on the role of regulatory agencies. Messengers must be viewed as neutral with no negative bias toward the targeted group. Messengers should be considered to have integrity with nothing to gain personally, to be trustworthy and to possess credibility. The recipient of the message should consider the content to be valuable and useful. Ministers and teachers fit this characterization. Members of the media may not fit the characterization, but can be useful messengers.

Many of the groups that should receive messages about seagrass conservation and restoration have been identified. They are the coastal residents, recreational fishermen, commercial fishermen, marine transportation companies and tugboat operators, dredge operators, recreational boaters and jetskiers, and operators and clients of point source wastewater effluents. Basically, all of the coastal population, whether resident or transient, should be targeted for some kind of message. All stakeholders should be involved in framing the message and choosing the messengers

The message must be easily comprehensible and carefully directed toward the desired behavior change. The message should suggest that personal actions can make things better and the citizen or her family will reap some reward.

Messages must deal with the various types of impacts that damage seagrass ecosystems. Both direct and indirect impacts must be considered in framing the message. There must be messages to all coastal residents about the importance of water quality. Citizens should understand the impacts of suspended solids, nutrients and other pollutants that occur in their waste water. Some groups are associated with direct damages and should be targeted for special attention. This includes damage caused directly by resource user groups, such as prop scars from fishing boats, sedimentation from trawling and dredging, and root damage from wade fishing.

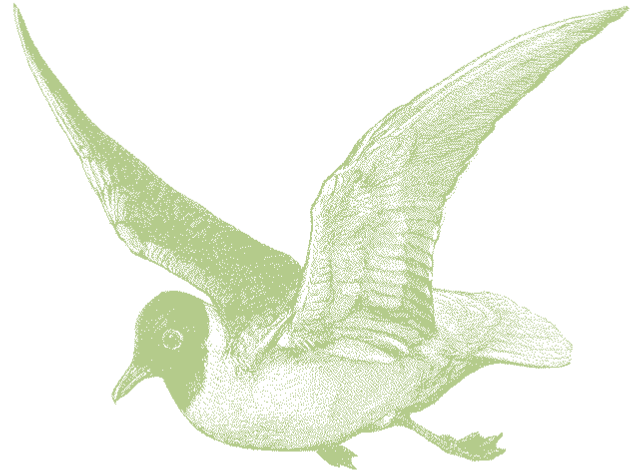
Our culture and economy have trained most citizens to operate in an egocentric fashion. The message must be framed for the average citizen. Ecologists and wildlife specialists are biocentric when they recommend saving seagrasses because they contribute to biodiversity and productivity. Economists and public policy experts are anthropocentric when they recommend protecting seagrasses because they contribute to fishing yields which enhance the economy. We also need messages that are egocentric and recommend protecting seagrasses because the average citizen will catch more seafood or will enjoy a better environment as a result of more responsible behavior.

TPW PHOTO

Seagrass education programs aim to link the fishery resources to the seagrass habitat.

Exactly what responses are desired? It is hoped that an educational and outreach program focused on seagrass conservation will lead citizens to avoid damaging seagrasses particularly and the estuaries in general. We can also hope that a corollary will be action by groups of citizens to reclaim seagrass ecosystems.

In addition to changes in the skills and behavior of individuals, the behavior of organizations needs to change. Government agencies need to modify environmental regulations so that seagrass conservation will be encouraged indirectly. The agencies need to create demonstration conservation efforts in government owned areas. When economic policies are developed, their impact on conservation must be considered. For example, boat licensing policies and fees could be created which would favor boats designed to be less destructive of submerged aquatic vegetation. Non-governmental organizations should engage in demonstration projects that agencies cannot. They should support publicity campaigns, advocacy positions, and citizen actions that favor seagrass conservation.



ACTIONS AND SKILLS FOR SEAGRASS CONSERVATION

What skills are required to obtain the desired responses? Coastal residents need to be trained in household management techniques that will generate the least non-point source pollution. Boat and dredge operators in seagrass areas need to know how best to avoid damaging seagrass. Citizens, especially children, need to know how to restore seagrass meadows. Corporations should be trained in accounting methods which internalize the cost of mitigating seagrass loss. Water treatment facilities need education on effluent parameters that will protect submerged aquatic vegetation. Some educational programs need to emphasize the coastal communities which depend most closely on these resources. These communities can be involved in projects that train boaters, fishermen and other resource users about where to seek information, how to communicate this information to neighbors, and how best to practice the new values which arise from their new knowledge.

Changes in knowledge, values and attitudes may be useful, but these changes must be measured by how they affect behavior.

Changes in knowledge, values and attitudes may be useful, but these changes must be measured by how they affect behavior. What makes people change their values and behavior? It is too simple to argue that education and training change behavior. Neither does creation of public policy automatically lead to change in citizen behavior. There is no scientific model that can be used to predict how many people will change their behavior as a result of an educational program. But people tend to change their behavior when they recognize the benefits that will accrue from the change. The challenge for this conservation plan is to craft messages that cause every citizen in the coastal population to acquire a stake in the conservation of seagrasses.

The development of an education and outreach program for seagrass conservation can be guided by the success stories in the environmental arena. The behavior of the public has changed dramatically with regard to highway litter. Anti-littering campaigns have been very successful at educating, altering values and changing behavior. Recycling campaigns have also produced changes in citizen behavior and public policy. Some of the change in behavior occurred even before there were markets and economic incentives for recycling. Wetlands preservation, mitigation and restoration have become accepted components of public policy and citizen opinion appears to concur. The priority obtained by wetlands in the valuation of natural ecosystems has little scientific foundation, but is accepted because the public has obtained some awareness, knowledge and concern about these ecosystems. Many other high priority ecosystems, such as seagrass meadows, have yet to obtain this stature with the public.

