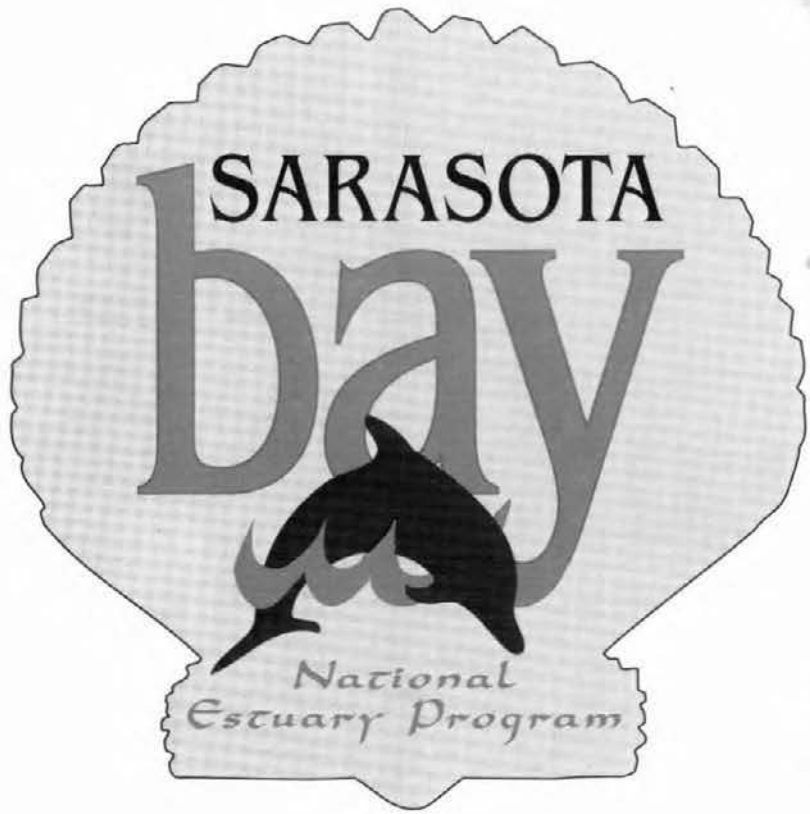
Framework For Action



Sarasota Bay National Estuary Program

Framework for Action

Sarasota Bay: Framework for Action

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A Preface to *Sarasota Bay: Framework for Action*

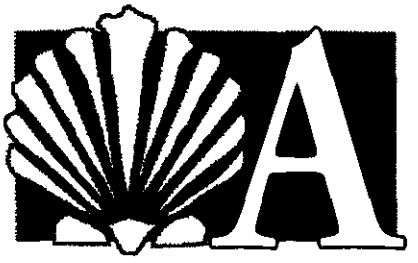
Sarasota Bay: Framework for Action was produced by the Sarasota Bay National Estuary Program to characterize the condition of Sarasota Bay and present preliminary options for Bay improvement. This publication is a precursor to the *Comprehensive Conservation & Management Plan* scheduled for completion in Summer 1994.

A summary of the Program's technical findings is presented in the *Framework's* State of the Bay chapter, with greater technical detail provided in succeeding chapters. Technical chapters were written by Principal Investigators whose work was performed under contract to the Sarasota Bay Program. A helpful synthesis of technical work, analyzing relationships between and among the scientific findings, can be found in the Technical Synthesis chapter.

The *Framework for Action* has been nationally peer-reviewed for technical accuracy. Additional technical detail is available in peer-reviewed technical reports provided to the Sarasota Bay Program by Principal Investigators.

To request additional copies of the *Framework for Action* or to submit comments on this document for review by the Sarasota Bay Program, write to: Sarasota Bay Program, 1550 Ken Thompson Parkway, Sarasota, FL, 34236, Attn: Heidi Smith.

Sarasota Bay: Framework for Action



A Vision for Sarasota Bay

s an estuary, where freshwater from creeks and rivers mixes with saltwater from the sea, Sarasota Bay provides a nursery for most marine life. Located on Florida's fast-growing southwest coast, Sarasota Bay also is the center of a community of more than a half-million people.

The community of Manatee and Sarasota counties depends on the Bay for both recreation and commerce. Boating, fishing, swimming and nature study are a few typical recreational uses that also help support a variety of local businesses. The Bay and beaches also are at the center of a multi-million-dollar tourism industry.

Because of their economic, aesthetic and recreational value, estuaries like Sarasota Bay are increasingly attractive to both people and commerce. It is estimated that 80 percent of the population of the United States will live within 50 miles of a seashore by the year 2000.

Like other areas of the United States and Florida, the Sarasota Bay region continues to experience rapid population growth and increased development. The area's population is expected to grow by 25 percent during the next 10 years, accompanied by increasing pollutant and use impacts likely to threaten the Bay's health.

Recognizing the potential for further destruction of the Bay's ecosystem, the local community is participating in the Sarasota Bay National Estuary Program to develop comprehensive strategies to improve the Bay and provide a vision for what Sarasota Bay can become.

Sarasota Bay Past

Barely 50 years ago, natives of the Sarasota Bay region painted a vibrant portrait of Sarasota Bay. Seagrass meadows were teeming with scallops, and oyster harvests were bountiful. Sand flats were thick with clams. The fish population was so abundant that one long-time resident recalls, "You could hardly row across to one of the keys without ending up with a dozen or so fish in your boat."

Sparsely developed, mangrove-lined shores stretched as far as the eye could see, with native plants filtering runoff from the land before pollutants reached the Bay.

Clear, clean water provided excellent habitat for fish and other marine life.

Small, intimate communities bounded the Bay; everyone knew everyone else, and the sense of place was strong.

Sarasota Bay Present

The present Sarasota Bay is very different.

Seagrass beds are diminished, and remaining seagrass flats are scarred by the tracks of boat propellers. Scallop, oyster and clam harvests have been reduced, and anglers' catches are generally reduced as well.

Natural shoreline habitats have been replaced by seawalls, and once-abundant mangrove wetlands are depleted.

Intense residential and commercial development is found throughout the Bay area, with an accompanying increase in stormwater runoff, wastewater pollution, sediment and chemical contaminants flowing into the Bay.

The human environment has changed as well, with people often unfamiliar with their neighbors and generally lacking a sense of place and community.

Sarasota Bay Future

Sarasota Bay's future depends on each of us, as tremendous opportunities exist for improving our damaged Bay. Through the Sarasota Bay Program, the community is creating a new vision for Sarasota Bay.

In this brighter future, water quality improves throughout the Bay, with a resurgence of submerged seagrasses and related marine life. Catches of fish increase for both recreational and commercial fishermen.

Wetlands, both freshwater and tidal, are restored. Existing wetlands, viewed as vital links between people and the Bay, are protected from harm. Canals in residential communities become dramatically more-productive habitats for marine life.

The community aggressively pursues stormwater management and treatment. Residents naturalize their yards, planting native habitats for birds and wildlife, and wildlife returns.

Direct discharges of wastewater to Sarasota Bay are minimized. Septic tanks and ineffective package treatment plants are replaced with environmentally appropriate treatment systems with effluent reuse. Treated wastewater is perceived by residents as a source of water to be used for irrigation, rather than a by-product for disposal.

Inlets and passes are managed and monitored as mechanisms for improving the Bay.

Recreational opportunities increase as the Bay improves and conflicts between user groups are resolved.

Management and protection of the Bay are central to the decisions of government and the practices of citizens. Citizens and government share a common goal: to implement a comprehensive Bay restoration plan.

The Role of the Sarasota Bay National Estuary Program

In an effort to reclaim paradise by achieving this vision for the Bay, the community, local governments and Mote Marine Laboratory brought the National Estuary Program to Sarasota Bay. National Estuary Programs combine the knowledge of citizen and technical advisors, senior governmental officials and staff, plus elected officials to promote bay protection and enhancement.

Sarasota Bay was selected for inclusion in the elite ranks of the National Estuary Program in July 1988 by the U.S. Environmental Protection Agency

(EPA). Unlike estuaries in many other areas of the country that already were part of the national program, Sarasota Bay was not faced with industrial pollution. Instead, pollution and habitat loss from development and overuse were the main threats to a once-pristine resource. Pressures from growth made Sarasota Bay an excellent national and state model for strategies to help other fast-growing coastal areas of the country.

