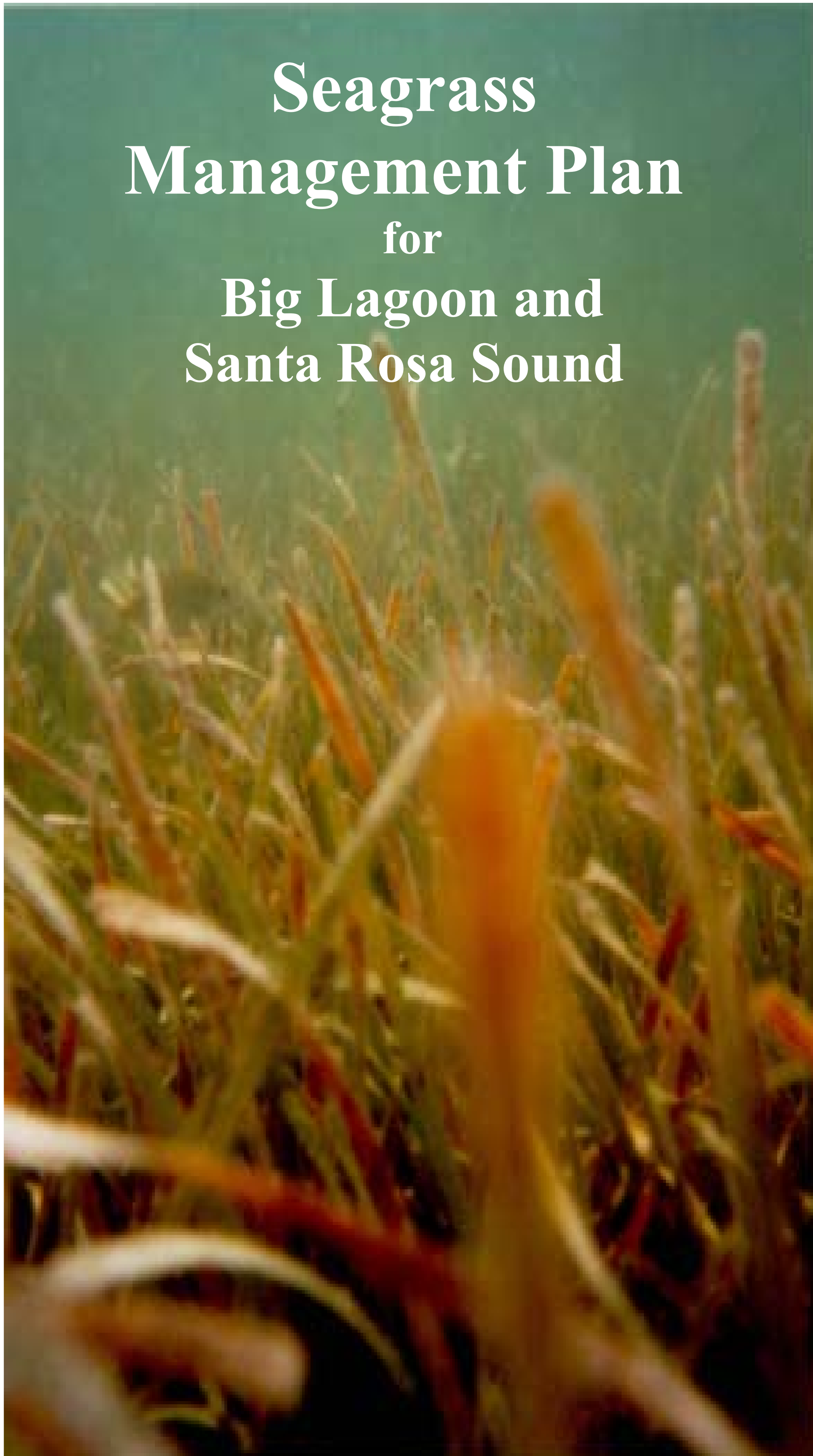
Seagrass Management Plan for Big Lagoon and Santa Rosa Sound



Dec 2001

To receive a hard copy of the Seagrass Management Plan for Big Lagoon and Santa Rosa Sound, write to:

Florida Department of Environmental Protection
Ecosystem Restoration Section
160 Governmental Center
Pensacola Florida, 32501

Or call:
(850) 595-8300

Acknowledgments

This plan focuses on the management issues regarding seagrass communities and the environmental and human surroundings that impact them. Several seagrass management plans have been prepared for other geographic locations. Due to the similarity of those areas to the Pensacola Bay System, some issues within those plans also apply to the Pensacola Bay System. This Seagrass Management Plan is a compilation of portions of those other plans that apply to the Pensacola Bay System, with regional concerns and recommendations added.

First and foremost, I would like to thank Warren Pulich Jr., PH.D. of the Texas Parks and Wildlife Resource Protection Division for allowing me to base the format of this plan after that found in the "Seagrass Conservation Plan for Texas". I would also like to recognize Sarah Dimitroff who assembled the "Pensacola Bay Watershed Management Guide" written in 1998, from which I drew information; Carrie Stevenson and Blair Burleson of the Florida Department of Environmental Protection (FDEP) for advising me in the area of stormwater runoff. I would also like to thank Barbara Ruth and Erick Harter of FDEP for their editing contributions.

The US Environmental Protection Agency Gulf Of Mexico Program, an integrated program initiated by the EPA, dedicated to preserving and restoring the natural beauty of the Gulf coastal communities, has helped fund and steer the Big Lagoon and Santa Rosa Sound seagrass monitoring study, from which this management plan took it's first breath.

It is our hope that this Seagrass Management Plan will identify areas of concern and suggest corrective actions to be taken by government agencies and concerned citizens.

Lisa M. Schwenning
Environmental Specialist I
Florida Department of Environmental Protection
lisa.schwenning@dep.state.fl.us

Cover photo: Bed of *Thalassia testudinum*

Executive Summary

Seagrass beds have long been recognized as a critical coastal habitat for estuarine fisheries and wildlife. They also function as a direct food source for fish, waterfowl, and sea turtles, major contributors of organic matter to marine food webs, participants in nutrient cycling processes, and stabilizing agents in coastal sedimentation and erosion processes (Texas Parks and Wildlife, 1999). Seagrass health and acreage is directly proportional to the health and status of many commercially and recreationally important seafood species such as shrimp, crabs, scallops, redfish, speckled trout, and mullet.

Pensacola Bay has been impacted by numerous sources of pollution, resulting in a system that does not have the natural biodiversity and productivity expected of a system of this complexity. As human population concentrates along our coastlines, anthropogenic impacts to seagrass habitats increase through nutrient loading from runoff, light reduction from increased turbidity and phytoplankton blooms , increased boat traffic, and more direct vessel impacts such as propeller scarring (Fonseca, Kenworthy, and Thayer, 1998). Point sources in the Pensacola Bay area are regulated through FDEP permits, and many point source discharges to the Bay System have been eliminated over the last several years. However, stormwater runoff (urban and landscaping) is the largest source of polluting nutrients, which can lead to eutrophication in Santa Rosa Sound and Big Lagoon. Stormwater is also a major contributor of suspended sediments to these bodies of water. Untreated stormwater contributes nine times more oxygen demanding substances to waterbodies than most point sources (FDEP, n.d.).

Tourism and recreational boating have been on the rise over the last decade. The main effects of these industries are related to boat operations, marina construction, and small localized oil spills in marinas. Recreational boating can also have a direct impact on shallow grass beds through propeller scarring. Scarring of seagrasses can be avoided if caution is used where seagrasses are present.

Dredge and fill activities have been widely recognized as a major anthropogenic disturbance contributing to the destruction of seagrass meadows. The direct and immediate effect of dredging on seagrass communities is mortality due to removal and /or burial. Proper and controlled dredging can alleviate much of the turbidity caused by boat traffic bottoming out within marked channels. Floating turbidity curtains allow for proper maintenance without causing a detrimental amount of turbidity.

The FDEP Ecosystem Restoration Section is currently involved in the second year of a seagrass monitoring study within Santa Rosa Sound and Big Lagoon. The study involves four major areas of research; seagrass monitoring, water quality monitoring, photosynthetically active radiation (PAR) monitoring, and porewater sulfide sampling. Results of this study suggest that immediately after a rainfall, stormwater input inhibits the amount of sunlight available to the seagrass. The effects are measured not only immediately after a storm, but because the turbidity takes time to settle, inhibited sunlight is evident for days after the rainfall.

To ensure that the water and sediment quality remain beneficial to the seagrass community, a series of objectives will need to be accomplished: 1) community acceptance of seagrass as an important habitat; 2) development of specific water quality guidelines and criteria to protect seagrass beds; and 3) developing and implementing Best Management Practices (BMPs) which protect seagrasses.

Education can be the best and most lasting way in which to protect seagrass. If done successfully, education will lead to behavioral changes that will reduce impacts on this important ecosystem (Texas Parks and Wildlife, 1999). Progress toward a better-informed and more involved citizenry will not occur without intensive efforts by educators, environmental groups, industry, business, and community organizations.

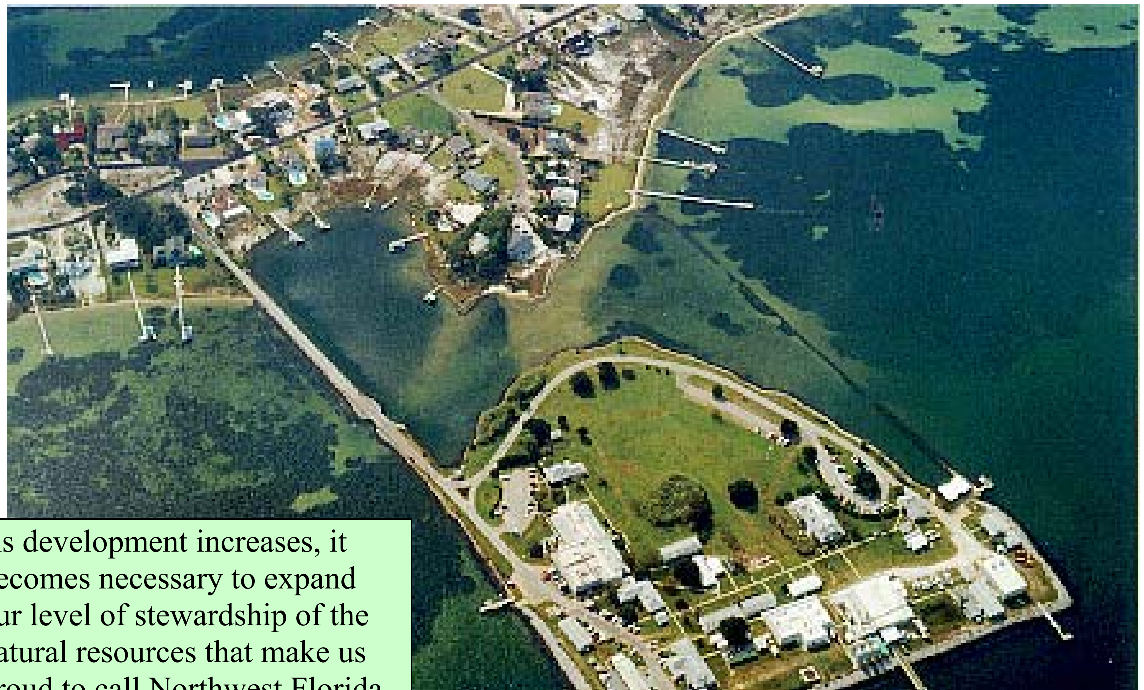
Important Note:

Photographic artifacts are common phenomena observed in satellite images and in aerial or astronaut-camera photographs. In the early days of seagrass mapping, many biologists reported that the methods of obtaining mapping information were especially adept to highlighting such artifacts. They chose to identify a significant fraction of these features as vegetative in nature, such as darker sediments and sudden increase in depth. Maps showing numerous artifacts of presumed grassbeds were produced and often published but too frequently without appropriate field verification. When several exacting studies discredited this interpretation of many such features (although some, and sometimes a majority, were verified), this form of mapping led to a lack of confidence in data. Today, we know to be careful, and properly use field inspections to verify our work.