SEAGRASS EDUCATION PLAN

VISION: *We envision a Texas where awareness, knowledge, concern, and skills will result in responsible behavior that conserves the seagrasses of our state.*

PRIORITY GOAL: To utilize education and outreach to promote stewardship of Texas seagrass habitat.

Objective 1: To educate the public on the status, values, ecology and conservation of seagrasses in Texas

- **Strategy 1.** Develop and deliver messages for targeted audiences
  Suggested Actions:

  1. Printed material will be created to supplement current educational programs or delivery systems, e.g., the Ethical Angler program.
  2. Handouts could be produced for Chambers of Commerce in coastal municipalities.
  3. Provide a supplement the AquaSmart education program.
  4. Provide materials for informal education groups, e.g., Girl Scouts, Boy Scouts, 4-H.

- **Strategy 2.** Develop and deliver messages for the general public through various media
  Suggested Actions:

  1. Provide press releases and public information messages on current research and restoration projects.
  2. Generate and distribute press releases, radio public service announcements.
  3. Hold media events associated with seagrass conservation activities.
  4. Create a seagrass conservation website.
  5. Distribute informational inserts to be included with voter registration, utility bills, etc.
  6. Add seagrass conservation messages to Conservation Passports.
  7. Make an educational video to inform organizations

- **Strategy 3.** Develop and deliver messages for formal education
  Suggested Actions:

  1. Make supplemental materials for K-12 curricula such as Project WILD, Project WET, Project Aquatic WILD.
  2. Obtain coverage of seagrass conservation activities on the school channel (Channel One).
  3. Train seagrass conservation experts to deliver a grade appropriate lessons

Objective 2: To convince the public to take action to conserve and restore Texas seagrasses

- **Strategy 1.** Develop skills through demonstration programs and workshops
  Suggested Actions:

  1. Provide shallow water boating demonstrations
  2. Deliver boater education seminars on seagrass protection skills at boat shows and fishing shows
  3. Provide detailed information on seagrass protection methods in Corps of Engineers permit applications
  4. Provide a workshop on seagrass conservation for Corps personnel who review and process applications
  5. TPW/TGLO/Sea Grant/NMFS seagrass restoration extension program.

- **Strategy 2.** Provide supplemental material and aids which support responsible behavior
  Suggested Actions:

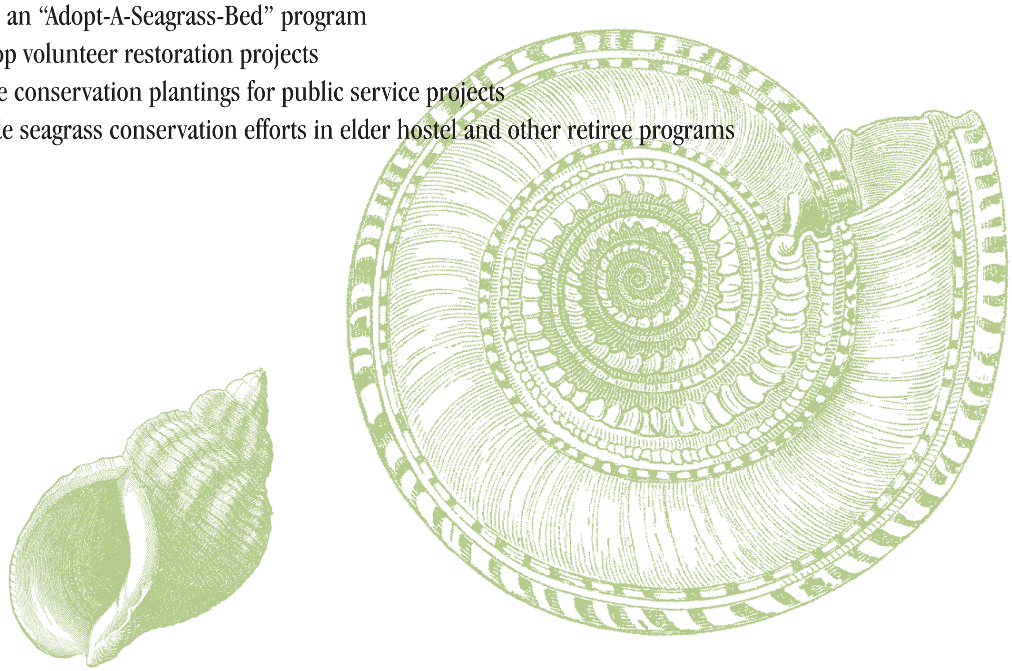
  1. Put up signs about seagrass protection at boat ramps
  2. Mark seagrass areas with buoys or signage
  3. Get mapmakers to designate seagrass habitats on fishing maps as areas to avoid
  4. Designate "no wake" zones in seagrass areas
  5. Provide "before and after" aerial photographs of damaged seagrasses to boating organizations or dealers