The Sarasota Bay Program officially began with the signing of a five-year agreement among local, state and federal government agencies on June 26, 1989. The agreement specified that the Program would produce three major documents: the *State of the Bay Report* in 1990, the *Framework for Action* in 1992 and the *Comprehensive Conservation & Management Plan* in 1994.

The Sarasota Bay National Estuary Program also established a broad-based committee network linking policy, management, citizen and technical leaders to develop a strategy to improve Sarasota Bay.

Seven goals guided initial stages of the Program and supported development of technical projects to investigate Bay problems. Those goals are:

- Improve water transparency.
- Reduce the quantity and improve the quality of stormwater runoff.
- Restore lost seagrasses and shoreline habitats, and eliminate further losses.
- Improve beach, inlet and channel management.
- Provide increased levels of managed access to Sarasota Bay and its resources.
- Establish a management system for Sarasota Bay.
- Restore and sustain fish and other living resources in Sarasota Bay.

Fostering a cooperative spirit among federal, state and local governments as well as private citizens, the Sarasota Bay Program initiated a variety of technical, public outreach and early action projects to support development of a comprehensive management plan for the Bay.

During the collection of technical data on the Bay for inclusion in this report, the Sarasota Bay Program achieved a number of unique accomplishments:

- The Program implemented one of the most spatially intensive water-quality monitoring programs in the United States, supported by state, local and private personnel and respective laboratories.

- The Program contracted to produce one of the most extensive environmental data bases on any bay and watershed in the United States, and analyzed data using a computer system to more definitely characterize Bay problems and develop solutions.

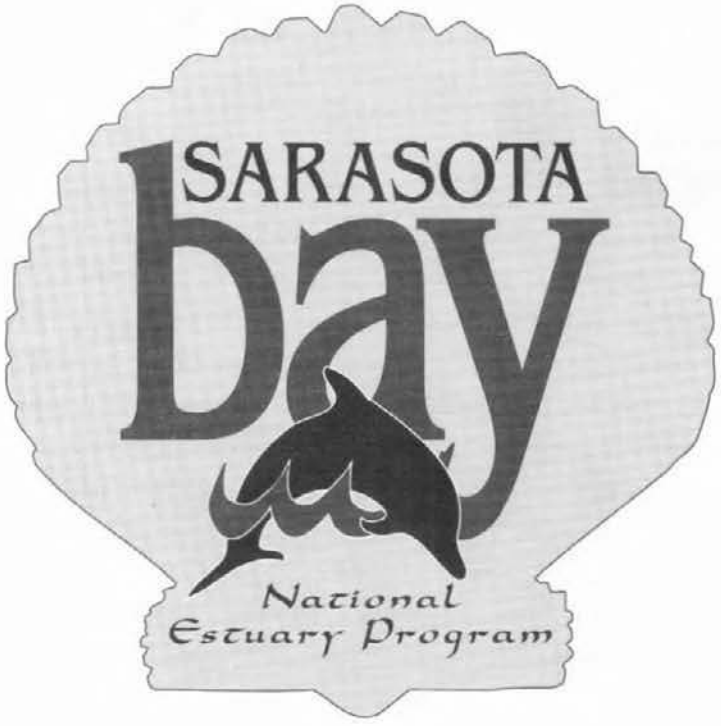
• The Program monitored ongoing local government actions that impact water quality in the Bay.

• The Program launched an aggressive public-education and outreach program in cooperation with the local school systems, Florida State University, Mote Marine Laboratory, Florida Sea Grant College and various community organizations in the region.

• The Program secured funding for and oversaw a series of projects that will restore 80 acres of intertidal habitat, or 4.5 percent of the habitat lost since 1950. These restoration projects have received national recognition for innovation and have been visited by environmental managers throughout the country.

The Program's first major document, the *State of the Bay Report 1990*, summarized existing information about the Bay and presented the Sarasota Bay Program's work plan. A companion publication, the *Bay Repair Kit*, is an award-winning homeowner's guide for Bay protection.

This report, *Sarasota Bay: 1992 Framework for Action*, will be extensively reviewed by citizens, government agencies, technical advisors and elected officials. The management options presented for discussion in this document will be refined and incorporated into the Program's final document, the *Comprehensive Conservation & Management Plan.* Scheduled for release in June 1994, the plan will present strategies and financing options the community will employ to solve Sarasota Bay's problems.



State of the Bay

State of the Bay

by Mark Alderson
Sarasota Bay Program

During the past 50 years, human activities have caused a slow but steady decline in the general health of Sarasota Bay. The people of Manatee and Sarasota counties are now realizing the extent of damage that began with massive dredge-and-fill projects in the 1950s, and continued with the community's rapid growth and associated pollution.

Only recently has the community noticed improvements in the Bay, largely as a result of concerted government action to improve water quality through better wastewater treatment. Still, past destruction of seagrasses and mangroves, and continuing pollution from wastewater and stormwater, present a major challenge for the stewards of Sarasota Bay.

Sarasota Bay: 1992 Framework for Action describes the state of the Bay in detail, presenting the most comprehensive technical information ever compiled on Sarasota Bay. Scientists report on nature's indicators – water and sediments, fish and shellfish, seagrasses and mangroves – to define the extent of Bay problems. This work, conducted by some of the state' s finest estuarine scientists, reveals a natural resource in jeopardy. In fact, past alterations to the Bay have been so dramatic that restoration to a pristine condition will not be possible.

Significant improvements in Sarasota Bay can be made, however – but only through intensive community action. In this spirit, *Sarasota Bay: 1992 Framework for Action* suggests solutions to Bay problems for community discussion. By the summer of 1994 a firm plan of action will emerge, including financing strategies and agency responsibilities.

With the involvement of area residents and concerted effort by local, state and federal governments, a better balance between human uses and the health of Sarasota Bay can be achieved. The area's economy and its residents' quality of life depend largely upon the community's success.

Findings of Fact

Circulation

Circulation is the movement and mixing of water throughout the Bay, important to its water quality because this movement disperses pollutants while distributing organic matter that contributes to the Bay's food web.

• Much of the environmental damage to Sarasota Bay occurred during the 1950s and 1960s, through construction of the Intracoastal Waterway and canal communities throughout the region. These dredge-and-fill projects covered productive seagrass beds that once provided habitat for fish and other Bay life. Dredging projects also changed water circulation and salt content (salinity), extensively altering habitats for finfish and shellfish. Damage to the Bay from altered circulation was exacerbated by stormwater and wastewater pollution as the area rapidly developed.

• Projects proposed to enhance water circulation, such as reopening Midnight Pass, have been hotly debated, polarizing the community. Enhancing water circulation in Little Sarasota Bay by opening Midnight Pass would significantly improve water clarity in the general vicinity of the pass, in addition to improving circulation from Coral Cove to Blackburn Point. However, circulation would decrease near Phillippi Creek and in southern Roberts Bay, increasing the potential for pollutant impact in those areas.

• Preliminary information suggests that circulation in northern Sarasota Bay is signficantly influenced by the Manatee River. Ongoing investigations will further define the river's impacts on the Bay.

Pollutant Sources, Water and Sediment Quality

The principal pollutants of concern in Sarasota Bay are nutrients (primarily nitrogen) and toxic substances (heavy metals and pesticides). An over-abundance of nitrogen harms the Bay by increasing algal growth, which reduces light penetration to submerged grasses and, through biological and chemical processes, depletes oxygen from the water. Toxic substances such as heavy metals and pesticides can be deadly or may interfere with reproduction or larval development in fish and shellfish.

Nutrients

• Human-induced sources of nitrogen include stormwater (including fertilizers from lawn care and agriculture), wastewater (including small and large wastewater-treatment plants) and groundwater (from septic systems and small treatment plants).

• Current nitrogen loadings into Sarasota Bay are approximately 300 percent of what existed before the region was developed. Nitrogen loadings are projected to increase only eight percent during the next 20 years, and 16 percent when the area is fully developed according to existing plans.

Wastewater

• Improvements at wastewater-treatment operations in Manatee County and the City of Sarasota have contributed to improved water quality in the central and northern portions of Sarasota Bay. Both plants pump the nitrogen-rich treated wastewater to irrigate golf courses and farms, where the water and nitrogen are both needed. Expansion of reuse systems at both plants is underway. Reusing treated wastewater for irrigation reduces nutrient pollution of the Bay and uses limited water resources more efficiently, by replacing potable water as a source of irrigation.