Incidentally, in the process of developing this plan, an inaccuracy of data was uncovered concerning the seagrass maps of Big Lagoon and Santa Rosa Sound for the 1980's and 1992. Data sets used to produce these maps were inconsistent with what we know to be most probable based on hydrologic history and recent monitoring. Although the maps used in this plan have been adjusted to reflect the most probable coverage, there has been no field verification and may still contain small inaccuracies. However, this is the extent of the data we have concerning seagrasses in Big Lagoon and Santa Rosa Sound and, with the understanding that a few artifacts will not discredit the information contained, we have resumed the final preparations of this management plan. Optimistically, this finding underlines the need for seagrass mapping and ground truthing in the Pensacola Bay system.

Table of Contents

Table of Figures



As development increases, it becomes necessary to expand our level of stewardship of the natural resources that make us proud to call Northwest Florida

Photo By: Erick Harter

Chapter 1.

Introduction

Vision and Purpose

The Florida Department of Environmental Protection (FDEP) Northwest District (NWD) Ecosystem Restoration Section (ERS) has been utilizing a tissue culture micropropagation technique to produce and restore seagrass populations in Pensacola Bay for over four years. But it appears the battle is being lost as the seagrasses are declining faster than they can be restored. For this reason, the ERS began a seagrass monitoring program that will allow us to more accurately determine the extent of the problem. Seagrass monitoring combined with a monthly water quality monitoring program and bi-monthly sediment analysis will allow us to better determine the probable reasons for the seagrass decline.

The results of this monitoring program, and information provided by outside technical sources, were utilized in the development of this document.

Process for Developing This Seagrass Plan

In a successful attempt to obtain information about, and tools necessary for, seagrass management, members of the ERS attended several workshops and symposia. These include the "Subtropical and Tropical Seagrass Management and Ecology Workshop", October,1998; "Gulf of Mexico Symposium", April 2000; and "Seagrass Management: It's Not Just Nutrients", August, 2000. FDEP also hosted a workshop, the "Big Lagoon Seagrass Management Workshop" in 1998. In addition to attending those workshops, members of ERS and representatives from county, state and federal agencies joined together to address seagrass and water quality monitoring and management.

The basic format of this management plan is based on the "Seagrass Conservation Plan for Texas", developed by a consortium of agencies and experts under the leadership of Texas Parks and Wildlife. Because of the similarity of the northern Gulf Coast of Texas and the northern Gulf Coast of Florida, action plans from the "Seagrass Conservation Plan for Texas" have been adopted with modifications for our specific region and concerns. Much information was also taken from the "Pensacola Bay Watershed Management Guide, 1998".

After reviewing and compiling proposed recommendations from the previously mentioned seagrass symposia and previously activated seagrass management plans, research, management, and education were determined to be the main issues concerning successful seagrass management and recovery. As a result, this plan focuses on three areas: Research, Management, and Education. The chapters are formatted to identify problems and formulate corresponding solutions in the form of action plans. Action plans are included at the end of Chapters two and four. It is anticipated that the strategies and recommendations will be implemented by the appropriate agencies and organizations, both governmental and non-governmental.

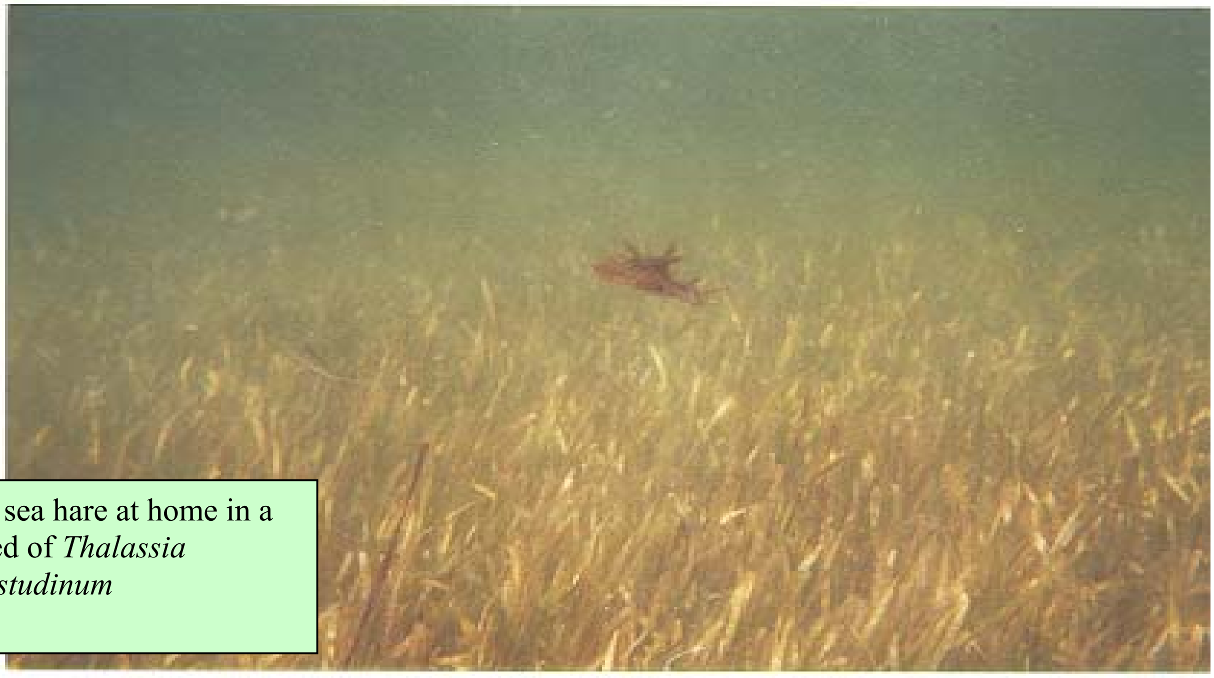
The Gulf of Mexico Program

The Gulf of Mexico Program (GMP) supported and funded us in the development of this seagrass monitoring program. The GMP's mission is "to facilitate the protection and restoration of the coastal marine water of the Gulf of Mexico and it's coastal natural habitats; to sustain living resources; to protect human health and the food supply; and to ensure recreational use of Gulf shores, beaches, and waters in ways consistent with the economic well-being of the region, through a network of citizens and institutions". Their vision is "a Gulf of Mexico flourishing in all it's natural richness and variety – beaches glistening in the sunlight, thriving coastal vegetation, and abundant fish, shellfish and waterfowl. The Gulf ecosystem is of incalculable value in itself, but our vision also embraces the human uses of the Gulf which are part of the cultural fabric of the region and which are critical to the economic well-being of the region and the nation".

Without the assistance of the GMP, this seagrass management plan, and hope for cleaner, healthier waters in the Pensacola area may not have been possible.

It's
Time

One Gulf…
One Community



A sea hare at home in a bed of *Thalassia testudinum*

Photo by: Lisa Schwnning

Chapter 2.

Research Issues

Value of Seagrass Beds

Seagrass beds have long been recognized as critical coastal habitat for estuarine fisheries and wildlife. They also function as a direct food source for fish, waterfowl, and sea turtles, major contributors of organic matter to marine food webs, participants in nutrient cycling processes, and stabilizing agents in coastal sedimentation and erosion processes (Texas Parks and Wildlife, 1999).

The status of seagrasses, or submerged aquatic vegetation (SAV), is a well-established indication of the overall health of an ecosystem. Seagrass health and acreage is directly proportional to the health and status of many commercially and recreationally important seafood species such as shrimp, crabs, scallops, redfish, speckled trout, and mullet. For these reasons, many areas in Florida have implemented seagrass monitoring programs to determine the health and trends of local seagrass populations (City of Tampa, Hillsborough County, City of Ft. Lauderdale, Tampa Bay, Sarasota Bay, Charlotte Harbor, Lignumvitae Key, Indian River Lagoon, Biscayne Bay, and others).

Status of Seagrasses in the Pensacola Bay System

Pensacola Bay is a saline bay with a ½ mile wide pass (Caucaus Channel) to the Gulf of Mexico. The Bay is the receiving body of water for Escambia and East Bays, and Bayous Texar, Chico and Grande, and included within the bay system are Santa Rosa Sound and Big Lagoon. Pensacola Bay is also the middle body of water connecting Santa Rosa Sound and Big Lagoon. Because environmental impacts do not stop with political boundaries it would be impractical, while discussing Santa Rosa Sound and Big Lagoon, not to address the status of the surrounding bodies of water as well. For this reason, the term "Pensacola Bay system" will be inclusive of all surrounding water bodies when speaking of environmental impacts.

Pensacola Bay's surface area is 54.1 square miles (133 square kilometers) with a mean depth of 19.5 feet. The Pensacola Bay System is located in both Escambia and Santa Rosa counties, with Santa Rosa Sound in Santa Rosa County and Big Lagoon located in Escambia County. Due to the geographic location and political boundaries of the Pensacola Bay System (Fig. 2-1), effective management of this system requires consistency and coordination of two states, Florida and Alabama, along with numerous local, state, and federal agencies.

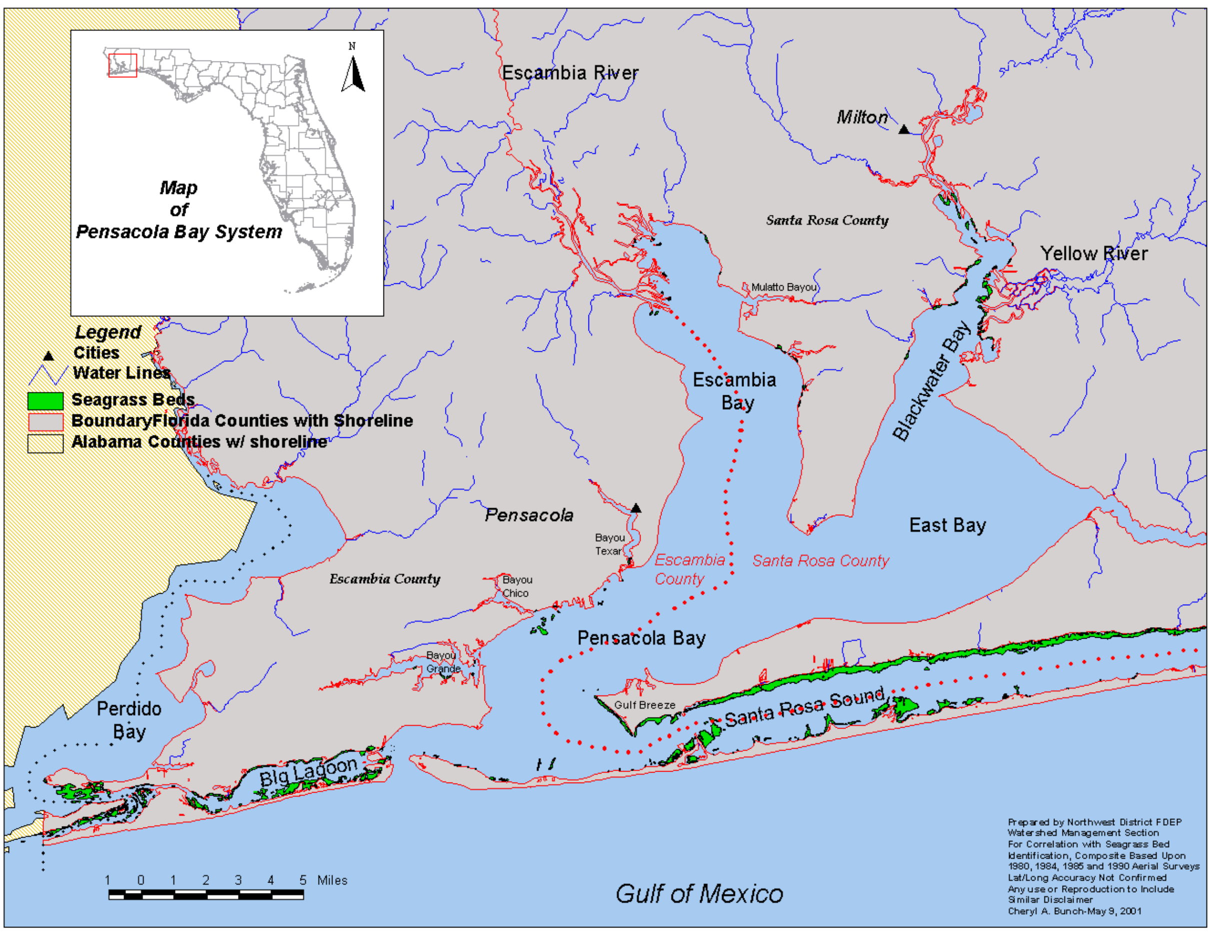


Figure 2-1. Watershed, political boundaries and seagrass distribution of the Pensacola Bay System.
The boundary of Escambia County and Santa Rosa County Florida divides the Escambia River, Escambia Bay, Pensacola Bay, and Santa Rosa Sound. The state boundary of Florida and Alabama divides the Perdido River and Perdido Bay.