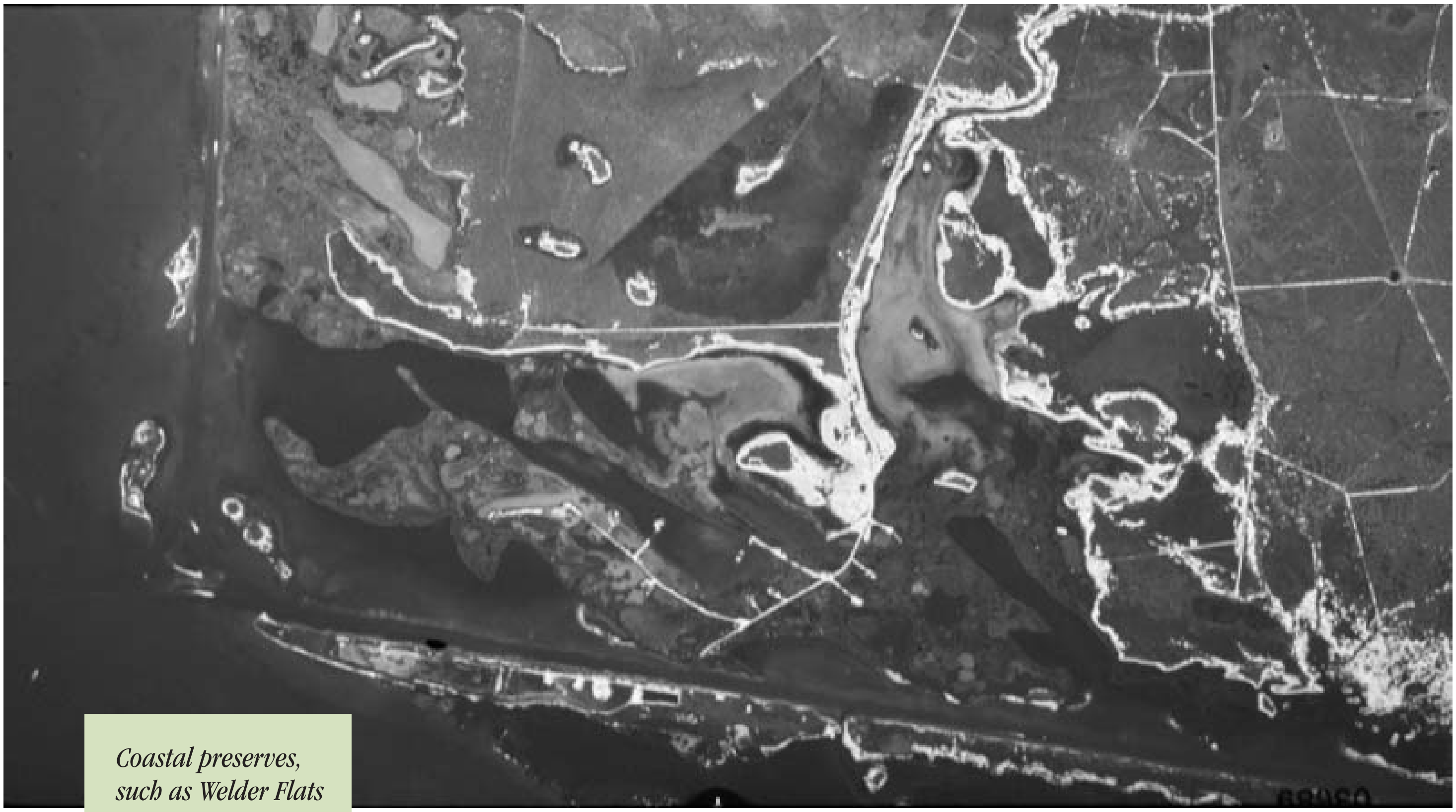
- **Strategy 3.** Provide opportunities for conserving and restoring seagrasses
  Suggested Actions:

  1. Establish seagrass conservation demonstration projects
  2. Create an "Adopt-A-Seagrass-Bed" program
  3. Develop volunteer restoration projects
  4. Initiate conservation plantings for public service projects
  5. Include seagrass conservation efforts in elder hostel and other retiree programs

"Nature in the 21st century will be a nature that we make"

Daniel Botkin





Coastal preserves, such as Welder Flats (shown here) in San Antonio Bay, are very effective at protecting submerged seagrass habitat in public waters

CHAPTER 5.
IMPLEMENTATION OF SEAGRASS PLAN OBJECTIVES

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The ideas developed and presented in the preceding chapters represent the consensus for a long-range seagrass conservation planning program in Texas. The sponsors envision this program in the context of a 5-10 year horizon. However, it is practical to approach implementation as a phased process. This requires the setting of priorities and establishing a schedule for completion. Some objectives and strategies can be considered more critical or urgent, since they must be accomplished as prerequisite to others.

After completion of the earlier chapters, the Seagrass Conservation Plan Steering Committee met and discussed the issue of implementing these actions. A decision was made to prioritize strategies into 1) those which should receive immediate action as short-term targets and 2) those considered longer-term targets, whose implementation could logically come later. Key Strategies serve as the foundation for the long-term programs. In this section, we present those selected Key

Strategies based on requirements of criticality and necessity for immediate action. All short-term strategies are considered of equal importance, and no difference in priority is ascribed to the order.

Short-Term, Key Strategies

Research Needs:

1. Develop a strategic long-term monitoring plan for sediment/water quality indicators and biological parameters, focusing on seagrass mapping and species distribution.

2. Conduct process-oriented research on seagrass autecology, including physiology, production ecology, reproduction, indicator development, landscape ecology, and demography.

3. Review and compile existing information on seagrasses in Texas and establish a data clearing-house.

4. Conduct applied studies that provide science-based answers to specific management questions (e.g., aquaculture discharge impacts, boating impacts, restoration rates of damaged areas, etc.)

Management Needs:

1. Protect water and sediment quality in seagrass beds:
   – Designate seagrasses as a high/exceptional ALU (Aquatic Life Use) under Texas Surface Water Quality Standards.
   – Determine coastal water quality criteria for seagrass in Surface Water Quality Standards.
   – Incorporate seagrass water quality criteria into new wastewater discharge permits where possible.