• Achieving Advanced Wastewater Treatment (AWT) standards at the City of Sarasota's plant in 1991 reduced the plant's nitrogen loading to the Bay by 80-90 percent, resulting in a 14-percent decline in Baywide nitrogen loadings. The plant now contributes less than three percent of the Bay's total nitrogen loadings.

• The amount of nitrogen that may be introduced into Sarasota Bay from wastewater-treatment plants is regulated by law; nitrogen pollution from septic systems is not regulated by federal, state or local laws,

Mark Alderson

Mark Alderson was appointed Director of the Sarasota Bay National Estuary Program in 1989. Mr. Alderson has extensive experience in developing and implementing coastal restoration and protection programs for the U.S. Environmental Protection Agency (EPA). He participated in EPA's Chesapeake Bay and Great Lakes programs, and assisted in forming the National Estuary Program while serving at EPA headquarters in Washington, DC. He also helped form coastal management initiatives throughout the south, including Galveston Bay, Albermarle/Pamlico Sounds, Tampa Bay, Sarasota Bay and Barataria-Terrebonne Bays. Mr. Alderson has an M.S. degree in Water Resource Management from Southern Illinois University and a B.S. degree in Environmental Science from the University of Maryland.

Current nitrogen loadings into Sarasota Bay are approximately 300 percent of what existed before the region was developed.

however. Septic systems remove bacteria to prevent hazards to human health, but removing nitrogen to protect water resources is not the primary function of a septic system. Residual nitrogen from septic systems is transported to the Bay by groundwater.

• Wastewater treatment in the Little Sarasota Bay region of Sarasota County is provided by 45,000 septic systems and 71 small wastewater-treatment plants, some of which can load nutrients similarly to septic systems.

• Septic systems in Sarasota County contribute approximately four times more nitrogen to the Bay through groundwater transport than the City of Sarasota's wastewater-treatment plant discharges into Whitaker Bayou.

Stormwater

• Baywide, stormwater contributes approximately 50 percent of Sarasota Bay's nitrogen content.

Residential land uses contribute 30 percent of nitrogen loads to the Bay. High nitrogen loads from residential areas are associated with the use of nitrogen-based fertilizers in yards.

• Land uses are important in calculating stormwater loadings of nitrogen into the Bay. Land uses in the Sarasota Bay region include 40 percent residential, 10 percent other urban development, 10 percent agricultural and 40 percent natural or pasture land.

• Residential land uses contribute 30 percent of nitrogen loads to the Bay. High nitrogen loads from residential areas are associated with the use of nitrogen-based fertilizers in yards.

• Stormwater pollution can be reduced in developed areas by improving existing stormwater-management structures, reducing erosion and improving landscape-maintenance practices. For example, an estimated 30 percent less nitrogen will reach Sarasota Bay from Clower Creek in Sarasota County when stormwater management is improved in the area. Also, up to 80 percent of suspended solids, which decrease water clarity, will be removed before they reach the Bay.

• Both Manatee and Sarasota counties have developed Stormwater Environmental Utilities to improve stormwater management. Sarasota County has adopted a fee structure and is planning improvement strategies for priority areas, including Phillippi Creek and Hudson Bayou. Manatee County is expected to adopt a fee structure in 1993.

Habitat Loss

- **Bay bottom disturbed: 15 percent**
- **Seagrass lost: 30 percent**
- **Tidal wetlands lost: 39 percent**
- **Freshwater wetlands lost: 16 percent**

Toxic Substances

• The major source of heavy metals and pesticides in Sarasota Bay is stormwater runoff, except in the case of zinc, which is largely deposited by rainfall directly on the Bay.

Heavy metals include elements such as lead, copper and cadmium. Lead and cadmium come from vehicle emissions and deterioration of brakes and tires. These metals collect on pavement and, when it rains, run into Sarasota Bay through the tributaries. Copper, often found near marinas, is thought to be associated with antifouling bottom paints used on boats. Copper-containing herbicides may be another source. The source of atmospheric zinc is undetermined.

• Levels of metals in shellfish were usually far below federal guidelines for health and safety, but were well above the averages in Florida for lead, zinc and copper.

• Heavy metals (copper, zinc and lead) were found in elevated levels in some creeks and bayous flowing into the Bay. Concentrations of heavy metals in some sediments were found to be at levels of ecological risk, but posed no risk to humans. Pesticides were also found in trace amounts in sediments in these low-salinity areas. The combined effects of toxic substances found in Sarasota Bay are a source of additional ecological concern.

• The concentration of toxic substances in vital low-salinity environments is of concern because fish and shellfish require these habitats during their sensitive juvenile stages.

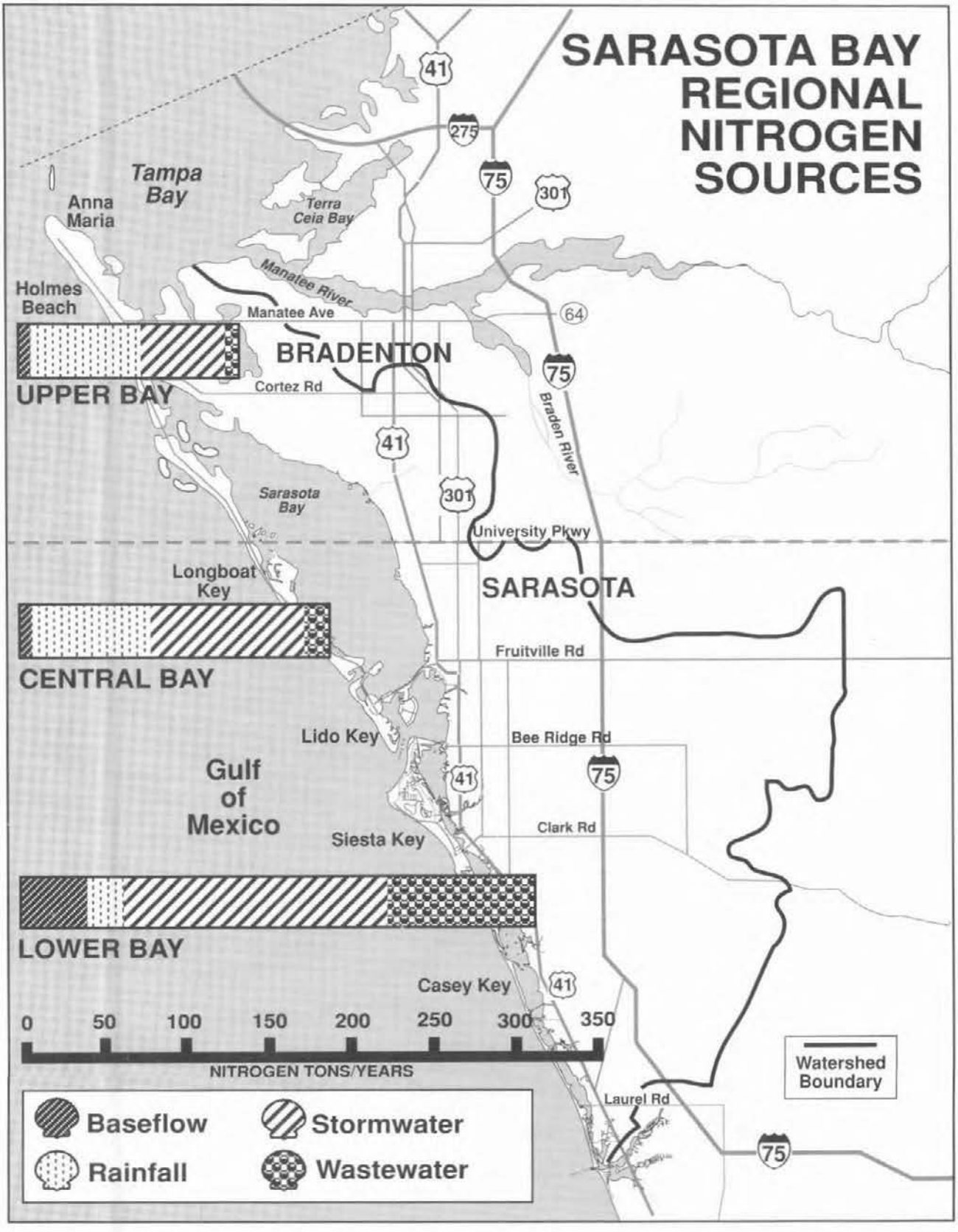
Wetlands and Bay-Bottom Habitats

Healthy wetlands and Bay bottoms are important to the vitality of Sarasota Bay because they provide food and shelter for Bay life. Wetlands, which include freshwater and intertidal habitats, also filter pollutants and help regulate the flow of fresh water into the Bay. Intertidal habitats, salt marshes and mangroves also help protect shorelines from erosion. Some Bay bottom habitats include seagrass beds, oyster reefs, sand and mud. Seagrasses support the Bay's fisheries, contribute to the food web and trap sediments.