Flushing of the bay is good, yet water quality problems exist due to nonpoint and point source pollution and urbanization. Oyster harvesting is prohibited year round (except in portions of East Bay). The shrimp harvests are now generally stable but have declined dramatically since the 1970's, and the scallop resources have collapsed partially due to the disappearance of seagrass beds (FDEP,1998). For improvement efforts to succeed, there must be shared knowledge of and concern for the values and vulnerabilities of this system between scientists, governing agencies, and the general public.

The Pensacola Bay System contains four species of true seagrasses, *Thalassia testudinum* (turtle grass), *Syringodium filiforme* (manatee grass), *Halodule wrightii* (shoal grass), and *Halophila engelmannii* (star grass), and two brackish water species *Vallisneria americana* (tape grass), and *Ruppia maritima* (widgeon grass). In 1949, seagrass beds were noted to be extensive throughout the Pensacola Bay System. In 1975, these beds were documented to have receded or disappeared (FDEP, 1998). For example, a recession and disappearance of most of Escambia Bay's true seagrass has occurred from 1950 to 1975 (Figure 2-2). A similar dramatic decline occurred in East Bay over the same time period (Figure 2-3). According to the U.S. Environmental Protection Agency (USEPA, 1975), the disappearance of several small beds was also documented near the north side of the Pensacola Bay Bridge, in 1951, likely attributable to dredging. Also, enlargement of the Port of Pensacola involved extensive dredge and fill activities in 1960. Additional work was done to the port in 1967. Figure 2-4 indicates the filled areas, before and after port expansion, and the related distribution of seagrass.

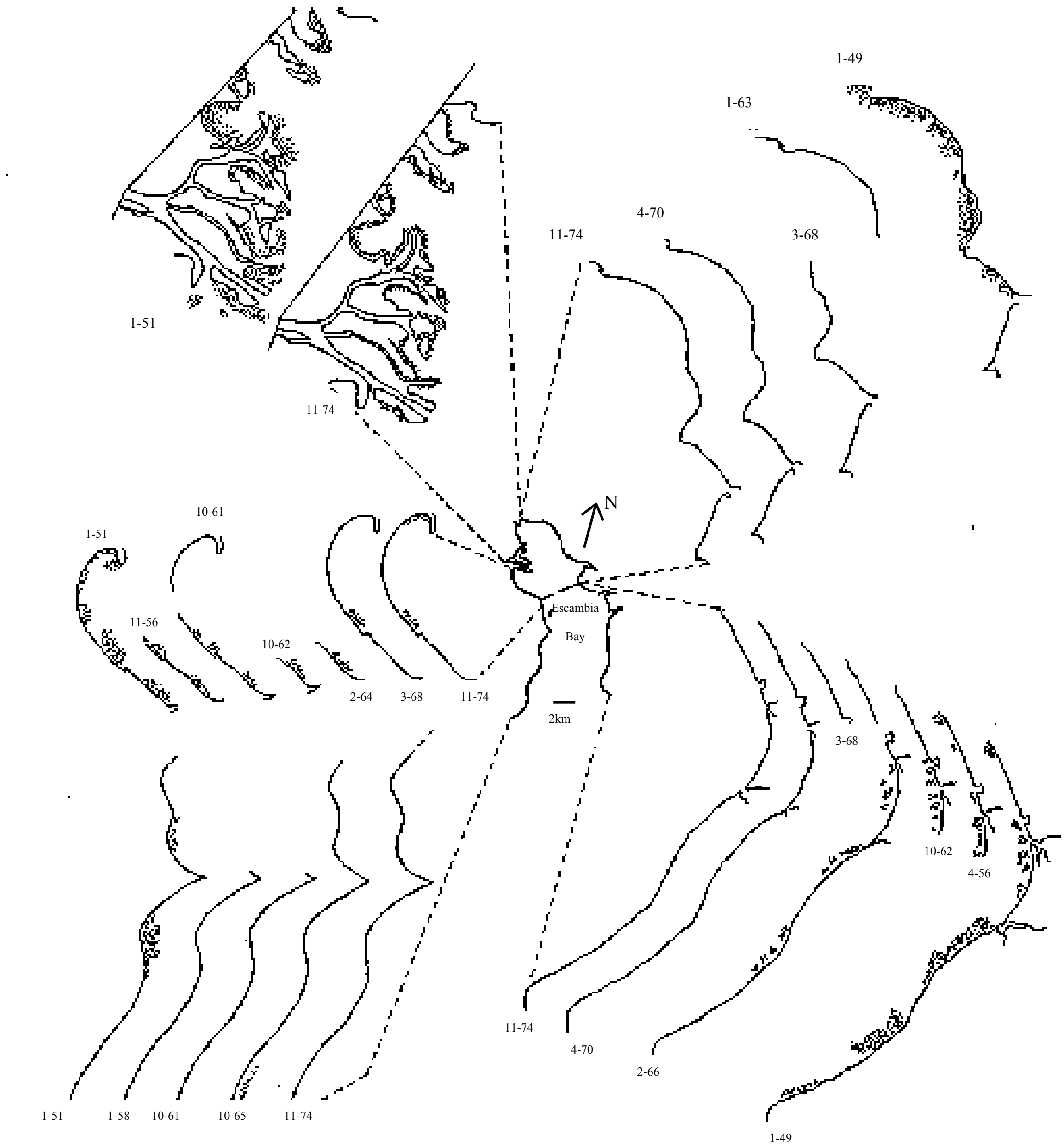


Figure 2-2. A time-lapse series of seagrass coverage: Escambia Bay, 1949 – 1974. Dashed numbers represent "Month – Year". (USEPA, 1975)

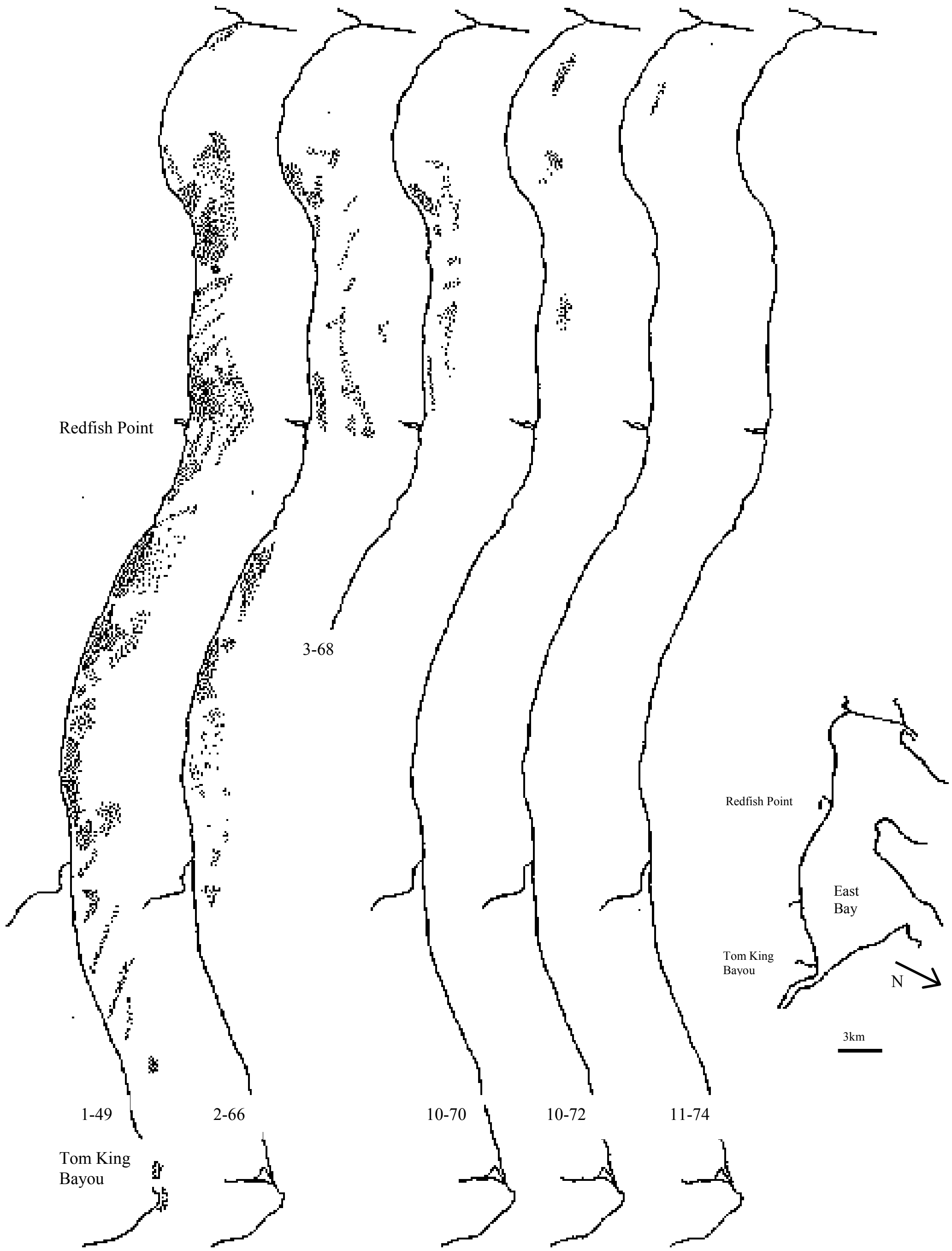


Figure 2-3. A time-lapse series of seagrass coverage: The south shore of East Bay from the Pensacola Bay bridge to Tom king Bayou, 1949 – 1974. Dashed numbers represent "Month – Year". (USEPA, 1975)