2. Protect seagrass beds through effective application of the permitting process:
   – Develop and implement a consistent interagency coordination procedure for projects impacting seagrasses.
   – Develop consistent, effective mitigation rules applicable to seagrass, based on a mitigation sequence of avoidance, minimization and compensation.
   – Recommend Best Management Practices to protect seagrasses from dredging impacts.

3. Support research, monitoring and data synthesis programs which provide sound technical basis for seagrass policies and regulations:
   – Establish a data clearinghouse and library.
   – Monitor seagrass status and current trends.
   – Develop desktop models for allocating wasteloads from permitted discharges to meet seagrass water quality criteria.

Education Needs:

1. Develop and deliver messages for the general public through various media.
   Includes: Producing and distributing press releases and public service announcements on research and restoration projects; holding media events on seagrass conservation activities; creating a seagrass conservation web site; distributing information, inserts with voter registration, utility bills, etc.; producing educational videos.

2. Develop skills through demonstration programs and workshops.
   Includes: Providing shallow water boat demonstrations; boater education seminars on seagrass protection; including seagrass protection information in Corps of Engineers permit applications; conducting workshops on seagrass conservation and restoration.

Long-Term Strategies

Proactive, as opposed to reactive, solutions would have the best chance of success.

While the remaining strategies and actions can be considered long-term, they are integral to carrying this Plan through to fruition. This would necessitate laying the foundation for their implementation as appropriate or as resources become available. Some of these later targets will be direct outgrowths of the accomplishment of key immediate strategies from above. Thus a schedule for their completion within the 5-10 year horizon should be developed.

Starting the Implementation Process

The strategy for implementation assumes that entities, groups or individuals will accept responsibility for undertaking seagrass strategies and actions, where appropriate. At this time, the SCPT sponsors do not expect to identify all possible stakeholders. However, existing avenues of management or public outreach would offer the best opportunity to begin implementing these actions. Proactive, as opposed to reactive, solutions would have the best chance of success. Moreover, by allowing the priority actions proposed in this plan to guide decisions, this should eventually achieve seagrass conservation goals in the most effective manner.

The implementation process should take advantage of various initiatives and projects at local levels which already target some key seagrass strategies identified above. With the SCPT now providing statewide focus on seagrass issues, a larger framework of resource management and sources of financial resources should be available to accomplish these strategies. In particular, careful integration of complementary programs will leverage the potential financial support for scientific research or public outreach on seagrasses. The following mechanisms are considered to serve as existing vehicles for initiating Seagrass Plan implementation.

- **State Wetlands Conservation Programs**

  The Seagrass Conservation Plan also represents another component of the comprehensive Texas Wetlands Conservation Plan (TPW, 1997) which was developed and approved by the TPW Commission, and has received final endorsement of the Governor. Over thirty public and private entities in Texas worked together in regional and statewide advisory groups to develop the information and recommendations found in this previous Plan. The infrastructure and policies developed by the Plan to guide statewide wetlands conservation apply to seagrasses as well. Seagrasses were identified by the Coastal Regional Advisory Group as a priority wetland type, and several recommendations in the Plan relate to seagrasses, including implementation of restoration projects on state-owned lands, providing additional protection for the Lower Laguna Madre, and identifying and restoring degraded seagrass beds. The SCPT formalizes the special issues related to seagrass conservation under this existing umbrella.

Seagrass protection in the coastal zone falls under the purview of authorized resource agencies whose policies and regulations are coordinated under the Coastal Zone Management (CMP) process. State-owned, submerged lands containing seagrasses will also be targeted in a State-owned Wetlands Conservation Plan (SOWCP) currently being developed by TGLO/TPW. Seagrass issues identified in the SOWCP should receive special CMP attention through a management process involving the Coastal Coordination Council. With this Seagrass Conservation Plan serving as a foundation for the SOWCP, the priority of seagrass issues is therefore established for further CMP action.

- **National Estuary Program Action Plans**

The SCPT is also integrated with Galveston Bay and Coastal Bend Bays and Estuaries Program actions relating to seagrass. The Bay Plans of these two former NEPs will be closely followed since these two Texas Estuary Programs are participating sponsors of the SCPT.

An example is the seagrass habitat restoration that is currently a cornerstone of the GBEP Plan. This program is actively pursuing the objective to re-establish 1400 acres of seagrass in Galveston Bay. This requires directed research and demonstration projects to develop and test techniques for restoration. This work in turn requires proper planning and funding. Some policy development and management procedures must also be addressed. The SCPT provides direction and a forum of experts to deal with these issues.

The Coastal Bend Bays and Estuaries Program's Comprehensive Conservation and Management Plan (CCMP), the Coastal Bend Bays Plan, closely mirrors the objectives of the Seagrass Conservation Plan. The Bays Plan is designed to complement and coordinate existing resource management programs and plans. Monitoring and research will be addressed in the Regional Monitoring Strategy section of the Bays Plan (this section has not yet been fully developed but is currently in progress). The need for a data clearing-house as described in the SCPT was also identified as a need by the CBBEP Management Conference and is addressed in the public education and outreach section of the Bays Plan. Other priority issues in congruence between the SCPT and the Bays Plan include enhancement of water and sediment quality, preservation of habitat and living resources including seagrass meadows and associated fauna, minimizing ecological impacts from dredging activities, and implementation of public education and outreach strategies. In addition, the Human Uses section specifically addresses the need to minimize impacts to bay resources from recreational activities including seagrass bed prop scarring resulting from recreational boating activities.