Wetlands

• The area of intertidal wetlands Baywide has declined 39 percent since 1950, and additional declines are likely as residents justify mangrove and wetland removal as a proprietary right.

• Settlement patterns in Manatee and Sarasota counties account for the majority of wetland loss. In Manatee County, agriculture and development began on the Manatee


SARASOTA BAY
REGIONAL
NITROGEN
SOURCES
Tampa
Bay
Anna
Maria
Terra
Ceia Bay
Manatee River
Holmes
Beach
Manatee Ave
BRADENTON
UPPER BAY
Cortez Rd
Braden River
Sarasota
Bay
University Pkwy
Longboat
Key
SARASOTA
CENTRAL BAY
Fruitville Rd
Lido Key
Bee Ridge Rd
Gulf
of
Mexico
Siesta Key
Clark Rd
LOWER BAY
Casey Key
0
50
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200
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300
350
NITROGEN TONS/YEARS
Watershed
Boundary
Laurel Rd
Baseflow
Stormwater
Rainfall
Wastewater
41
275
75
301
64

River, then moved westward to the Bay. This led to the destruction of many freshwater wetlands, but allowed recent regulation to spare many mangrove wetlands on the Bay. Conversely, Sarasota County's growth centered on the Bay, leading to destruction of 80 percent of the natural mangrove shoreline but sparing many freshwater systems.

• The quality of existing wetlands, both fresh and saltwater, depends on the amount of disturbance by people and nature.

• Radical pruning of mangroves does not appear to be common practice. While about 33 percent of mangrove wetlands show some amount of trimming, only seven percent of the total remaining mangrove wetlands are pruned to less than one-third of their natural height. By comparison, about 66 percent of mangrove wetlands are affected by encroachment of non-native plants, such as Brazilian pepper and Australian pine.

• From 1975-91, 16 percent of all freshwater wetlands in the Sarasota Bay watershed were lost at an average rate of 85 acres per year. Non-forested wetlands (grassy marshes) were hardest hit, with 35 percent lost during the same period.

Bay Bottom

• Seagrasses currently cover about 26 percent of the Bay's 33,000 total bottom acres.

• Although seagrasses have declined approximately 30 percent Baywide, areas such as New Pass and Longboat Pass show sustained and significant increases in seagrass coverage. The increases near Longboat Pass may be due to new growth on shoals created by dredging, while at New Pass better water quality appears to be allowing seagrasses to grow into deeper water.

• Significant shifts of seagrass species (from *Thalassia* to *Halodule* and *Ruppia*) in Little Sarasota Bay indicate declining water quality there. *Thalassia* (turtle grass) generally requires better water quality than *Halodule* (shoal grass) or *Ruppia* (widgeon grass).

• Extensive acreage on the Bay's bottom was altered to create homesites and boat channels during the 1950s and 1960s. Many of these disturbed areas are now "sinks" for fine-grain sediment and pollutants. Approximately 15 percent (4,800 acres) of Sarasota Bay's bottom has been disturbed; many of these disturbed bottom areas are anoxic (no oxygen) or hypoxic (low dissolved oxygen) and can no longer support diverse aquatic life.

Sea-Level Rise

• At current observed rates of sea-level rise, higher high tides esperienced in the Sarasota Bay area will be 2.2 inches higher in the year 2020 and 9.8 inches higher in 2115 than at present. Accelerated rates of sea-level rise based on the best, most recent estimates of global warming indicate that higher high tides could be 5.8 inches higher in 2020 and 25.2 inches higher in 2115 than present levels.

• These higher water levels could cause saltwater to intrude into shallow-water aquifers, decrease efficiency of septic-tank drainfields, erode beaches, causeways and seawalls, drown tidal wetlands that are unable to migrate landward, eliminate some seagrasses due to loss of adequate light and increase surface runoff and associated pollution as soils become more saturated.

Fisheries

A productive fishery contributes to the Sarasota Bay area's economy and quality of life. Given that almost 50 percent of Sarasota Bay is less than three feet deep, the Bay is a prime area for flats fishing by recreational anglers. Sarasota Bay is also home to Cortez village, one of the oldest commercial fishing centers in Florida. Recreational anglers may hook trout, redfish and snook, while both commercial and recreational fishermen net mullet in the Bay.

Fisheries
- **Sea-trout landings down 50 percent since 1950**
- **Contaminated shellfish**
- **One keeper fish every three-four hours**

• Declines in water quality and productive habitats, combined with increased fishing pressure, have resulted in reduced fisheries in Sarasota Bay. Landings of sea trout by commercial and recreational fishermen combined are down by 50 percent from 1950's levels; environmental alteration and degradation is the most likely cause of the decline. The average recreational angler in Sarasota Bay now catches one "keeper" fish every three to four hours.

• Preliminary information suggests that small artificial reefs for seawalls increase fish abundance in residential canals. An average of 250 fish were found in canal locations with the reefs; no fish were found in locations without the structures.

Recreation

• Recreational use of Sarasota Bay — including swimming, boating, fishing and the most-often-cited recreational activity, simply enjoying the view — contributes to the area's economy and quality of life.

• Increased use of Sarasota Bay has resulted in areas of conflict between user groups (anglers vs. skiers, boaters vs. swimmers). Areas of conflict are the Intracoastal Waterway (ICW) around Phillippi Creek, Manatee Avenue Causeway, Venice Inlet, Big Pass, Longboat Pass and the ICW entrance to Big Sarasota Bay just south of the Sister Keys.

Citizen Involvement

• A public-opinion survey conducted by the Sarasota Bay Program concluded that people are not well-informed about the Bay's problems, but are willing to pay for improving it.

• Most existing educational opportunities related to Sarasota Bay emphasize identification and functions of natural systems; they rarely focus on Bay problems and their solutions.

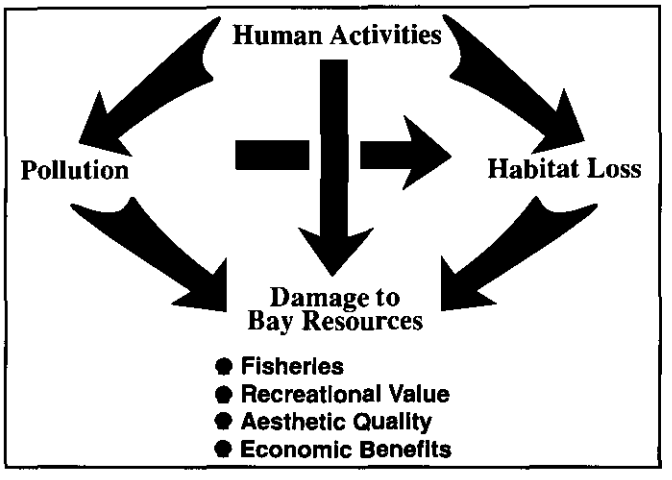
Seeking Solutions

Although damage to Sarasota Bay is extensive, improving the Bay is possible and financially feasible. Management approaches suggested in *Sarasota Bay: 1992 Framework for Action* focus on major problems of the Bay: wastewater, stormwater and habitat loss. Additional areas for discussion include fisheries management, recreational use, overall management of the Bay and citizen involvement in Bay restoration and protection.

Most Bay-restoration strategies will need to be tailored to regional priorities within the Sarasota Bay watershed. For example, Sarasota County's dramatic loss of mangrove wetlands requires emphasis on restoration, while the existence of many mangrove areas in Manatee County points to a need for continued protection.

Likewise, determining priorities between stormwater and wastewater solutions needs to be applied on a regional basis. Although stormwater runoff contributes 50 percent of nutrients *Baywide,* wastewater is of equal concern *in Sarasota County,* where septic systems and package-treatment plants contribute a high percentage of nutrients. Eliminating pollution from both wastewater and stormwater would be extremely effective in reducing nutrient and toxic pollution in that area.