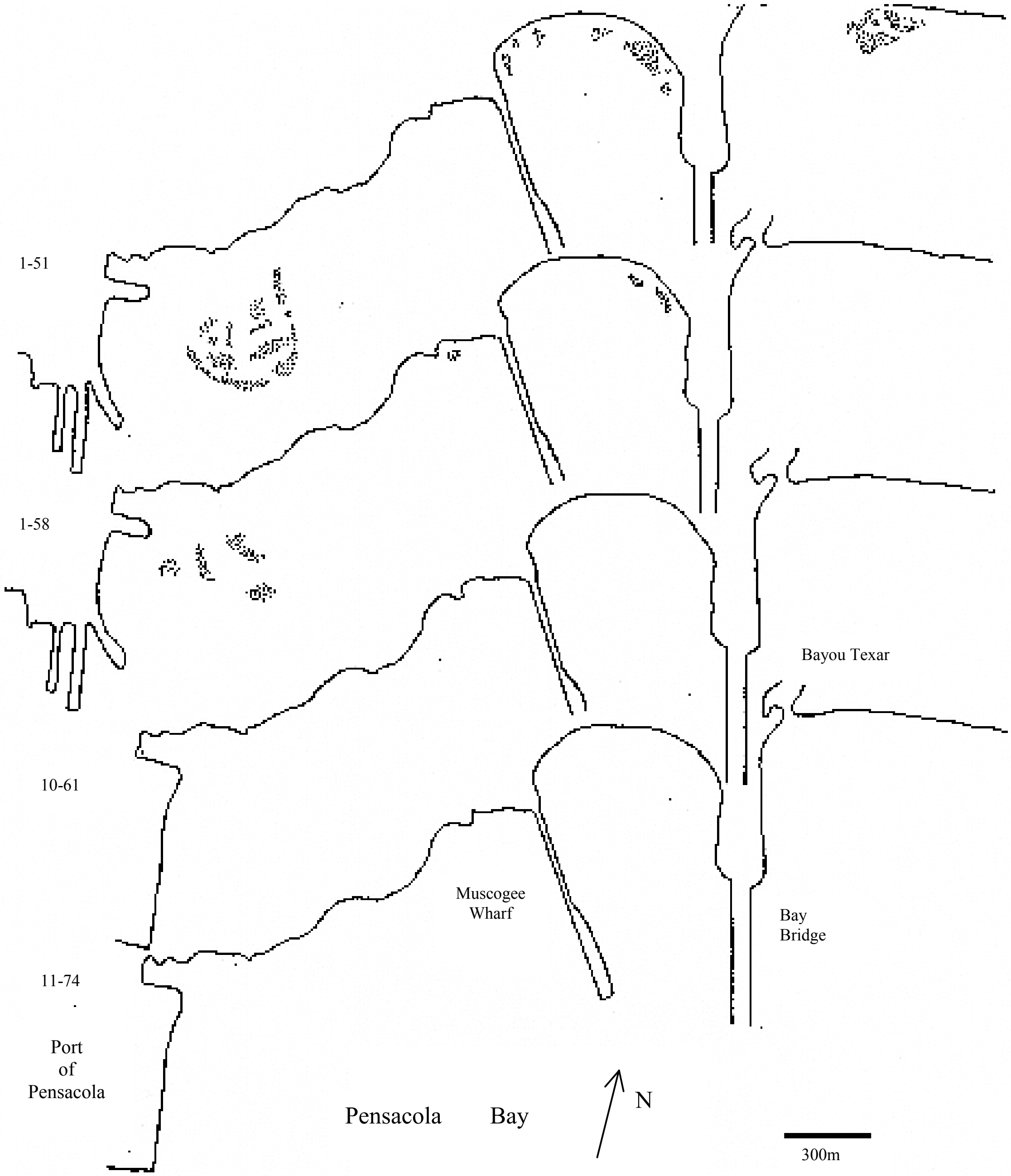


Figure 2-4. A time-lapse series of seagrass coverage: The north shore of Pensacola Bay with ship terminal and the Pensacola Bay bridge, 1951 – 1974. Dashed numbers represent "Month – Year". (USEPA, 1975)

Major causes of vegetation loss were sewage and industrial waste discharges, dredge and fill activities, beachfront alteration, and changing watershed characteristics. In the Pensacola Bay System, many factors have synergistically affected the entire system, with certain factors having an increased local effect. Along the southern shore of East Bay, bulkheads and groins likely caused changes in nearshore water movements and, therefore, erosion of seagrass beds. Industrial discharge, no doubt, caused the loss of vegetation in the northeast section of Escambia Bay since these effluents remained near shore in that area. For instance, the loss of vegetation around the Northeast STP was caused first by laying a discharge pipe directly through the bed and later by sewage effluents (USEPA, 1975).

The massive quantities of point source waste previously discharged into the Pensacola Bay system between 1955 and 1964 have been significantly reduced. Based on surveys by USEPA and its predecessor agencies, the combined quantity of waste discharged by the four major dischargers into the Escambia Bay drainage area (Container Corporation of America, Monsanto Chemical Co., American Cyanamid Co., and Air Products and Chemical Co) was reduced by 40% for biological oxygen demand (BOD), 71% for total nitrogen, and 96% for total phosphorus by 1975 (USEPA, 1975).

Pensacola Bay waters have been impacted by numerous sources of pollution, resulting in a system that does not have the natural biodiversity and productivity expected of a system of this complexity. While it’s true today that point sources have decreased significantly, non-point sources are increasing and pollution continues to degrade water and sediment quality throughout much of the system. Santa Rosa Sound and Big Lagoon are two of the few remaining bodies of water within the Pensacola Bay System that still harbor seagrass beds (Figure 2-1). For that reason, they are the main focus of this plan.

Santa Rosa Sound is a 42.4 square mile lagoon, which connects Choctawhatchee Bay to the east and Pensacola Bay to the west. The majority of Santa Rosa Sound is designated as Class II waters, waters designated for shellfish propagation or harvesting. A portion of Santa Rosa Sound, the Gulf Island National Seashore, is also classified as an Outstanding Florida Waters (OFW), waters designated by the Environmental Regulation Commission as worthy of receiving the highest level of protection because of their natural attributes. Florida surface water classifications are arranged in order of the degree of protection ranging from Class I, the most stringent water quality criteria, to

Class V, the least. A complete list of Florida surface water classifications and Outstanding Florida Waters can be found in the Florida Administrative Code 62-302, Surface Water Quality Standards.

Santa Rosa Sound is one of the few waterbodies with fairly diverse seagrasses when compared to the rest of the Pensacola Bay system. Unfortunately, stresses on the habitat resulting from development pressures and an increase in stormwater runoff are affecting the Sound's ability to maintain productivity. Santa Rosa Sound has experienced habitat loss due to rapid development on Santa Rosa Island and along U.S. Highway 98. The Sound also receives discharge from Navarre and Pensacola Beach wastewater treatment plants, as well as runoff from at least one golf course and spray irrigation for disposal of treated municipal wastewater (FDEP 1998).

The continuing presence of seagrass in Santa Rosa Sound indicates that the water quality has not declined below the threshold required for seagrass survival. However, the Sound does have problems with nutrients and some heavy metals. Action plans associated with stormwater would benefit this water body as well as address the nutrient input from municipal sources (FDEP 1998).

Big Lagoon is approximately 18 square miles and connects Perdido and Pensacola Bays. Although much of the southern portion of the lagoon is within Florida Aquatic Preserve boundaries, which falls under OFW designation, it continues to receive a moderate amount of stormwater input carrying nutrients and heavy metals.

Causes of Seagrass Loss

Two main processes are responsible for apparent seagrass loss: 1) A natural shift of the bed as part the natural dynamic trend, producing a loss of grass in one particular area yet an increase in another. A dynamic trend "loss" may appear as a net loss in one area and net gain in another but, in fact, is merely a shift of the seagrass bed resulting in no net loss or gain. 2) Loss due to weather and human disturbances resulting in a net loss of seagrass. This category includes both natural and anthropogenic causes.

Natural Disturbances

Natural causes of seagrass loss can include storms, floods, and droughts. Disturbances by large storms can result in a massive redistribution of sediments that can burying seagrasses. But natural storm events often have variable impacts on estuarine and coastal biotic communities. 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. However, storms are stochastic events that cannot be predicted. (Texas Parks and Wildlife 1999). Past hurricane events in Northwest Florida have demonstrated the detrimental effects storms can have on coastal ecosystem. In natural events such as these, loss "prevention" is not an issue to be controlled and restoration becomes the focus.

Other natural causes of seagrass loss include high turbidity, sedimentation, and bioturbation. Sediment carried by rivers and streams into the bay system can be kept in suspension by wind driven water turbulence, not only increasing turbidity but being deposited in areas of calm water.

Designed by Ken Dunton – Used by permission of Texas Parks and Wildlife

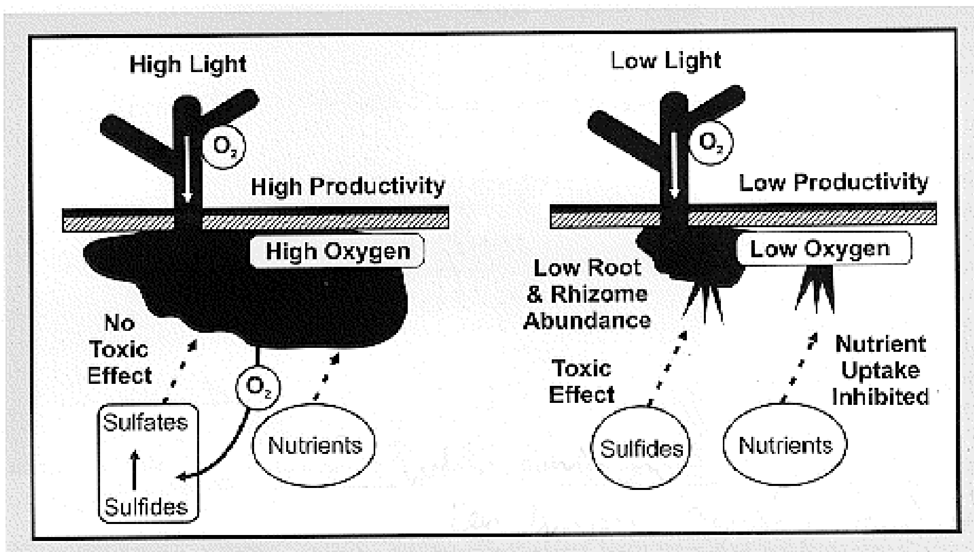


Figure 2-5. A conceptual model of seagrass productivity depicting the effects of reduced light on seagrass production. Under low light conditions, less oxygen is produced in photosynthesis, resulting in lower oxygen availability to roots and rhizomes, which cause death of tissues from sulfide toxicity.

Shading due to high turbidity can cause decreased primary productivity of the seagrasses. In extreme cases, seagrass burial can result from high sedimentation events (Texas Parks and Wildlife, 1999). Bioturbation is the result of deposit feeding (benthic) organisms or "biological bulldozers" turning over sediments rapidly through moving, burrowing, and feeding disrupting the habitat. The action of bioturbation, though, is probably not a significant cause of turbidity in the seagrass community and is beneficial in that it results in bringing oxygen to the root system, thus preventing sulfide toxicity (Figure 2-7) (Day et al. 1989).

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, to which organisms are not adapted, e.g., trawling, dredging, and nutrient inputs (Texas Parks and Wildlife, 1999).

As human population concentrates along our coastlines, anthropogenic impacts to seagrass habitats increase through nutrient loading from runoff, light reduction from increased turbidity and phytoplankton blooms, increased boat traffic, and more direct vessel impacts such as propeller scarring (Figure 2-8) (Fonseca et al. 1998). The impacts are a direct result of marine transportation, commercial fishing, tourism, and recreational boating (Texas parks and Wildlife 1999), as well as landscaping practices a lack of construction controls.

Used by permission of Texas Parks and Wildlife

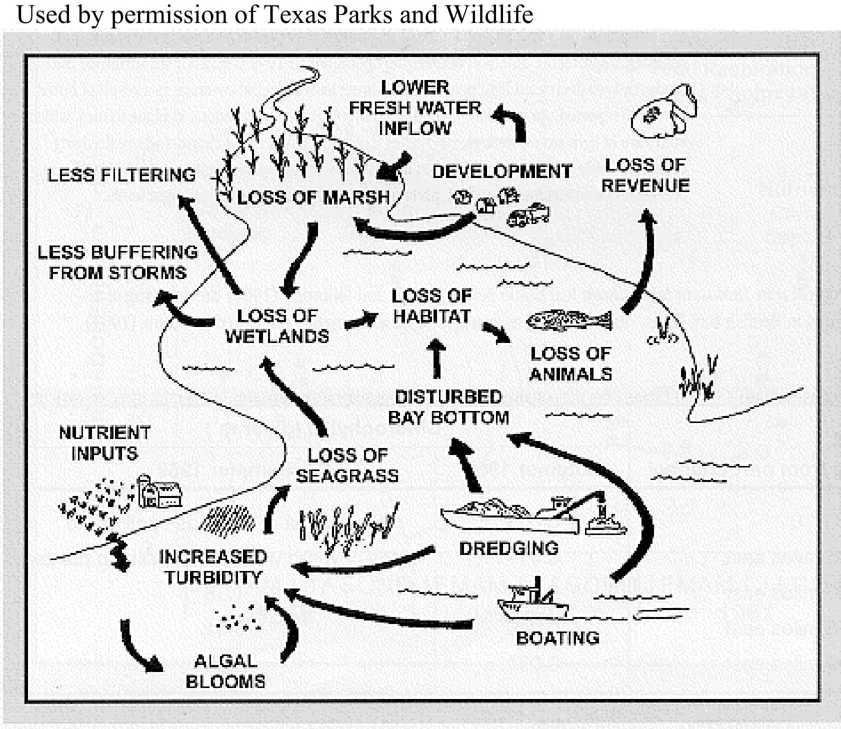


Figure 2-6. The major factors that contribute to loss of seagrass habitat are primarily from human induced impacts and include dredging, excessive nutrient inputs, and boating activities.