- **Using the Plan to Support and Justify Research Proposals**
  Funding for needed priority research projects should be sought by coastal scientists immediately from any appropriate source. While research funds will continue to be scarce, the SCPT plan will provide strong evidence to state and federal, as well as non-governmental, funding agencies to justify support of seagrass projects identified as high priority.

- **Using Outreach and Education Methods to Inform the Public**
  The *Boating and Seagrasses* brochure developed by Texas Parks and Wildlife in association with the Boating Trades Association of Texas is a good example of public outreach focused on seagrasses. Such methods are very effective in bringing the positive message of seagrass stewardship to target user groups of the coastal zone. Any outreach method which helps to inform the public and coastal user community, while at the same time forming alliances between the public and resource managers, will have a better chance at achieving conservation goals compared to direct regulatory actions. The use of electronic media (e.g., Internet web sites focusing on nature) offers another very popular mode for communicating to the public about seagrass conservation problems.

Commitments of Agencies

Some state agencies that currently have existing mandates for coastal resource protection are listed below. Increased attention to seagrasses and their habitat is expected as an outgrowth of the Seagrass Planning process.

1. **Texas Parks and Wildlife (TPW)** intends to continue its coastwide efforts *to inventory seagrass beds and species distribution* on a regular basis. Such status and trends monitoring data are essential criteria that establish the success and effectiveness of management or public education actions. These distribution data will be maintained in a *central seagrass library and database developed by TPW and other resource agencies*. Efforts to *improve and standardize the permit review process* should begin as soon as possible in coordination with TGLO, TNRCC, USFWS, NMFS, and COE. Procedures dealing with *restoration and transplanting projects are being reevaluated and guidelines will be redesigned* to better protect the donor seagrass beds. *Public education activities focused on protecting seagrass* from human disturbances (such

as motorboat prop damage, nutrient-rich discharges) are being targeted for the Department's Conservation Education programs in partnership with local groups such as the National Estuary Programs. In cooperation with TGLO, the *Department supports the establishment of additional coastal preserve areas* to protect sensitive coastal seagrass systems.

2. The **Texas General Land Office (TGLO)** has jurisdiction for state-owned submerged lands (the area from mean high tide along the Gulf beach or bay-estuary shoreline to 10.36 miles offshore in the Gulf). The TGLO issues leases and easements for various projects to applicants on these state-owned submerged lands, and these activities can potentially impact seagrasses. The TGLO is committed to the previous seagrass conservation objectives and will work with TPW to achieve the goals stated herein. TGLO proposes that two critical actions be given highest priority in the near future to ensure protection of seagrass resources on coastal public lands. 1) *Formal action should be taken to establish other Coastal Preserve areas, possibly in the Coastal Bend area of Texas, to protect Texas seagrass ecosystems* from development impacts. This goal also complements planning needs identified by the CCBNEP for that region. 2) *Coordination procedures in the permit review process should be strengthened and integrated.* This requires the development of consistent and perhaps more standardized guidelines between permitting and permit-review agencies for seagrass projects requiring compensatory mitigation or restoration.

3. The **Texas Natural Resource Conservation Commission (TNRCC)** has responsibility for water quality protection of seagrass habitat, except where regulatory authority for certain activities has been assigned to other agencies. [The Texas Railroad Commission implements environmental protection for the development of oil and gas resources, and the Texas Soil and Water Conservation Board regulates non-point source impacts from agriculture and silviculture activities.] TNRCC regulatory actions that potentially address water quality in seagrass areas include (1) permitting of domestic and industrial wastewater discharges, (2) 401 certification of federal dredge and fill permits, (3) consistency reviews of permitted actions in accordance with the Texas Coastal Management Plan, (4) management of nonpoint source programs under Section 319 of the federal Clean Water Act and under the pollution abatement program in Section 26.177 of the Texas Water Code, and (5) development and implementation of the Texas Surface Water Quality Standards.

   To implement this Seagrass Plan, TNRCC will consider the addition of seagrasses as a beneficial aquatic-life use in the Texas Surface Water Quality Standards. Establishing a specific seagrass category for aquatic life would facilitate the use of seagrasses as an indicator of estuarine and coastal biological health. TNRCC will develop more defined procedures for conducting 401 certifications of federal permits which could affect seagrasses and other coastal habitats. TNRCC will coordinate with TPW and other resource agencies in order to promote consistency and effectiveness of regulatory and watershed management programs which protect coastal water quality and seagrass habitat.

REFERENCES

Burkholder, J. M., H. B. Glasgow, Jr., J. E. Cooke. 1994. Comparative effects of water-column nitrate enrichment on eelgrass *Zostera marina*, shoalgrass *Halodule wrightii*, and widgeongrass *Ruppia maritima*. *Marine Ecology Progress Series* 105:121-138.

Burkholder, J. M., H. B. Glasgow, Jr., and C. W. Hobbs. 1995. Fish kills linked to a toxic ambush-predator dinoflagellate: distribution and environmental conditions. *Marine Ecology Progress Series* 124:43-61.

Cambridge, M. L. and A. J. McComb. 1984. The loss of seagrass in Cockburn Sound, Western Australia. 1. The time course and magnitude of decline in relation to industrial development. *Aquatic Botany* 21: 229-243.

Carlson, P. R., Jr., L. A. Yarbro, T. R. Barber. 1995. Relationship of sediment sulfide to mortality of *Thalassia testudinom* in Florida Bay. *Bulletin of Marine Science* 40:160-172.

Chambers, J. R. 1992. Coastal degradation and fish population losses. p. 45-52 *In*: Stroud, R.H. (ed.), Stemming the tide of coastal fish habitat loss. *Mar. Rec. Fish. Pub*. No. 14. 258 p.