Moreover, some strategies, such as improving residential lawn care and water conservation, can be applied Baywide. An overview of potential Bay improvement strategies is provided in a later chapter.



Save Sarasota Bay

In summary, information collected by the Sarasota Bay Program reveals that many dramatic changes have already occurred in the Bay. Signs of healing are apparent in some areas, while others – particularly the tributaries and parts of the lower Bay – may no longer be fulfilling their natural functions.

By pursuing National Estuary Program status for Sarasota Bay, the local community expressed a desire to restore Sarasota Bay to a past, less-damaged condition. *Sarasota Bay: 1992 Framework for Action* suggests ways the community can improve the Bay. However, the question remains, "How much investment of effort and resources are citizens willing to make to restore the Bay?"

The people of Manatee and Sarasota counties will have an opportunity to answer that question during coming months as *Sarasota Bay: 1992 Framework for Action* is reviewed. The challenge facing the people of Sarasota Bay between now and June 1994 is to determine priorities among potential solutions, and to implement a comprehensive strategy to improve Sarasota Bay.

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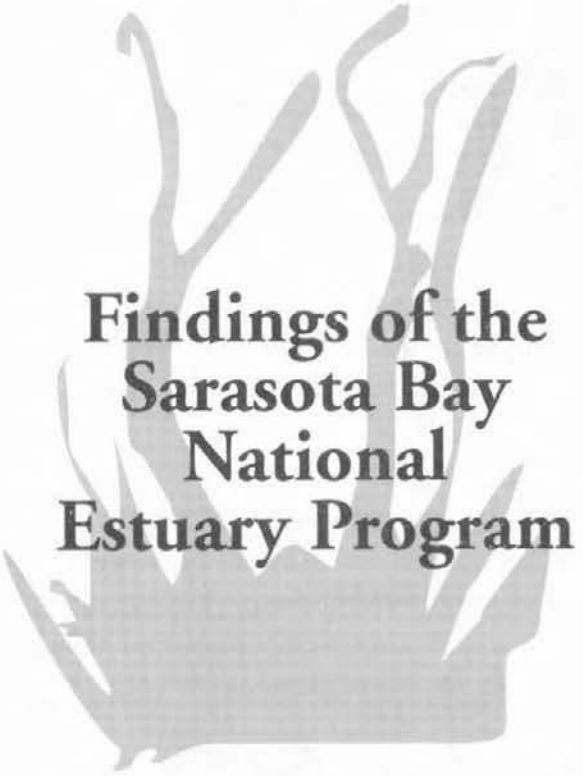
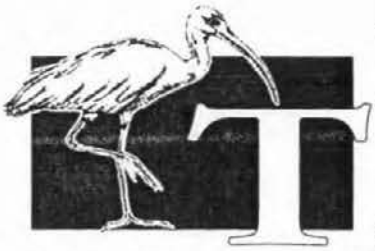


Findings of the Sarasota Bay National Estuary Program

Findings of the Sarasota Bay National Estuary Program



Technical Work Plan Development

The findings included in the Framework for Action are the result of 2 1/2 years of intensive investigation of technical and sociological factors related to Sarasota Bay. This work was guided by a plan developed in 1989, based on the "Nomination Document" used to support Sarasota Bay's inclusion in the National Estuary Program. The Nomination Document included technical information presented at the 1988 SARABASIS Conference, as well as information from regulatory agencies, Mote Marine Laboratory and individuals in the community.

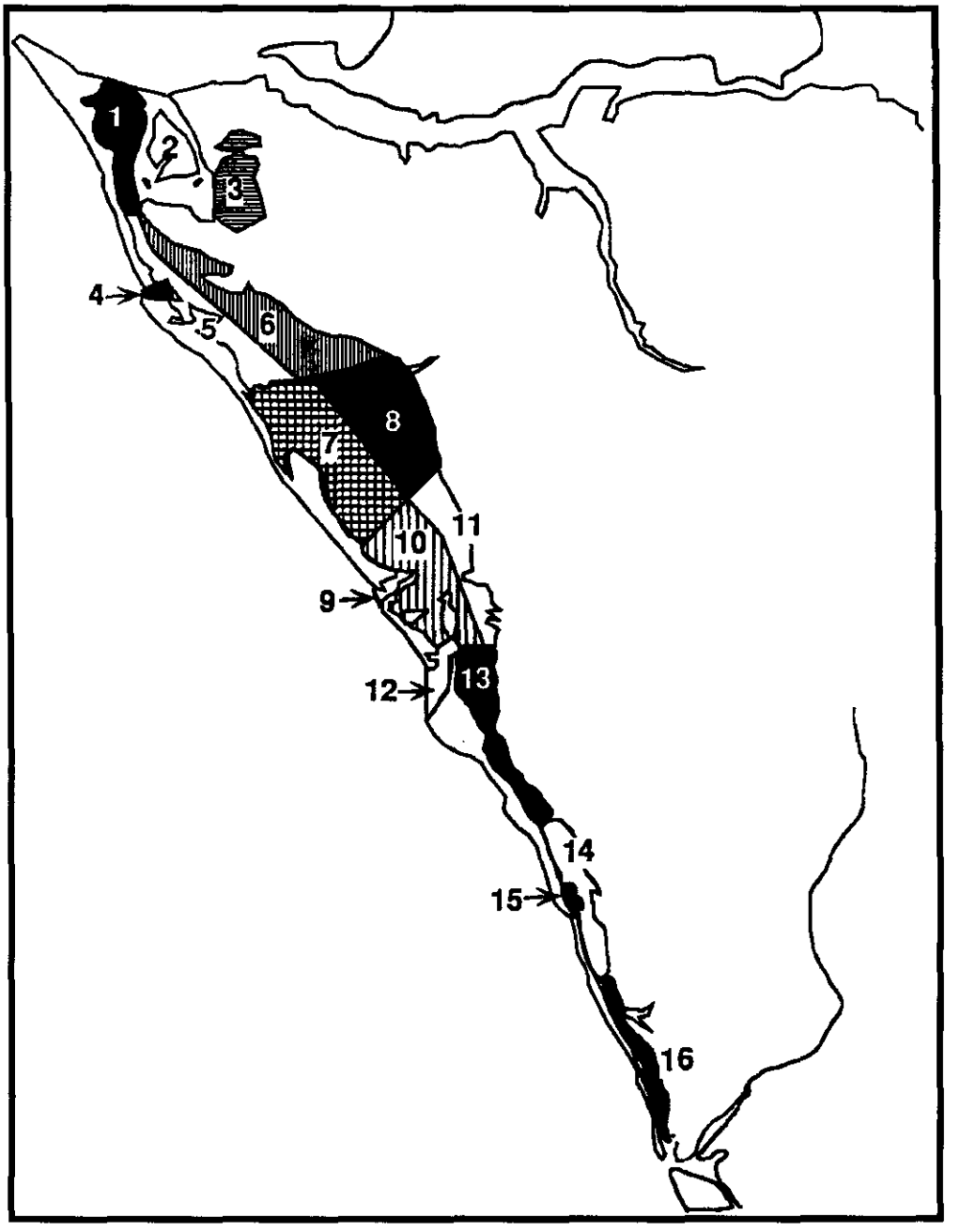
The technical work plan for the Sarasota Bay Program was developed by staff and the Technical Advisory Committee. The Management Committee approved the three-year study plan, which focused on defining the Bay's problems in order to develop solutions through a comprehensive management plan.

Investigators for the 14 technical projects were selected through a competitive bidding process. The projects included Segmentation, Wetlands Assessment (Freshwater and Tidal), Water-Quality Monitoring, Sediment Chemistry, Historical Water-Quality Analysis, Estuarine Bottom Assessment, Fishery Resource Assessment, Pollutant-Loading Model, Circulation, Shellfish Contamination, Data Management, Sea-Level Rise and Resource Access and Use (Recreation).

Segmentation of Sarasota Bay

The following chapters present the results of the most intensive scientific investigation ever conducted on Sarasota Bay. To facilitate collecting data and presenting results, scientists used a segmentation system to divide the Bay into smaller sections.