Nutrient Loading Effects

Eutrophication from nutrient loading in Big Lagoon and Santa Rosa Sound is rapidly becoming a problem as human population and development continue to increase. A 3-year study , beginning in August 1996 by Heck (1996), revealed a constant percentage of coverage but a decline in density and above ground biomass over the three year period for both *H. wrightii* and *T. testudinum* in Santa Rosa Sound and

Big Lagoon. However, biomass was lowest in Big Lagoon. These grasses also appeared to be lacking a new cohort of young shoots with the turtle grass showing a reduction of young and old shoots. A marginal light regime due to turbid water and stressful salinities were presumed to be involved in the declining seagrass stock for this area. The presence of epiphytes on seagrass leaves caused additional reductions in light available for growth. It was estimated that seagrass in Big Lagoon had decreased about 30% over the three-year period. (FDEP, 1998). Many point source discharges to the Pensacola Bay System have been eliminated over the last several years, however, stormwater runoff (urban and landscaping) has now become the largest source of polluting nutrients, which can lead to an imbalance in estuarine systems called eutrophication. The impact of eutrophication on seagrasses has been associated with stimulated growth of both epiphytic and drift macroalgae. Experimental work has demonstrated that nutrient loading can reduce seagrass productivity and health by stimulating algal competition and by direct nitrate toxicity (Texas Parks and Wildlife, 1999).

Stormwater

The "Florida State of the Environment: Stormwater Management", provided by FDEP offers several important facts regarding stormwater and it's effects. The following is an excerpt from that document:

- ✓ Stormwater accounts for more than half of our State's water pollution. In some waters, it is the sole source.

- ✓ Stormwater generates almost all of the sediment in Florida waters.

- ✓ Untreated stormwater contributes nine times more oxygen demanding substances to waterbodies than most point sources. These are the organic and inorganic materials that use up the dissolved oxygen in the water when they decompose. Often, these conditions may lead to fish kills, especially in the summer when hot temperatures and frequent rains combine to lower oxygen levels even more.

- ✓ Untreated stormwater flushes nutrients into water bodies at a rate comparable to discharge from wastewater treatment plants. This nutrient flushing is a major cause of the warm weather algae blooms that cause our area beaches to be closed down.

- ✓ Untreated stormwater deposits 80-95 percent of the heavy metals that reach the water. Lead, zinc, copper, cadmium, and chromium, along with oils and greases, are flushed from highways and parking areas into water bodies. Heavy metals are toxic to plankton, fish, and other aquatic/marine organisms, reducing their ability to reproduce.

- ✓ Untreated stormwater can also carry viruses and bacteria - disease organisms - into the waterways, often causing health officials to close them to shellfish harvesting and swimming.

Non-point source control is the central theme of the various stormwater management methods or Best Management Practices (BMPs). The term BMP refers to that practice which is used for a given set of conditions to achieve satisfactory water quality and quantity enhancement at a minimum cost. Chapter 6 of the "Florida Development Manual: A Guide to Sound Land and Water Management" contains an extensive discussion of the use, design, construction, and operation of a wide variety of stormwater management and erosion / sediment control BMPs (Florida Department of Environmental Regulation, n.d.).

Marine Transportation

Marine transportation is fairly common within the Pensacola Bay System. Barges, carrying heavy loads, travel through the intracostal waterway. Often, these barges will stir up sediment causing turbidity, which will in turn decrease sunlight availability to the seagrasses. In severe cases, a noticeable sediment plume can be seen behind these vessels (figure 2-9).

Photo by: Erick Harter

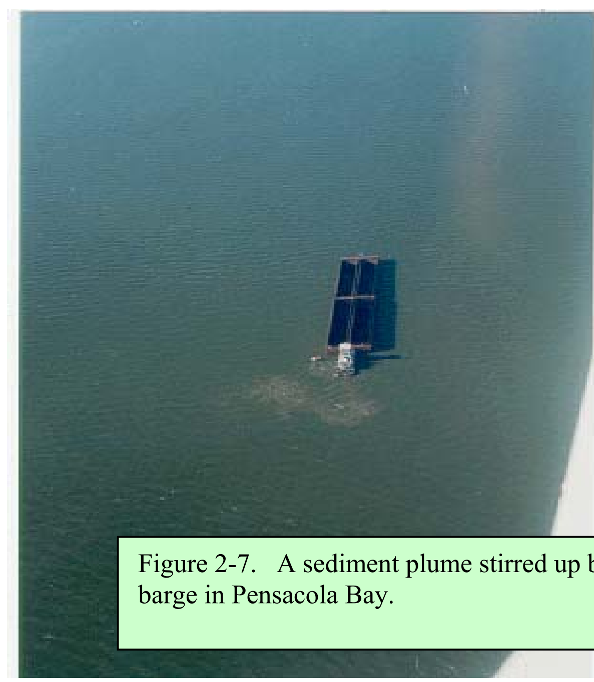


Figure 2-7. A sediment plume stirred up by a barge in Pensacola Bay.

One way to decrease the frequency of this form of resuspension is proper and timely channel maintenance. Keeping the channels adequately marked and at proper depth is crucial to the minimization of excessive turbidity. And responsible use of BMP's during channel dredging is just as important (i.e. use of turbidity controls).

Photo by: Erick Harter

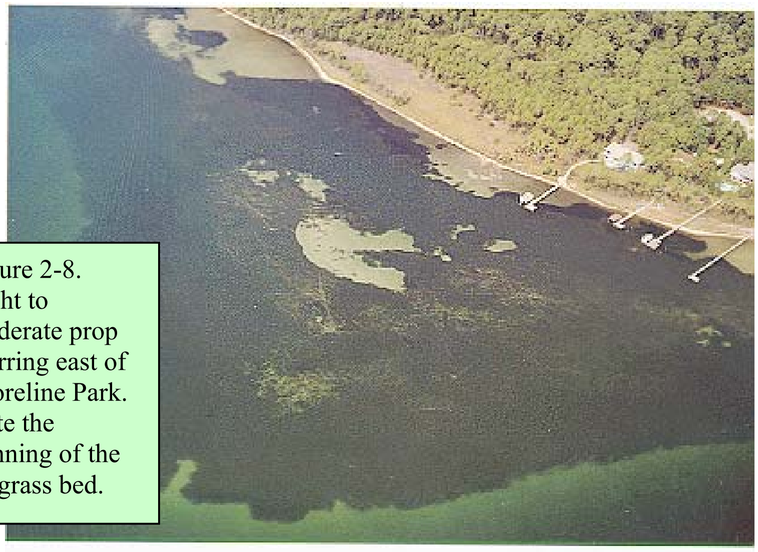


Figure 2-8. Light to moderate prop scarring east of Shoreline Park. Note the thinning of the seagrass bed.

Tourism and recreational boating have been on the rise over the last decade. The main effects of these industries are related to boat operations, marina construction, and small localized oil spills in marinas. Careless boating activities can have a distinct impact on shallow grass beds through propeller scarring (Figure 2-10). This scarring results in direct damage to seagrasses through the physical destruction of seagrass leaves and below ground tissue (roots and rhizomes) by boat propellers. These scars are then subject to erosion, leading to further damage.

The Florida Marine Research Institute (FMRI) surveyed seagrass beds using aerial photography along the Florida Coast (FDEP, 1998). The aerial surveys were used to determine an index, which ranked the severity of scarring as light (L), moderate (M), or severe (S) (Figure 2-11). Propeller scars tend to occur in areas less than 1m deep at low tide. They are visible from the water surface and can be recorded with low altitude aerial photography. Eleuterius (1987) indicated that once a prop scar is created, wave action could lead to erosion within the scar resulting in scouring and deepening of the disturbed area. Substantial scarring of shallow seagrass beds results in a cumulative reduction of productive habitat (FDEP 1998). Scarring of seagrasses can be avoided if caution is used where seagrasses are present. Anglers and recreational boaters can reduce the effects of seagrass scarring by being aware of the depth of their props and location of seagrass beds, avoiding areas where prop scarring is likely to occur (FDEP 1998).

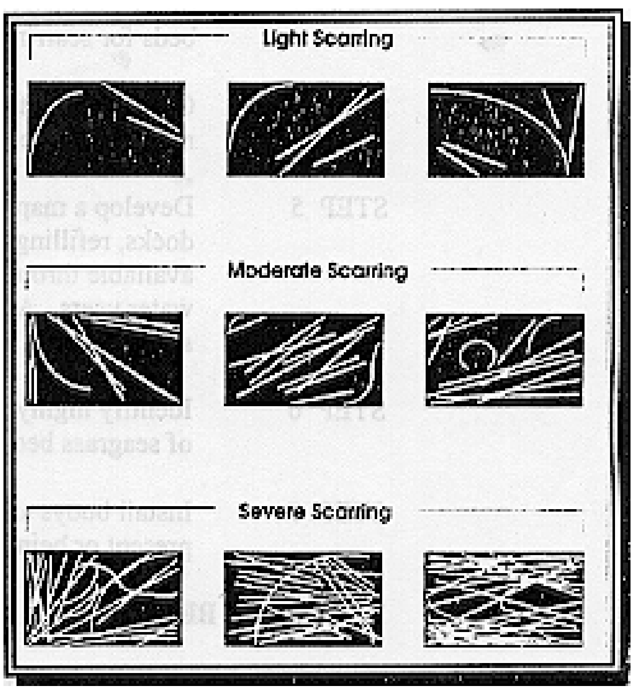


Figure 2-9. FMRI developed a propeller scar severity index.

Although there were approximately 44,000 recreational vessels registered in the Pensacola Bay system in 2000 (Porter, 2000), recent aerial photographs (Spring and fall 2000) taken over Santa Rosa Sound and Big Lagoon indicate areas of only light to moderate scarring. While there have been restoration plans developed addressing prop scar damage, the first step that must be taken in our local water body is prevention.

Dredging Effects

Dredge and fill activities have been widely recognized as a major anthropogenic disturbance contributing to the destruction of seagrass meadows. The direct and immediate effect of dredging on seagrass communities is mortality due to removal and/or burial. In addition, there are indirect losses resulting from the disturbance of sediments during dredging operations. Sediment disturbance results in increased turbidity, and decreased light availability. Seagrasses have high light requirements and the decreased light availability associated with sediment resuspension has been closely associated with seagrass loss (Texas Parks and Wildlife, 1999).

Furthermore, dredged material disposal areas are not always suitable for the colonization and growth of seagrass. Dredging may 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 redox potential of sediments within meadows. As a result of changes in hydrologic conditions occurring due to dredging of navigational channels, seagrass meadows can also undergo erosion (Texas Parks and Wildlife, 1999). Proper and controlled dredging can alleviate much of the turbidity, reducing the impact on estuarine communities. Fortunately, dredge and fill activities within the Pensacola Bay system are highly regulated. Environmental controls are required with dredge activities and open water disposal of dredge material is generally not permitted. There are exceptions, however, but the intentions and impacts of these activities are thoroughly researched before a permit is issued. Detailed information on dredge and fill activities of the Pensacola Bay system can be found in the Florida Administrative Code 62-312, Dredge And Fill Activities.

Seagrass Research Plan

Priority Goal: To gain a better understanding of natural and anthropogenic impacts on the seagrass ecosystem through sound scientific research in an effort to maintain seagrasses as a valuable resource.

Objective 1: Regularly assess status and trends of seagrass distribution throughout the Pensacola Bay System.

1. Strategy: Maintain a strategic long-term monitoring program that includes biotic and abiotic parameters of the community. Such parameters include, but are not limited to, areal coverage, shoot length, epiphyte load, percent coverage, density, and water / sediment quality indicators.