Chesapeake Bay Program. 1995. Guidance for protecting submerged aquatic vegetation in Chesapeake Bay from physical disruption. EPA 903-R-95-013. 15 pp.

Cobb, R. A. 1987. Mitigation evaluation study for the South Texas coast, 1975-1986. Project Report to U.S. Fish and Wildlife Service. Center for Coastal Studies, Corpus Christi State Univ., Corpus Christi, TX. 88 p.

Conner, W. H., J. W. Day, Jr., R. H. Baumann, and J. M. Randall. 1989. Influence of hurricanes on coastal ecosystems along the northern Gulf of Mexico. *Wetlands Ecology and Management* 1:45-56.

Daly, H. E. and J. B. Cobb, Jr. 1994. For the Common Good. 2nd Ed. Beacon Press. Boston 534 p.

Dennison, W. C., R. J. Orth, K. A. More, J. C. Stevenson, V. Carter, S. Kollar, P. W. Bergstrom, and R. A. Batiuk. 1993. Assessing water quality with submersed aquatic vegetation. Habitat requirements as barometers of Chesapeake Bay health. *BioScience* 43(2):86-94.

Dunton, K. 1990. Production ecology of *Ruppia maritima* L. s.l. and *Halodule wrightii* Aschers. in two subtropical estuaries. *Journal Experimental Marine Biology and Ecology* 143:147-164.

Dunton, K. 1994. Seasonal growth and biomass of the subtropical seagrass *Halodule wrightii* Aschers. In relation to continuous measurements of underwater irradiance. *Marine Biology* 120:479-489.

Dunton, K. 1996. Photosynthetic production and biomass of the subtropical seagrass *Halodule wrightii* along an estuarine gradient. *Estuaries* 19:436-447.

Dunton, K. 1998. *In:* Montagna, P. A., et al., Characterization of anthropogenic and natural disturbance on vegetated and unvegetated bay bottom habitats in the Corpus Christi Bay National Estuary Program Study Area. Report CCBNEP-27. Corpus Christi Bay National Estuary Program, TAMU-CC, Corpus Christi, TX. 100 pp.

Eleuterius, L. N. 1987. Seagrass ecology along the coasts of Alabama, Louisiana, and Mississippi. pages 11-24, *In* M. J. Durako, R. C. Phillips, and R. R. Lewis (eds.), Proceedings of the Symposium on Subtropical-Tropical Seagrasses of the Southeastern United States. Florida Marine Research Publication No. 42, Florida Department of Natural Resources, St. Petersburg, FL.

Fesenmaier, D. R., S. Um, W. S. Roehl, A. S. Mills, T. Ozuna, Jr., L. L. Jones and R. Guajarado. 1987. Regional and statewide economic impacts of sportsfishing, other recreational activities and commercial fishing associated with bays and estuaries of the Texas Gulf Coast. TAES, Texas A&M Univ., College Station, Texas, 55 pp.

Glasgow, Jr., H. B., J. M. Burkholder, D. E. Schmechel, P. A. Tester, and P. A. Rublee. 1995. Insidious effects of a toxic estuarine dinoflagellate on fish survival and human health. *Journal of Toxicology and Environmental Health* 46:501-522.

Hershman, M. J. And K. A. Lind. 1994. Evaluation and developing seagrass policy in the Pacific Northwest. *In*: Wyllie-Echeverria et al.(eds). Proceedings of a seminar series on Seagrass Science and policy in the Pacific northwest. EPA Rept. 910/R-94-004 pp. 48-53.

Hinga, K. R., D. W. Stanley, C. J. Kleig, D. T. Lucid, and M. J. Katz. (eds.). 1991. The national estuarine eutrophication project: Workshop proceedings. National Oceanic and Atmospheric Administration and the University of Rhode Island Graduate School of Oceanography Publication. Rockville, Maryland.

Hoese, H. D., 1960. Biotic changes in a bay associated with the end of a drought. *Limnology and Oceanography* 5:(3):326-336.

Kemp, W. M., W. R. Boynton, R. R. Twilley, J. C. Stevenson, and L. G. Ward. 1984. Influences of submersed vascular plants on ecological processes in upper Chesapeake Bay, pages 367-394. *In* Kennedy, V. S. (ed.), The estuary as a filter. Academic Press, New York.

Kenworthy, W. J. and D. E. Haunert (eds.) 1991. The light requirements of seagrasses: Proceedings of a workshop to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses. NOAA Technical Memorandum NMFS-SEFC-287. 181 pp.

Kenworthy, W. J., G. W. Thayer, and M. S. Fonseca. 1988. The utilization of seagrass meadows by fishery organisms. p. 548-560. *In*: Hook, D. D., *et al*., (eds)., The ecology and management of wetlands, Vol. 1. Ecology of wetlands. Timera Press, Portland, OR.

Lee, V. and S. Olsen. 1985. Eutrophication and management initiatives for the control of nutrient inputs to Rhode Island coastal lagoons. *Estuaries* 8:191-202.

Lipton, D. W., K. F. Wellman, I. C. Shiefer and R. F. Weiher. 1995. Economic valuation of natural resources -- A Handbook for Coastal Resource Policymakers. NOAA Coastal Ocean Program Decision Analysis Series No. 5. NOAA Coastal Ocean Office, Silver Spring, MD. 131 pp.

McMahan, C. A. 1968. Biomass and salinity tolerance of shoalgrass and manateegrass in Lower Laguna Madre, Texas. *Journal of Wildlife Management* 32:501-506.