The segmentation system for Sarasota Bay includes 16 segments of the Bay and near-shore Gulf of Mexico. The segments follow natural and artificial boundaries, allowing similar areas to be compared and contrasted. Using drainage basins, stream reaches, Bay segments and Gulf reaches as geographic references helps scientists design research and collect data.



Water and Sediment

Physical and Chemical Properties — Bay Water and Sediment Quality

by Susan Lowrey
Mote Marine Laboratory

Executive Summary

Since 1968, Sarasota Bay has become less saline, and the pH of its water has declined. This finding is consistent with increased freshwater inputs that are the result of increased urbanization. General water-quality trends show some improvement. In general, nutrients are declining, with the exception of nitrate and nitrite nitrogen. *Chlorophyll a* is declining in 93 percent of the segments showing trends. Secchi depth is increasing in the six segments that showed significant trends. Color is increasing in some segments and decreasing in others. Nutrients and *chlorophyll a* exhibit an expected decline along an east-to-west transect.

Three areas of immediate concern – north Sarasota Bay in the vicinity of Tidy Island, eastern Sarasota Bay near Whitaker Bayou and Little Sarasota Bay – were identified in both the nomination document for the National Estuary Program and an early version of the monitoring plan. Water quality in the first two areas is improving; Little Sarasota Bay shows some conflicting trend results. Decreases in *chlorophyll a* and suspended solids, coupled with the increase in secchi depth, tend to indicate improvements in water clarity in this segment. The increased turbidity, however, indicates just the opposite.

Trend results for east Sarasota Bay (segment 8) indicate that water quality in this segment may be declining. *Chlorophyll a*, nitrates and nitrites, total nitrogen, total phosphorus and total organic carbon are all increasing over time for this area.

In Sarasota Bay, non-point sources of pollution, in particular stormwater, apparently influence many areas. Tributaries to the Bay act as pipelines for dispensing stormwater and suspended matter into the estuary. Although the overall Trophic State Index for Sarasota Bay is "good," the segments that receive water from the tributaries have the poorest water quality.

Toxic contaminants such as chlorinated pesticides, PAH and metals were found in tributary sediments, as opposed to sediments from the open Bay. Tributaries with the highest levels of these contaminants are Hudson Bayou, Cedar Hammock Creek and Whitaker Bayou. These areas also are contaminated by more than one of these classes of toxic compounds. While the percentage of contaminated sediments is comparatively small with respect to the Bay bottom of the entire study area, the tributaries are vital low-salinity habitats for larval and juvenile life stages of many fish. Adverse biological impacts attributed to these contaminants would be directed against these more-sensitive life stages.

Physical and Chemical Properties — Bay Water and Sediment Quality

Susan S. Lowrey

Susan Lowrey is a Senior Chemist at Mote Marine Laboratory in Sarasota, FL. She has worked as a water chemist in Florida and Hawaii since graduating from Christopher Newport College in 1973. Ms. Lowrey's experience includes managing the Water Resources Research Center laboratory at the University of Hawaii and teaching laboratory classes in water-quality chemistry and microbiology to graduate students from civil engineering and public-health disciplines. She also coordinated all aspects of the grant-funded Myakka River Basin Project for Sarasota County's Dept. of Natural Resources prior to joining Mote in 1991. She has authored 10 technical reports and five journal articles.

Monitoring Program

The overall monitoring plan developed for the Sarasota Bay study area (Estevez, 1989) included a total of 26 elements or tasks for routine or continuous monitoring. Four of these tasks were recommended for immediate implementation by the Water Quality Monitoring SubCommittee. The full Technical Advisory, Management and Policy Committees approved the ranking and the tasks were implemented. Three of those four will be discussed here: 1) a Baywide monitoring of nutrients and light-related parameters, 2) a characterization of past and present water quality and 3) a collection and partial characterization of sediment contamination. The fourth, a study of whitening in Whitaker Bayou, was completed in 1990.

Scope

Monitoring Light and Light-Related Parameters

Nutrients support increased phytoplankton growth and indirectly contribute to light attenuation in the water column. Particulate matter scatters and absorbs light. Increased loadings of sediments and nutrients to the Bay system can, therefore, reduce the total amount of light received by the Bay floor in waters of a fixed depth. Alterations in circulatory patterns caused by dredging can also act to resuspend and transport existing sediments, decreasing light penetration in areas at some distance from potential dredging projects.

Quarterly Baywide samplings provide a synoptic water-quality data set for the Sarasota Bay study area. These "snapshots" of the Bay for nutrients and other light-related parameters have provided some insight into the stresses due to lowered light levels that have been proposed as a primary cause for the regional trend of decreasing seagrass coverage. The monitoring addresses Program goals of describing the Bay in an integrated fashion as well as identifying problem areas.

Summary of Existing Water-Quality and Sediment Data

The primary objective of this task was to characterize the existing and historic water-quality and sediment-quality data within the Sarasota Bay study area. The task met the general objective of the National Estuary Program of determining temporal trends within the study area, helping to identify pressing problems in the Bay and possible causes and describing the Bay in an integrated fashion. Sources of data for this characterization included the STORET (EPA's STOrage and RETrieval system) database, published and unpublished studies within Sarasota Bay that had not been entered into the STORET database, and the first four quarterly Baywide Monitoring Events. Data analysis was primarily conducted on a segment basis.

Sediment-Contamination Assessment

Sediment analyses provide useful measures of long-term water quality or chronic pollution climates. This is due to the preferential adsorption of toxic ions and compounds onto fine-grained suspended particulates and the eventual incorporation of the suspended material into benthic deposits. In Sarasota Bay, non-point sources of pollution, in particular stormwater, apparently influence many areas. Rainfall runoff from urban areas is known to contain a number of toxic compounds, making the bottom sediments in and near tributaries the most likely repository for contaminants.

Due to the comparative lack of toxic-contaminant data in either the water column or sediments of Sarasota Bay, a one-time scan of sediments was conducted for major classes of pollutants. The areas evaluated were to include the potentially worst cases of pollutant contamination, and so emphasized the tributary areas over deeper, open-water locations where the sediments were less likely to contain elevated levels of contaminants.

Parameter classes for analysis included toxic metals, commonly associated with urban runoff; fecal sterols, commonly used as

indicators of mammalian wastes; toxic organic compounds, such as chlorinated and organophosphate pesticides; and polynuclear aromatic hydrocarbons, indicative of petroleum or combustion-product contamination. In addition to the analyses for contaminants, data on sediment grain size distribution, aluminum, moisture and organic content allowed normalization of raw station data, permitting spatial comparisons and identification of basins for remedial efforts. Sarasota Bay sediments were compared with either statewide norms or levels of potential adverse biological effects.

Summary of Existing Data

The data used for analysis of historical data covered the period January 1, 1968-May 14, 1991. The resultant database contained 8,562 records. Data sources were STORET and five other field and laboratory investigations.

STORET Inventory

An inventory of the existing data for the study area was performed, and the pertinent data were downloaded from the STORET database. The data were requested by polygons that corresponded to the segmentation scheme developed for the Sarasota Bay National Estuary Program. Data for the period January 1, 1968-December 31, 1989 were included. The parameters included were:

Turbidity	Total Nitrogen
Secchi Depth	Organic Nitrogen
Color	Ammonia Nitrogen
Conductivity	Total Kjeldahl Nitrogen
Dissolved Oxygen	Nitrate + Nitrite Nitrogen
pH	Ortho Phosphate
Salinity	Total Phosphorus
Total Suspended Solids	Total Organic Carbon
Volatile Suspended Solids	Total Inorganic Carbon
Chlorophyll a	*Chlorophyll b*
Copper	Lead
Zinc	

Data retrievals were limited to ambient stations, exclusive of ambient-groundwater data. Review of the inventories revealed that, with three exceptions (copper, lead and zinc) insufficient data exists on metals or organics within the STORET system to perform trend analyses.

Other Data Sources

FDNR/MML

During the period 1975-80, Mote Marine, Laboratory (MML) was under contract to the Florida Dept. of Natural Resources (FDNR) to provide near-shore surface truthing of airborne digital color scanners, intended to identify outbreaks of red tide. Seven stations were sampled routinely, but only the near-shore station, two miles off the former Midnight Pass, falls within the present NEP study boundaries. Instrumental and physical data were collected in the field, and laboratory analysis for major nutrients, phytoplankton species composition and algal assays were performed.