2. Strategy: Maintain standardized mapping of seagrass beds at appropriate temporal and spatial scales.

Objective 2: Determine causes in changes of seagrass species composition, density, and distribution including total loss or gain.

1. Strategy: Conduct research on water column and sediment parameters that affect seagrass health and distribution.

    Action: Assess specific parameters required to maintain 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, epiphytes, and drift macroalgae.

    Action: Assess the biogeochemical environment occupied by below ground tissue, such as, pore water composition.

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

   Action: Determine how donor stocks, including drift grass (detached plants), should be selected to achieve maximum success.

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

   Action: Develop or identify methods for evaluating restored seagrass beds.

Objective 3: Identify habitat functions and productivity of natural seagrass community types and identify linkages with other habitats to support habitat conservation, creation, enhancement, and restoration in the Pensacola Bay system.

1. Strategy: Monitor shoot density and measure faunal communities to determine habitat function and productivity.

2. Strategy: Compare the apparent health and function of associated ecosystem communities with the monitored health of the seagrass beds to establish an interrelation.

Objective 4: Provide data for development of management policies in response to human induced impacts.

1. Strategy: Review existing data on seagrass in the Pensacola Bay system .

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 [jet skis, motor boats, sail boats])
   - Effects of non-point pollution sources on seagrass beds
   - Socioeconomic values and impacts of management on users
   - Effects of the increase of the human population (non-point nutrient loading, user impacts)
   - Repairing propeller scar damage
   - Dredging effects on light attenuation
   - Indirect effects of dredging

Chapter 3.
Management Issues for Pensacola Bay System

Water and Sediment Quality

To ensure water and sediment quality beneficial to the seagrass community, a series of objectives will need to be accomplished: 1) community acceptance of seagrass as an important habitat; 2) developing specific water quality guidelines and criteria to protect seagrass beds; and 3) developing and implementing Best Management Practices (BMPs) which protect seagrasses. Watershed management programs can play an important role in insuring water and sediment quality beneficial to seagrasses.

A strong connection has been established between clean waters and improved boating practices as creating greater potential profits for marinas. It has been shown that marinas can benefit both themselves and the environment by implementing Best Management Practices (BMPs), which reduce pollution in Florida waters. An excellent resource that addresses this issue is the Clean Marina Program, a voluntary program that has been implemented in Northwest Florida by FDEP. The goal of this program is to assist marinas in improving the environmental water quality of Florida's waterways (FDEP, 1998).

Stormwater runoff is the largest contributor to water quality degradation in the Pensacola Bay system. To achieve the desired objectives of water quality protection, erosion control, as well as improved aesthetics and recreation, a stormwater management system must be an integral part of the plan. The most effective deterrent to harmful stormwater runoff is filtration through vegetation.

Marshes and submerged grass habitats are crucial to maintaining health in the Bay system. These various plant species anchor sediments, stabilize the shorelines reducing erosion, and act as filters for stormwater runoff (Figure 3-1). This filtering system can remove pollutants and toxins from the runoff which, in high quantities, often results in algae blooms.

Figure 3-1. Bruce Beach marsh. A mitigation marsh planted in 1991 by the FDEP Ecosystem Restoration Section. This photo was taken approximately 10 years after initial planting.

The economic value of wetlands is indisputable. Acre for acre, wetlands are more productive than many agricultural lands. Florida's sport and commercial fisheries are dependent upon healthy wetland ecosystems. Wetlands bring in tourism dollars from hunters, fisherman, campers, and boaters- as well as those who merely want to look at, photograph, or paint them. (FDEP, 1998)

The Pensacola Bay Watershed Management Guide (FDEP,1998) offers several ideas encouraging environmentally friendly stormwater, landscaping and shoreline erosion control:

1. Encourage the local governments to adopt integrated best management policies and implement environmentally friendly landscaping.

2. Reduce the area of impervious surfaces around homes and buildings. These surfaces increase stormwater pollution by preventing the stormwater from seeping into the ground. Reducing impervious surfaces will reduce stormwater runoff and associated pollution by allowing more water to filter through the soil. The runoff from the first few minutes of rainfall is often equivalent, in nutrient levels, to untreated sewage (Florida Department of Environmental Protection, n.d.).

3. Encourage local jurisdictions to promote the assessment of unpaved roads. There are literally hundreds of miles of dirt roads in Escambia County's District Five, which stretch from Nine Mile Road to the Alabama state line. Poor drainage can be found along almost every dirt road in the rural district. Steady rain erodes the top layer of the red clay roads, creating rivers of sediment and pollutants leading from the ditches to the rivers and streams. This clay and dirt runoff has a direct impact on the vegetation and wildlife. Increasing the sediment in these creeks and rivers not only impacts them directly but impacts the entire drainage basin of the bay. By eliminating or controlling the large amounts of unnatural sediment in our bay and waterways, there will be an overall increase in water quality.

4. Encourage the use of environmentally responsible erosion control methods, especially near creeks, bayous, and shorelines.

Urban development has altered the natural shoreline leading to a significant decline in intertidal marshes, replacing them with "seawalls". Seawalls, though they stabilize the immediate shoreline, offer no buffering treatment to stormwater runoff and may cause excessive erosion to neighboring shorelines by interruption of a natural process known as "long shore drift". The natural alternative to seawall construction is maintaining and restoring intertidal marshes or other shoreline vegetation. These submerged and emergent marshes, directly surrounding the coast's edge, are referred to as buffer zones. Buffer zones provide food and shelter for marine life, stabilize sediments preventing erosion, and filter pollutants from runoff.

Figure 3-2.

FDEP volunteers prepare to vegetate a residential shoreline. Nov 17, 2000

Shoreline is planted. Nov 17th, 2000

Mature buffer zone after approx. one year of growth. Aug 1, 2001

Vegetation also absorbs energy from falling rain, which prevents erosion, and allows for more percolation of water into the ground. Waterbodies without buffer zone protection receive pollutants directly, with no treatment, producing significant impacts on water and sediment quality (FDEP 1998). For this reason, maintaining buffer zones in areas that are already vegetated, and restoring vegetation to areas that have been negatively impacted are important aspects in sustaining and improving the water quality in our area waterways. Natural buffer zones are also pleasing to the eye, allow for view of the water, and require no maintenance while offering all the benefits of a healthy shoreline.

Current Seagrass Monitoring Program

The FDEP Ecosystem Restoration Section is currently involved in the second year of a seagrass monitoring study within Big Lagoon and Santa Rosa Sound. The study involves four major areas of monitoring: seagrass monitoring, water quality monitoring, photosynthetically active radiation (PAR) monitoring, and porewater sulfide sampling. At this time, there are 20 study sites- eight in Big Lagoon and twelve in Santa Rosa Sound (Figure 3-2).

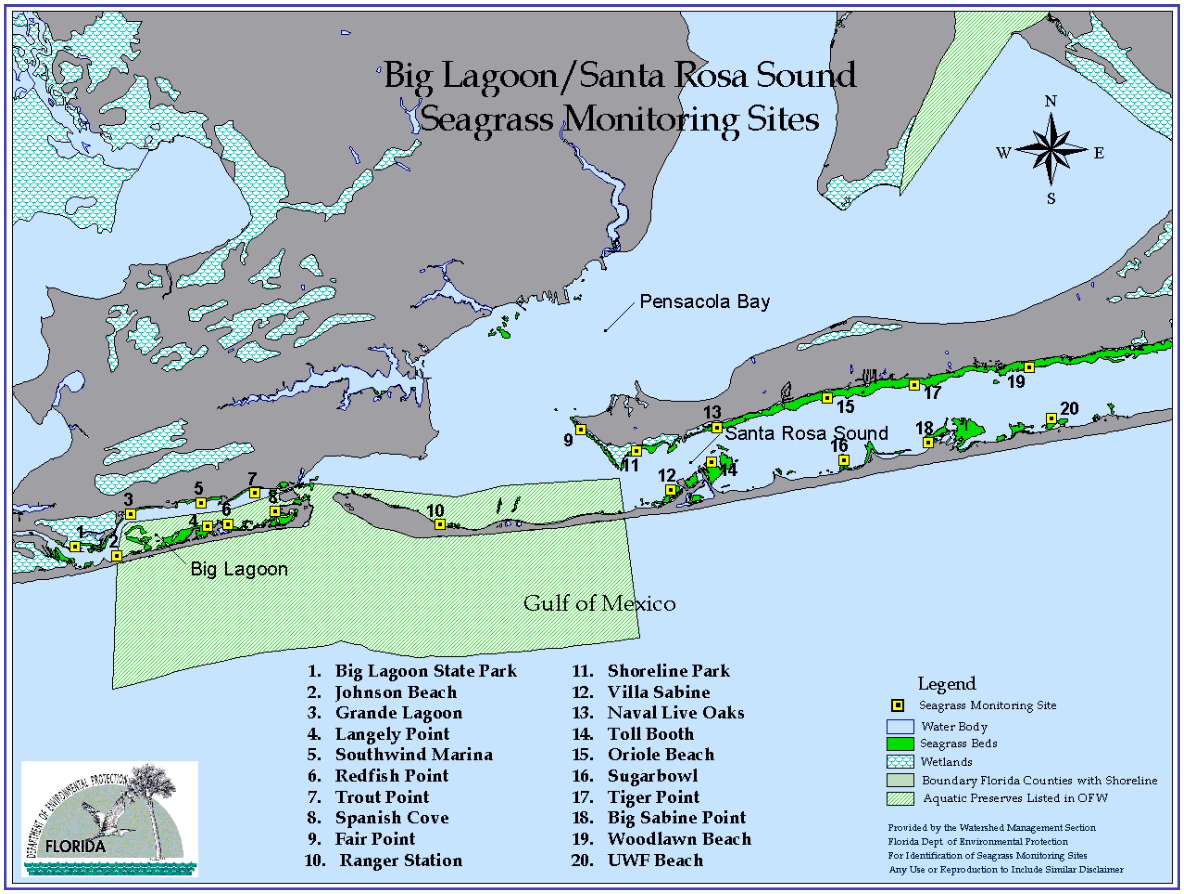


Figure 3-3. Current seagrass monitoring sites.
Big Lagoon has been assigned eight sites with the remaining twelve in Santa Rosa Sound. Site ten is considered to be located within Santa Rosa Sound.

Detailed monitoring of the twenty transects involves physically measuring water depth, blade height, percent coverage, density, and species composition of the seagrass (Figure 3-3). This monitoring takes place twice a year; once at the beginning of the growing season (April), and once again near the end of the growing season (September). In addition to seagrass monitoring, porewater sulfide is sampled bi-monthly, water quality is monitored monthly, and PAR is monitored bi-weekly. For accuracy in establishing baseline data, monitoring was performed the same time each year for 1999, 2000, and 2001.

Figure 3-4. Seagrass Monitoring

Based on the information obtained, a fairly accurate evaluation can be made to determine the current status and health of local seagrass communities, and possibly extrapolate the health of the grass beds for the near future. Trends, however, are more difficult to identify with only two years of data. The purpose of this monitoring program, therefore, is to provide a solid baseline needed to determine a trend from future monitoring, and provide a starting point for future management activities.

Preliminary Monitoring Results

Maximum depth of seagrass growth: Out of this baseline data, a spatial comparison can be drawn about the maximum depth at which the grass beds are growing. Three graphs were created depicting the maximum depths to which the grass beds grow at each of the twenty monitoring sites. Comparisons were drawn between the north and south shores, Big Lagoon and Santa Rosa Sound, and distal / proximal sites in reference to Pensacola Pass. The orientation of the graphs below correspond to the natural geographic orientation of Big Lagoon and Santa Rosa Sound (east to west) where Pensacola Pass lays between sites 7 and 9 (see Figure 3-2 for exact site location).

Along the north shore, seagrass grows to a deeper depth in Santa Rosa Sound (approximately 2.5m) than in Big Lagoon (approximately 1.5 meters) (Figure 3-5). The white bars indicate the water depth at the deep edge of the grass beds on the north shore of Big Lagoon. The green bars indicate the depth at the deep edge of the grass beds on the north shore of Santa Rosa Sound. Refer to Figure 3-2 for exact site location.