McRoy, C. P., and C. McMillan. 1977. Production ecology and physiology of seagrasses, p. 53-81. *In* McRoy, C.P. and C. Helfferich (eds.), Seagrass Ecosystems: A Scientific Perspective, Marcel Dekker Publ., New York,

Merkord, G. W. 1978. The distribution and abundance of seagrasses in Laguna Madre of Texas. M.S. Thesis, Texas A&I University, Kingsville, Texas. 56 pp.

Montagna, P. A., J. Li and G. T. Street. 1996. A conceptual ecosystem model of the Corpus Christi Bay National Estuary Program study area. Corpus Christi Bay National Estuary Program Report 8, January 1996.

National Oceanic and Atmospheric Administration (NOAA). 1990. Fisheries of the United States, 1989. Current fisheries statistics no. 8900. National Marine Fisheries Service. Silver Spring, MD: U.S. Government Printing Office. 111 pp.

Nessmith, C. 1980. Natural and induced revegetation processes in an artificially disturbed seagrass meadow in Texas: The University of Texas at Austin, Unpublished M.S. Thesis, 318 pp.

Nixon, S. W. 1995. Coastal marine eutrophication: a definition, social causes, and future concerns. *Ophelia* 41:199-219.

NOAA-ORCA (National Oceanic and Atmospheric Administration, Office of Ocean Resources Conservation Assessment). 1996. National Estuarine Eutrophication Survey. Draft Report, NOAA, Strategic Environmental Assessments Division, Silver Spring, Md. 48 pp.

Odum, H. T. 1963. Productivity measurements in Texas turtle grass and the effects of dredging an intracoastal channel. *Publications of the Institute of Marine Science* 9:48-58.

Onuf, C. P. 1994. Seagrasses, dredging and light in Laguna Madre, Texas, U.S.A. *Estuarine, Coastal and Shelf Science* 39:75-91.

Onuf, C. P. 1996. Seagrass responses to long-term light reduction by brown tide in upper Laguna Madre, Texas: distribution and biomass patterns. *Marine Ecology Progress Series* 138:219-231.

Orth, R. J. and K. A. Moore. 1984. Distribution and abundance of submerged aquatic vegetation in Chesapeake Bay: an historical perspective. *Estuaries* 7:531-540.

Orth, R. J. 1971. The effect of turtle grass, *Thalassia testudinum*, on the benthic infauna community structure in Bermuda. Bermuda Biological Station Special Report No. 9:18-37.

Orth, R. J. 1977. The importance of sediment stability in seagrass communities, p. 281-300. *In:* B. C. Coull (ed.), Ecology of Marine Benthos. Univ. of South Carolina Press, Columbia.

Orth, R. J., K. L. Heck, Jr., and J. van Montfrans. 1984. Faunal communities in seagrass beds: A review of the influence of plant structure and prey characteristics on predator-prey relationships. *Estuaries* 7(4A):339-350.

Phillips, R. C. 1960. Observations on the ecology and distribution of the Florida seagrasses. Prof. Papers Series No. 2, Florida State Board Conserv., Tampa, FL. 65 pp.

Phillips, R. C. 1980. Responses of transplanted and indigenous *Thalassia testudinum* Banks ex Konig and *Halodule wrightii* Aschers. to cold stress and sediment loading. *Contributions in Marine Science* 23:79-87.

Phillips, R. C. 1984. The ecology of eelgrass meadows in the Pacific northwest: a community profile. U.S. Fish Wildl. Serv. USFWS/OBS-84/24. 85 p.

Poore, G. C. B. 1982. Benthic communities of the Gippsland Lakes, Victoria. *Aust. J. Mar. Freshw. Res.* 33:901-915.

Pulich, W., Jr. 1980. The ecology of a hypersaline lagoon: The Laguna Madre. pages 103-122, *In* P. L. Fore and R. D. Peterson (eds.), Proceedings of the Gulf of Mexico Coastal Ecosystems Workshop. USFWS, Albuquerque, New Mexico. Biological Report FWS/OBS-80/30.

Pulich, W., Jr. 1985. Seasonal growth dynamics of *Ruppia maritima* L.s.l. and *Halodule wrightii* Aschers. in southern Texas and evaluation of sediment fertility. *Aquatic Botany* 23:53-66.

Pulich, W. M., Jr., C. Blair, and W. A. White. 1997. Current status and historical trends of seagrass in the Corpus Christi Bay National Estuary Program study area. Report CCBNEP-20. Corpus Christi Bay National Estuary Program, Natural Resources Center, TAMU-CC, Corpus Christi, TX. 131 p.

Pulich, W. M., Jr. and W. A. White. 1991. Decline of submerged vegetation in the Galveston Bay system: chronology and relationship to physical processes: *Journal Coastal Research* 7(4)1125-1138.

Pulich, W. M., Jr., and Leland Roberts. 1996. Seagrass Conservation Plan for Texas, Conceptual Draft. Prepared for discussion at the Symposium on Texas Seagrasses, Corpus Christi, TX. 13 pp.

Quammen, M. L. and C.P . Onuf. 1993. Laguna Madre: seagrass changes continue decades after salinity reduction. *Estuaries* 16:302-310.

Reise, K. 1978. Experiments on epibenthic predation in the Wadden Sea. *Helg. Wiss. Meeresunters.* 31:55-101.

Sand-Jensen, K. and J. Borum. 1991. Interactions among phytoplankton, periphyton, and macrophytes in temperate freshwaters and estuaries. *Aquatic Botany* 41:137-175.

Santos, S. L. and J. L. Simon. 1974. Distribution and abundance of the polychaetous annelids in a south Florida estuary. *Bulletin of Marine Science* 24:669-689.