Sarasota High School

In conjunction with the advanced marine science class at Sarasota High School, students and instructors routinely sampled open-Bay waters in Sarasota Bay during 1975-83. Measured parameters changed over time, but generally included instrumental parameters, physical parameters, ortho phosphate phosphorus, nitrite + nitrate nitrogen and *chlorophyll a.* Stations were distributed roughly between the Siesta Key bridge and mid-Sarasota Bay.

Waste Load Allocation

In 1981-82, a wasteload allocation study (WLA) of Sarasota Bay was funded by the Florida Dept. of Environmental Regulation (FDER) and implemented by Priede-Sedgwick, Inc. (PSI). The monitoring program was designed by PSI, which contracted with MML to conduct the field and laboratory analyses. Parametric coverage varied with station location and sampling episode, but stations were established from Cortez bridge to Phillippi Creek.

WCIND Upper Sarasota Bay Study

Manatee County and MML jointly conducted a baseline water-quality study of upper Sarasota Bay during 1987-88 through grant funding provided by the West Coast Inland Navigation District (WCIND). Twenty-two water-quality stations, ranging from Anna Maria Sound to mid-Sarasota Bay, were sampled for nutrients, bacteriological parameters, instrumental and physical parameters and total organic carbon.

Baywide Monitoring Events

The data from the first four sampling events conducted for the Sarasota Bay Project were also included in the database. Each sampling event involved 101 stations sampled synoptically during a four-hour high-tide "window." The events took place on August 8 and November 14, 1990 and February 12 and May 14, 1991. The parameters measured and the results obtained are described in detail elsewhere in this report.

Trends

Linear-regression analysis can show increases or decreases that may occur over time for a parameter. Whether an increasing or a decreasing trend over time indicates an improvement or degradation of water quality depends on the parameter in question. For example, a decreasing, or negative, trend in the concentration of chlorophyll present in the water column can indicate a decrease in the biomass of phytoplankton in the water column, a positive trend relative to water quality. Conversely, an increasing trend for secchi depth, which is a measure of the effective penetration of light into the water column, is also a positive trend relative to water quality.

Linear-regression analyses were performed using time as the independent variable, and the measure of each parameter as the dependent variable. The analyses were performed by individual segment, and on a Baywide basis. Trends were considered significant at the 0.05 probability level.

In general, the results of the trend evaluation by segments agree with the trends in water quality developed for the SARABASIS Symposium (Heyl and Dixon, 1986). The results also agree with the non-parametric evaluations of Sarasota Bay performed by FDER and reported in the Sarasota Bay Technical Report [Appendix to: *305(b) Water Quality Assessment for the State of Florida*] (FDER, 1988). The percent of segments showing increasing or decreasing trends and the number of segments in which significant trends developed is summarized in *Table 1*, below.

In general, Sarasota Bay appears to be less saline, and the pH of its water is declining. This finding is consistent with increased freshwater inputs, the result of increased urbanization. Nutrients are declining, with the exception of nitrate plus nitrite nitrogen. *Chlorophyll a* is declining. Secchi depth is increasing in all segments that showed significant trends. Color is increasing in some segments, and decreasing in others.

Table 1. Sarasota Bay segments that show significant (p< 0.05) trends.

Parameter	Percent of Segments with Significant Trends	Percent Improving	Percent Degrading
Chlorophyll a	67	93	7
Secchi depth	29	100	0
Total nitrogen	43	67	33
TKN	48	90	10
Ammonia	48	100	0
Nitrate + Nitrite	57	8	92
Total phosphorus	62	69	31
Ortho phosphate	52	91	9
Organic carbon	52	91	9
Color	52	45	55
Supended solids	29	83	17

Three areas of immediate concern — north Sarasota Bay in the vicinity of Tidy Island, eastern Sarasota Bay near Whitaker Bayou and Little Sarasota Bay — were identified in both the nomination document for the NEP and an early version of the monitoring plan. These areas are associated with segments 6, 11 and 14, respectively.

In segment 6, *chlorophyll a*, suspended solids, turbidity, ammonia and organic carbon are decreasing with time; salinity, color and phosphorus are increasing. These changes are likely due to the changes in irrigation practices that have occurred; this Bay segment appears to be improving.

All significant trends that developed for segment 11 were decreasing over time. The parameters that exhibited these relationships were color, pH, salinity, turbidity, total nitrogen, total phosphorus and organic carbon. These changes may be linked to regulations that limit wastewater-treatment-plant effluent discharge into Whitaker Bayou. Water quality in this segment of the Bay also appears to be improving.

Segment 14 shows significant decreases in *chlorophyll a*, suspended solids, salinity and ammonia over time. Turbidity, secchi depth and nitrate plus nitrite nitrogen are increasing. Decreases in *chlorophyll a* and suspended solids coupled with the increase in secchi depth tend to indicate improvements in water clarity in this segment. The increased turbidity, however, indicates just the opposite.

In addition to the conflicting results for trend analyses, the multivariate analysis for segment 14 was unusual. For all segments that demonstrated significant trends for secchi depth (2, 3, 6, 13 and 14), a parameter group (total nitrogen, total phosphorus, turbidity, color and chlorophyll) was regressed with secchi depth. In all segments except 14, this parameter group could reasonably predict secchi depth.

Trend results for segment 8 (east Sarasota Bay) indicate that water quality in this segment may be declining. *Chlorophyll a*, nitrates and nitrites, total nitrogen, total phosphorus and total organic carbon are all increasing in this segment. Additional nutrient inputs here could result in algal blooms that could stress the existing plant and animal communities through limiting light available for photosynthesis and lowering dissolved oxygen levels.

Implementation of Baywide Water-Quality Monitoring

The primary objective of the water-quality monitoring effort was to provide a synoptic "snapshot" of the waters of the study area during selected seasons and conditions.

Monitoring Stations, Parameters and Participants

Each event sampled 101 stations during a four-hour high-tide "window." Stations were as spatially balanced as possible to reflect both relative segment area and characteristics (i.e., grassbeds, depth, tributaries). Quarterly samplings were scheduled to take advantage of seasonal hydrological conditions typical for this region of Florida, and accommodated the range of temperature and growth conditions for primary producers. Daytime high tides, although not indicative of the areal "worst case" conditions for the waters of the Bay, were selected for characterization to permit more rapid and economical sampling and to provide accessibility to the numerous shallow areas of the Bay. Diurnal tides were selected as being most representative of the study area.

Data were collected during the present monitoring program for the parameters listed below, with *in situ* observations generally made at surface and bottom. Water-quality samples were collected at near surface depths only.

Parameters
Dissolved oxygen, mg/l
Temperature, °C
Specific Conductance, mmhos
Secchi depth, meters
PAR, uEm^{-2}s^{-1}

Coordination of the Baywide monitoring and monitoring support were performed by Mote Marine Laboratory for the Sarasota Bay National Estuary Program. Co-operators for the Baywide monitoring for both field and laboratory work included Manatee County Utilities Central Laboratory, Manatee County Environmental Protection Commission Laboratory, Sarasota County Environmental Services Laboratory and the Sarasota County Natural Resources Dept. Additional help, primarily in the form of meters, was provided by Environmental Quality Laboratory of Port Charlotte, Florida Dept. of Natural Resources, Southwest Florida Water Management District, the City of Tampa and the United States Geologic Survey.

Baywide Monitoring – Results and Discussion

The high spatial density of stations in the monitoring plan allowed the mapping of various parameters, such as total nitrogen or secchi depth for the individual events. Through interpolation, lines of equal value or concentration can be computer-generated. In addition to between-segment and between-station comparisons, within-station comparisons were possible using surface and bottom *in situ* readings.

Figure 1 illustrates the turbidity results from the third sampling event, which occurred on February 12, 1991. During this sampling, treated wastewater and brine effluent from reverse osmosis was being discharged into the Whitaker Bayou/Hog Creek area, and the resultant turbidity plume is in evidence. During the event on May 14, 1991, turbidity plumes are in evidence along much of the eastern side of the Bay *(Figure 2)*, this time a consequence of runoff from a thunderstorm than occurred early that day.