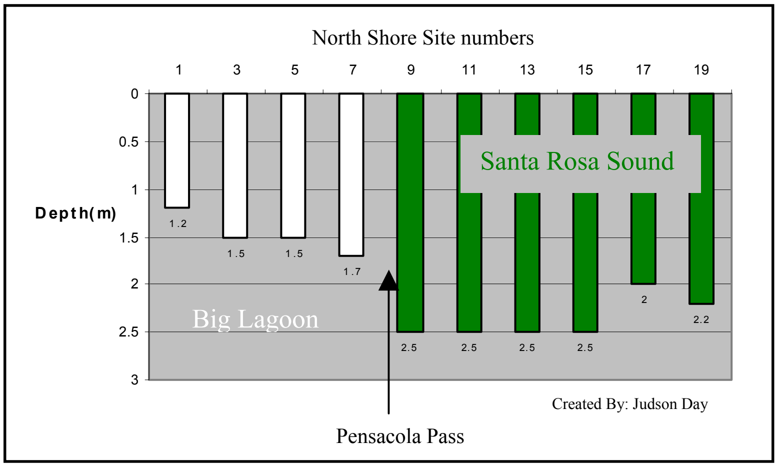


Figure 3-5. Depth of the deep edges of seagrass on the north shores of Big Lagoon and Santa Rosa Sound.

Along the south shore of Santa Rosa Sound, seagrass grows to approximately 2.0 meters, where growth in Big Lagoon reaches, on average, 1.4 meters (Figure 3-6). Red bars indicate water depth at the deep edge of the grass beds on the south shore of Big Lagoon. Yellow bars indicate depth at the deep edge of the grass bed along the south shore of Santa Rosa Sound. It is evident that seagrass not only reaches a deeper depth in Santa Rosa Sound, but is deeper along the north shore than the south shore.

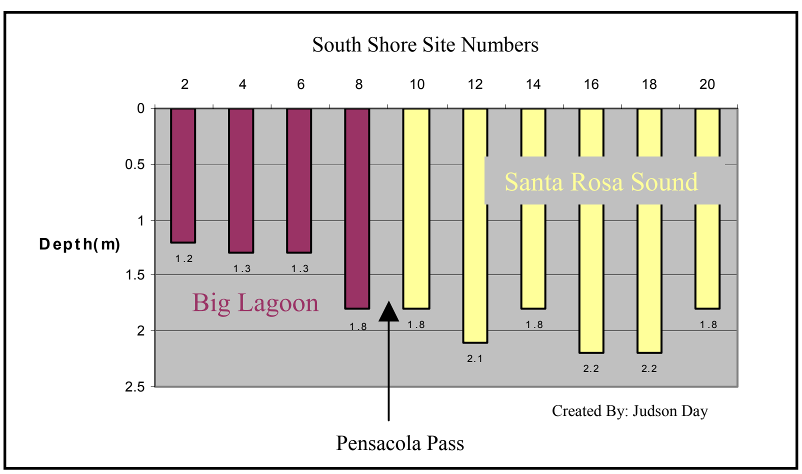


Figure 3-6. Depth of the deep edges of the seagrass beds on the south shores of Big Lagoon and Santa Rosa Sound.

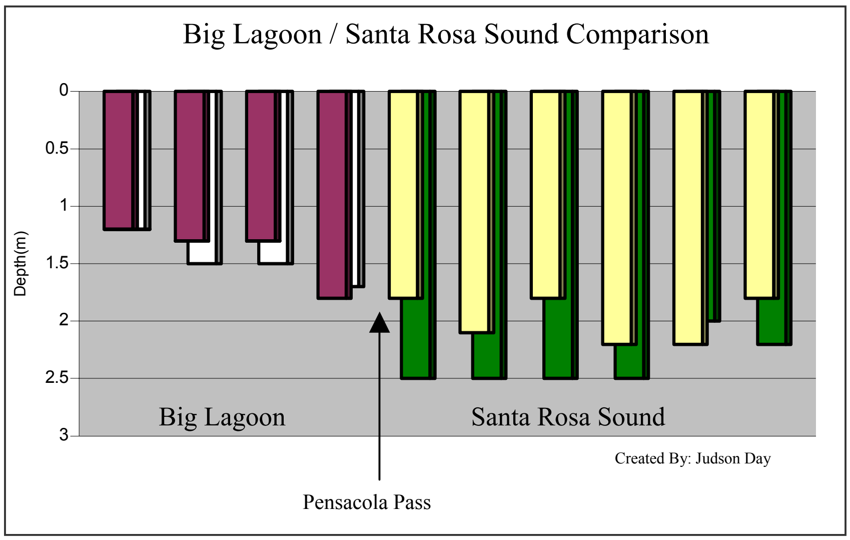
On a larger scale, seagrass grows to a deeper depth on both shores of Santa Rosa Sound than in Big Lagoon. The average depth for growth in Big Lagoon is 1.4 meters, with the most shallow at the far west end (around Big Lagoon State Park) and slowly increasing in depth eastward toward the pass. The average depth in Santa Rosa Sound is 2.2 meters, with one of the most shallow sites at UWF Beach (site 20) and slowly increasing westward toward the pass on the north shore. The south shore remains, on average, constant westward (Figure 3-7). Figure 3-7 was created by an overlay of Figure 3-5 onto figure 3-4.

The results show that as you move toward the pass, the grass beds grow increasingly deeper. This, and the fact that Santa Rosa Sound has a deeper average depth, may be due to increased flushing, and an overall better water quality (i.e. lower light availability in Big Lagoon caused by excessive turbidity and stormwater impacts).

Figure 3-7. A 4-way comparison between the deep edge depths on the north and south shores, and between Big Lagoon and Santa Rosa Sound.

White = Big Lagoon North Shore
Red = Big Lagoon South Shore

Green = Santa Rosa Sound North Shore
Yellow = Santa Rosa Sound South Shore



Epiphyte Load: Epiphytes refer to tiny plants and animals attached to the blades of the seagrass, yet living independently from them. While there is no parasitism involved in this relationship, a high quantity of epiphytes on the blades can reduce the amount of sunlight available to the seagrass plant.

An area marked by high epiphytic growth may be a sign of eutrophication. The excessive nutrients in the water column can stimulate the growth of epiphytic algae.

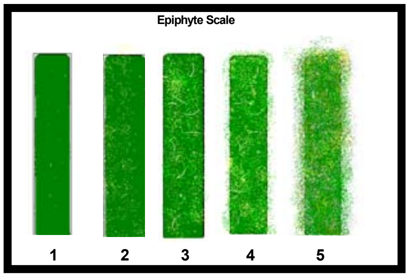


Figure 3-8. Epiphyte load is measured on a scale of 1 to 5, where 5 represent fully covered blades that appear fuzzy.

Epiphytes are rated on a scale of 1 to 5 (figure 3-8) with measurements taken every 20 meters along the monitoring transect. The readings for that transect were then averaged to provide and accurate representation of overall epiphyte coverage for that monitoring site at that time.

As a result, 17 out of 20 sites monitored in Spring 2001 indicate an increase of epiphytic coverage compared to the previous 2 years, with the most dramatic increase is in Big Lagoon (Figure 3-9). This suggests there may have been an increase in the amount of nutrients in our local waterways over the past 2 years. If eutrofication has taken place, there should be more indications of this in other areas of monitoring, such as water quality.

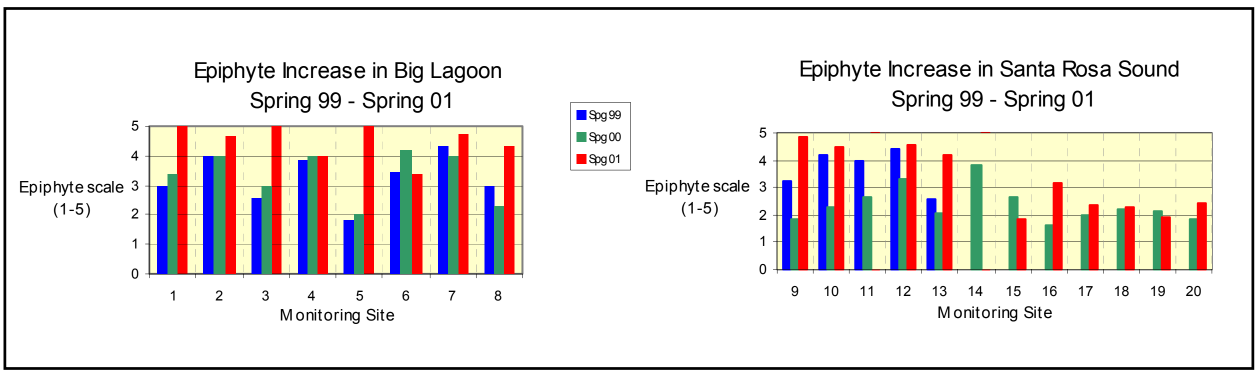


Figure 3-9. An overview of epiphyte data for all 20 monitoring locations. Data from spring 1999 is part of a preliminary study conducted before the 2-year monitoring program began.

Water Quality Monitoring: Water quality monitoring is conducted every month at each of the 20 monitoring sites. The data is catagorized into two sets of parameters, hydrolab and laboratory. The hydrolab parameters are measured on site with a water quality meter and include temperature, dissolved oxygen, pH, and salinity. Secchi depth is also included with the hydrolab parameters. Laboratory parameters require chemical analysis and include turbidity, color, conductivity, nonfiltered residue, ammonia, Kjeldahl nitrogen, nitrate + nitrite, total phosphate, and chlorophyll-a. Algal growth potential (AGP) is measured every other month.

Algal blooms and excessive turbidity in the water column can reduce the amount of sunlight available to seagrass for photosynthesis. One indication of increased algae due to excessive nutrients is an increase in both chl-a and color. However, when turbidity has increased, while chl-a and color remain low, stormwater runoff, or some other stirring mechinism (i.e. boating), may be the cause of light attenuation. Results of water quality monitoring for the parameters of chl-a, color and turbidity suggest an increased eutrification over the past 2 years (Figure 3-10). The summer months of July and August normally show seasonal trends of increased Chl-a and color compared to other months of the same year. Not only is this trend evident in the data, but those seasonal highs have also increased over the last two years.

1999		Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99	Jul-99	Aug-99	Sep-99	13Oct99	Nov-99	Dec-99
	Chl-a (ug/L)	no data				und	und	und	und		und	und	und
	Color (Pt-Co)					5.0	5.0	10.0	10.0		5.0	10.0	5.0
	Turb (NTU)					1.0	0.0	1.0	1.0		1.0	2.0	0.0

2000		Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00
	Chl-a (ug/L)	und	und	und	und	und	und	und	8.0	8.5	und	und	und
	Color (Pt-Co)	5.0	5.0	0.0	5.0	5.0	20.0	20.0	20.0	30.0	5.0	5.0	10.0
	Turb (NTU)	2.0	4.0	1.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	1.0	2.0

2001		Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Aug-01	Sep-01	Oct-01	Nov-01	Dec-01
	Chl-a (ug/L)	und	und	6.7	und	und	und	5.9	9.6	und	und	und	
	Color (Pt-Co)	5.0	5.0	30.0	20.0	10.0	20.0	20.0	30.0	20.0	20.0	10.0	
	Turb (NTU)	1.0	0.0	2.0	2.0	1.0	7.0	2.0	4.0	7.0	5.0	4.0	

* und = undetectable

Figure 3-10. Water quality monitoring results for the parameters of chl-a, color, and turbidity. While there currently are no set standards for chl-a, color, and turbidity for the state of Florida, current monitoring results are compared to the proposed Impaired Waters Rule (Chapter 62-303, F.A.C).

Light Attenuation Monitoring: Photosynthetically active radiation (PAR) is the part of the spectrum, between 400 and 700 nanometers (nm) that plants use for energy. Seagrass requires about 25% of surface PAR for photosynthetic production. For example, if the PAR is 9.5 Moles per square meter (M/m2) just below the surface of the water, then the seagrass requires 2.4 M/m2 of PAR for optimal survival. Underwater vegetation is less likely to receive sufficient sunlight (PAR) to sustain growth when light reaching the plants is reduced due to water turbidity and algae blooms.