Sargent, F. J., T. J. Leary, D. W. Crewz, and C. R. Kruer. 1995. Scarring of Florida's seagrasses: Assessment and management options. F. M. R. I. Technical Report TR-1. Florida Marine Research Institute, St. Petersburg, Fl. 37 pp. plus appendices.

Short, F. T., D. M. Burdick, and J. E. Kaldy, III. 1995. Mesocosm experiments quantify the effects of eutrophication on eelgrass, *Zostera marina*. *Limnology and Oceanography* 40(4):740-749.

Short, F. T. and D. M. Burdick. 1996. Quantifying eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. *Estuaries* 19(3):730-739.

Simmons, E. G. 1957. An ecological survey of the Upper Laguna Madre of Texas. *Publications of Institute of Marine Science, University of Texas* 4:156-200.

Stevenson, J. C., L. W. Staver and K. W. Staver. 1993. Water quality associated with survival of submersed aquatic vegetation along an estuarine gradient. *Estuaries* 16(2):346-361.

Texas Almanac. 1992-93. The Dallas Morning News. Distributed by Gulf Publishing Company, Houston, TX. 656 pp.

Texas Coastal Management Program, Final Environmental Impact Statement. 1996. Prepared by National Oceanic and Atmospheric Administration, Office of Ocean and Coastal Resource Management and State of Texas, Coastal Coordination Council. variable pagination.

Texas Parks and Wildlife. 1997. Texas Wetlands Conservation Plan. Resource Protection Division, Texas Parks & Wildlife Department, Austin, TX. 64 p.

Texas State Soil and Water Conservation Board. January, 1991. A comprehensive study of Texas watersheds and their impacts on water quality and water quantity, Temple, TX.

Thayer, G. W., S. M. Adams, and M. W. LaCroix. 1975. Structural and functional aspects of a recently established *Zostera marina* community. *Estuarine Res.* 1:518-540.

Thayer, G. W., K. A. Bjorndal, J. C. Ogden, S. L. Williams, and J. C. Zieman. 1984. Role of larger herbivores in seagrass communities. *Estuaries* 7:351-376.

Tilmant, J. T., R. W. Curry, R. Jones, A. Szmant, J.C. Zieman, M. Flora, M.B. Robblee, D. Smith, R.W. Snow and H. Wanless. 1994. Hurricane Andrew's effects on marine resources. *BioScience* 44(4):230-237.

Tomasko, D. and B. E. Lapointe. 1991. Productivity and biomass of *Thalassia testudinum* as related to water column nutrient availability and epiphyte levels: Field observations and experimental studies. *Marine Ecology Progress Series* 75:9-17.

Tomasko, D., C. J. Dawes, and M. O. Hall. 1996. The effects of anthropogenic nutrient enrichment on turtle grass (*Thalassia testudinum*) in Sarasota Bay, Florida. *Estuaries* 19(28):448-456.

Valiela, I., K. Foreman, M. LaMontagne, D. Hersh, J. Costa, P. Peckol, B. DeMeo-Anderson, C. D'Avanzo, M. Babione, C.-H. Sham, J. Brawley, and K. Lajtha. 1992. Couplings of watersheds and coastal waters: sources and consequences of nutrient enrichment in Waquoit Bay, Massachusetts. *Estuaries* 15(4):443-457.

van Tussenbroek, B. I. 1994. The impact of hurricane Gilbert on the vegetative development of *Thalassia testudinum* in Puerto Morelos coral reef lagoon, Mexico: a retrospective study. *Botanica Maina* 37:421-428.

Virnstein, R. W., P. W. Mikkelson, K. D. Cairns, and M. A. Capone. 1983. Seagrass beds versus sand bottoms: The trophic importance of their associated benthic invertebrates. *Fla. Sci.* 46:363-381.

White, W. A., T. R. Calnan, R. A. Morton, R. S. Kimble, T. G. Littleton, J. H. McGowen, H. S. Nance and K. S. Schmedes. 1983. Submerged lands of Texas, Corpus Christi area: sediments, geochemistry, benthic macroinvertebrates, and associated wetlands. The University of Texas at Austin, Bureau of Economic Geology Special Publication. 154 pp + appendices.

Whitledge, T. E. 1995. Effects of the nutrient distributions on phytoplankton in lower Laguna Madre, with particular reference to brown tide. Report by University of Texas Marine Science Institute, Port Aransas, Texas.

WRI/IUCN/UNEP, 1992. Global Biodiversity Strategy. World Resources Institute (WRI), The World Conservation Union (IUCN) and United Nations Environment Programme (UNEP). New York 244 p.

Young, D. K. and M. W. Young. 1982. Macrobenthic invertebrates in bare sand and seagrass (*Thalassia testudinum*) at Carrie Bow Cay, Belize, p. 115-126. *In:* K. Rutzler and I. G. Macintyre (eds.), The Atlantic Barrier Reef Ecosystem at Carrie Bow Cay, Belize, 1.

Zieman, J. C. 1976. The ecological effects of physical damage from motor boats on turtle grass beds in southern Florida. *Aquatic Botany* 2:127-139.

Zieman, J. C. 1975. Tropical seagrass ecosystems and pollution. Chapter 4. *In*: E.J.F. Wood and R.E. Johannes, (eds.), Trop. Mar. Poll., Elsevier Publ. Co., New York.

Zieman, J. C. 1982. The ecology of seagrasses of south Florida: a community profile. U.S. Fish Wildl. Serv. USFWS/OBS-82/25. 158 p.

Zieman, J. C. and R. T. Zieman. 1989. The ecology of the seagrass meadows of the west coast of Florida: a community profile. U.S. Fish Wildl. Serv. Biol. Rep. 85(7.25). 155 p.

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