The current light attenuation study suggests that immediately after a heavy rainfall, stormwater input inhibits the amount of PAR available to the seagrass. Figure 3-7 illustrates light attenuation at the deep edge of a grass bed in 4.5 feet of water. Although the storm event lasted only one day, the inhibited PAR persisted for several days after the rainfall due to increased turbidity and nutrient enrichment from stormwater runoff.

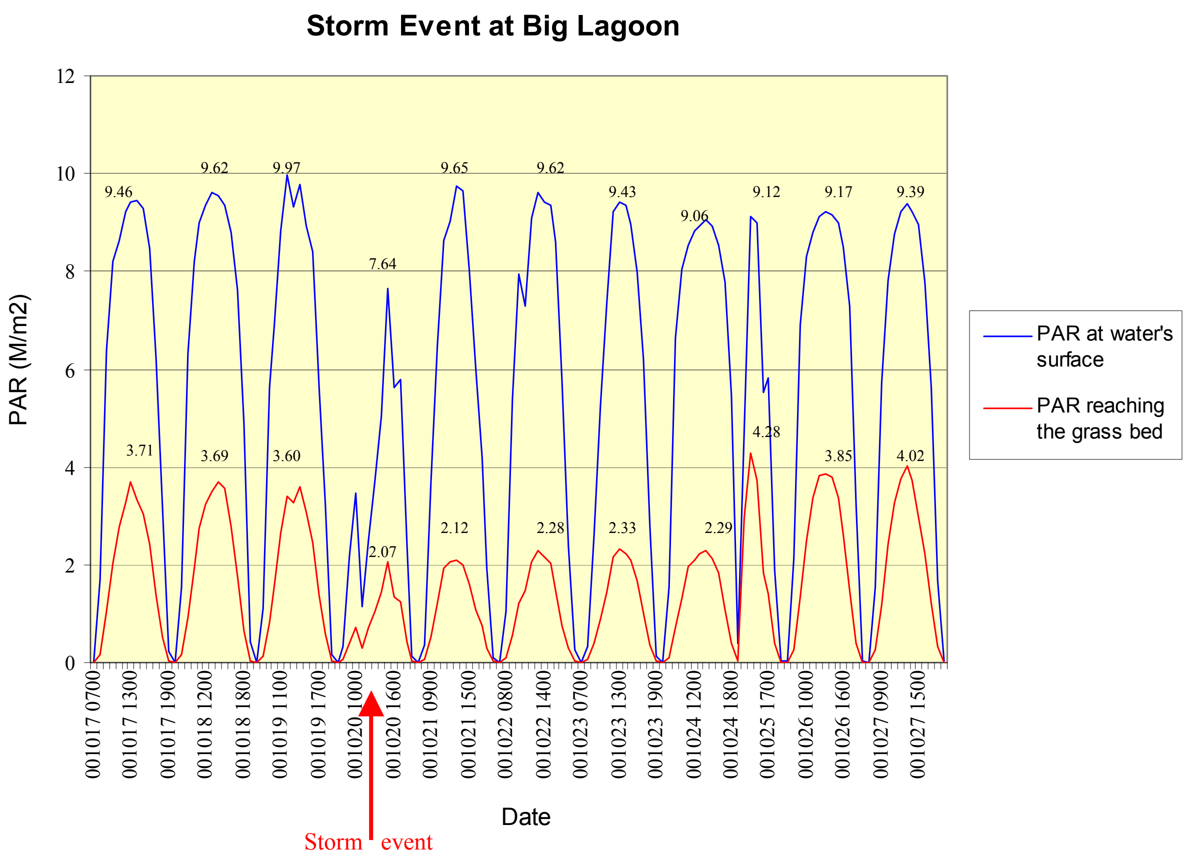
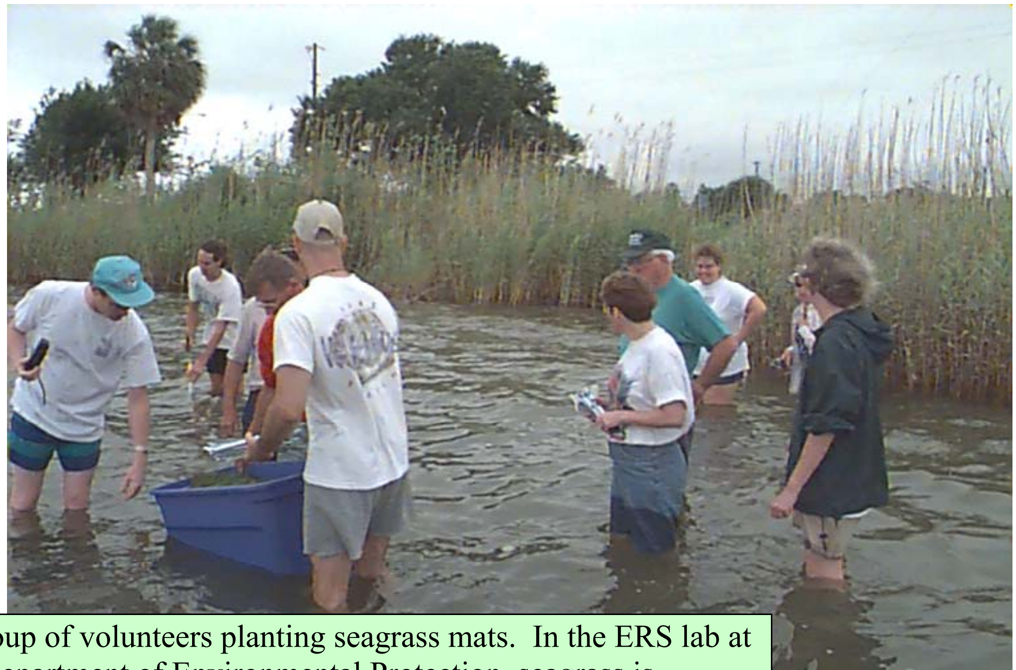


Figure 3-11 A sufficient amount of PAR was diminished for several days while turbidity settled after a storm event. Dates are listed YYMMDD HHMM.

October 19th indicates a normal day with surface PAR around 9.6 M/m2 and underwater PAR (grass blade depth) around 3.7 M/m2. Available PAR to the grass bed is about 38% of surface PAR.

October 20th indicates a storm event with decreased surface and underwater PAR due to clouds and rain. Following the storm event, surface PAR returned to normal while underwater PAR remained inhibited for days due to increased turbidity from stormwater runoff. Available PAR has decreased to insufficient levels of around 22%, and persisted for four days before returning to normal.



A group of volunteers planting seagrass mats. In the ERS lab at the Department of Environmental Protection, seagrass is

Chapter 4.

Environmental Awareness Through Education and Public Outreach

Education Outreach

Seagrasses are an important natural resource for the citizens of NW Florida, but few realize the many benefits or their personal impacts on these resources. Education can be the best and most lasting way in which to protect seagrass because, if done successfully, education will lead to behavioral changes that will reduce impacts on this important ecosystem (Texas Parks and Wildlife, 1999).

One of our most pressing tasks is that of balancing the overall development of our society with the ecological health of our communities. The challenge will be met only through active and informed citizens. Defining a new social and ecological balance requires that we understand our place in the ecosystem, that we recognize our responsibilities toward this ecosystem, and that we be prepared to take action on this basis. By learning and taking independent action, environmental citizens help prevent problems that otherwise would require difficult and costly solutions. Informed participation in public debate over issues of environment and development inspires good policy making (FDEP 1998).

Progress toward a better-informed and more involved citizenry will not occur without intensive efforts by educators, environmental groups, industry, business, and community organizations. Active citizenship means being involved. Effective citizenship requires that we first become informed. Environmental citizens must understand the interrelationship between ecosystems and the importance of biological integrity. The effects of the growing population on surrounding areas must be realized (FDEP 1998).

At this time, members of the FDEP Ecosystem Restoration Section freely spend time educating members of the community, both adults and children. This is accomplished through tours of the seagrass laboratory and plant nursery, through educational workshops, through community meetings concerning local environmental and restoration issues, and through on-hands restoration opportunities available to individuals, schools and organizations (no experience necessary).

Figure 4-1. A group of students accept the opportunity to help restore an area of wayside

Without such educational opportunities, people remain uninformed of the true causes of ecosystem degradation. If people remain uninformed in this area, then it is expected that further degradation will be in our future.

Seagrass Education Plan

Priority Goal: To provide the public with a better understanding of the importance of seagrass ecosystems and how human activities affect these systems.

Objective 1: To educate the public on the status, value, ecology, and conservation of seagrasses in the Pensacola Bay System.

Strategy 1: Develop and deliver messages for targeted audiences

Suggested actions:

1. Distribute pamphlets to homeowners located in the identified critical areas regarding proper maintenance of septic systems and landscaping.
2. Produce pamphlets for availability at sporting goods and recreation businesses and other public areas such as yacht clubs where people will be likely to pick one up.
3. Provide materials for formal and informal education groups (girl scouts, boy scouts, 4-H)

Strategy 2: Develop and deliver messages for the general public through various media.

Suggested Actions:

1. Provide press release and public information messages on current research and restoration projects.
2. Generate radio press releases, radio public service announcements (WUWF)
3. Hold media events associated with conservation activities.
4. Create a seagrass conservation web site.
5. Distribute information inserts to be distributed with voter registration, utility bills, etc.
6. Make an educational video to inform organizations.

Strategy 3: Develop and distribute messages for formal education.

Suggested action

1. Offer and accept speaking engagements to local schools and universities regarding seagrasses

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

Strategy 1: Develop skills through demonstration programs and workshops

Suggested actions

1. Deliver boater education seminars on seagrass protection skills at boat shows and fishing shows.
2. Provide detailed information on seagrass protection methods.
3. Provide workshops on seagrass conservation and restoration.

Strategy 2: Provide supplemental material and aids, which support responsible behavior.

Suggested actions

1. Post signs about seagrass protection at boat ramps.
2. Mark seagrass areas with buoys or signage.
3. Encourage mapmakers to document seagrass areas on fishing maps as areas to avoid or use caution.
4. Designate “no wake” or “non-combustion” zones in seagrass areas.
5. Provide “before and after” 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. Develop volunteer restoration projects.
3. Initiate conservation plantings for public service projects.

References Cited

Day, John W.; Hall, Charles A. S.; Kemp, W. Michael; Yanez-Arancibia, Alejandro 1989., Estuarine Ecology, Ch 9- The estuarine Bottom and Benthic Subsystem, 558pp.

Florida Department of Environmental Protection, 1998. The Pensacola Bay Watershed Management Guide: An Integrated Ecosystem Action Plan, 268pp plus appendices

Florida Department of Environmental Protection, n.d. Florida State of the Environment: Stormwater Management, 16pp.

Florida Department of Environmental Regulation, n.d. Stormwater Management: A Guide for Floridians, 72pp.

Florida Department of Environmental Regulation, 1988. The Florida Development Manual: A Guide to Sound Land and Water Management. Chapter 6, 721pp.

Fonseca, Mark S. ; Kenworthy, W. Judson ; and Thayer, Gordon W., 1998. Guideline for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters. NOAA Coastal Ocean Program Decision Analysis Series No. 12. NOAA Ocean Office, Silver Springs, MD. 222pp

Heck, K. L. Jr., et al. 1996. An Ecological Analysis of Seagrass Meadows of the Gulf Island National Seashore – Years One, Two, and Three: Seasonal Assesment and Inventory, Interaction Studies and Assessment/Inventory.
Marine Environmental Science Consortium, University of South Alabama, P.O. Box 369 Dauphin Island, Al 36528

Porter, Mona. Florida Department of Highway Safety and Motor Vehicles, E-mail, 2000. porter.mona@hsmv.state.fl.us

Texas Parks and Wildlife, 1999. Seagrass Conservation Plan for Texas, Resource Protection Division, Austin, TX. 79pp

U.S. Environmental Protection Agency, 1975. Environmental And Recovery Studies of Escambia Bay And The Pensacola-Bay System Florida, Ch 12, EPA 904/9-76-016.