The water-quality data was also examined along suspected gradients. For example, *Figure 3* shows nitrogen and *chlorophyll a* at four stations located between Cortez and

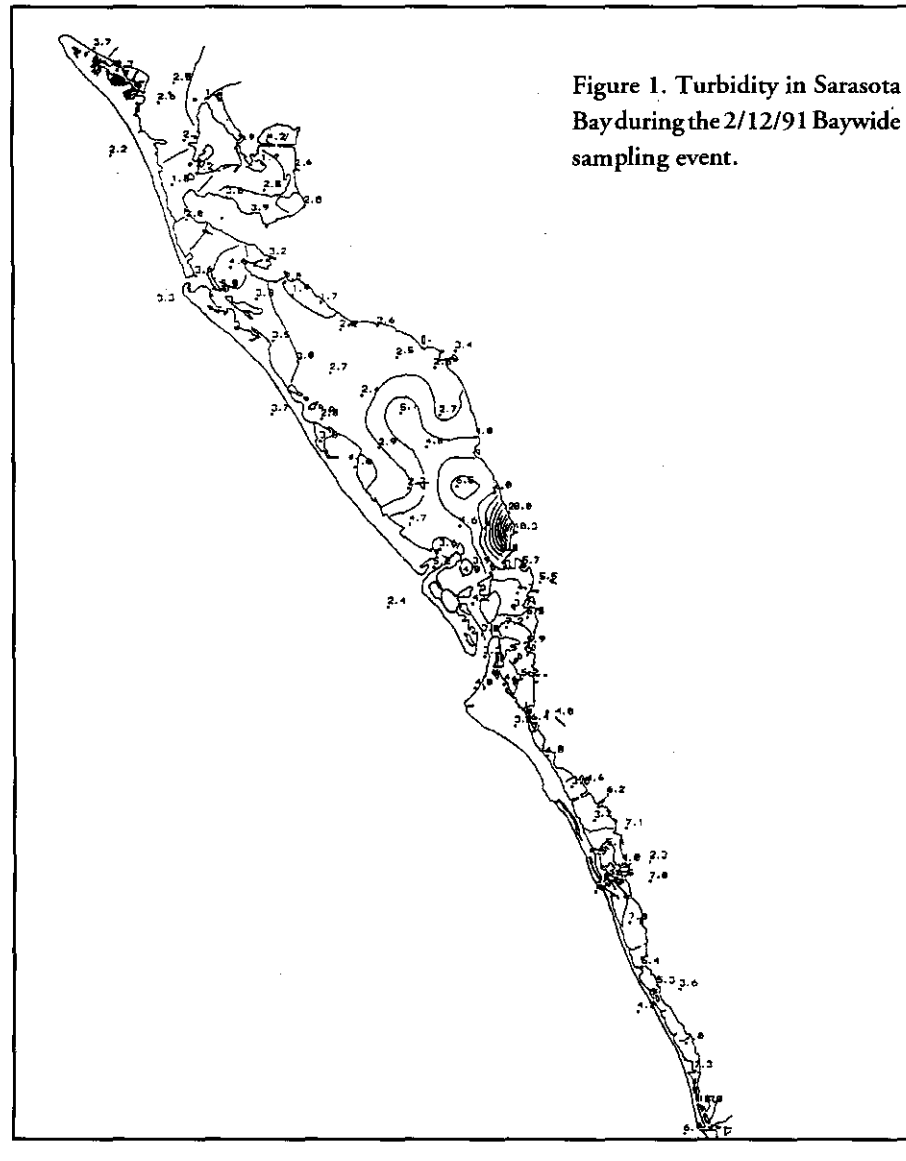


Figure 1. Turbidity in Sarasota Bay during the 2/12/91 Baywide sampling event.

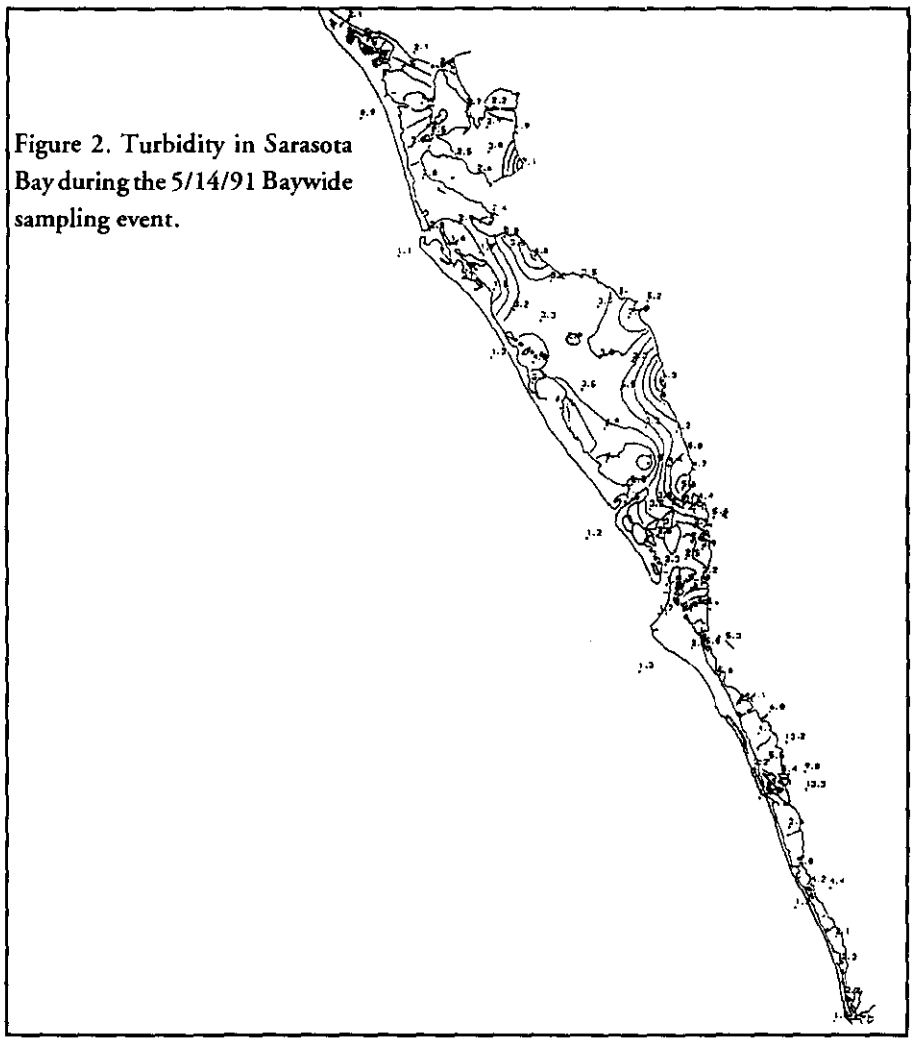


Figure 2. Turbidity in Sarasota Bay during the 5/14/91 Baywide sampling event.

Tidy Island to outside of Longboat Pass. Here, and in general Baywide, these parameters decrease along an east-to-west gradient, with the strongest relationships observed for chlorophyll. The gradients observed reflect an increasing dilution of relatively nutrient-rich freshwaters with more oligotrophic coastal waters.

Comparison of Surface and Bottom *In Situ* Data

Dissolved-oxygen, salinity and temperature observations were made at both near-surface and near-bottom depths within the water column, and the information used to determine the degree of water-column stratification. As expected from the shallow nature of the estuary, little difference existed between the surface and bottom readings for the *in situ* parameters Baywide. The stations located in tributaries (category 5) to the Bay, where wind influence was minimal and freshwater was a larger percentage of the water column, generally showed larger differences between the surface and bottom readings than stations located in open water (category 1).

The *in situ* parameters also show seasonal differences in surface and bottom observations. Dissolved-oxygen differences were greatest for all categories of stations during the first sampling (August 1990), and surface dissolved oxygen was generally higher than bottom. During the third event (February 1991), the bottom dissolved oxygen was generally greater than surface. Although dissolved-oxygen levels exhibit daily fluctuations, with daily minimums usually occurring just before sunrise and daily maximums occurring mid-afternoon, the timing for these two events does not account for the observed differences. The first event took place 11:30 a.m. - 3:30 p.m., when the production of oxygen by phytoplankton and macrophytes and, consequently, dissolved oxygen in the water column, was near the daily maximum. The third event took place 9:45 a.m. - 1:45 p.m., when dissolved oxygen was still approaching the daily maximum. This pattern is duplicated in surface- and bottom-temperature observations. Not surprisingly, bottom-salinity readings are generally higher than surface readings.

Presenting the nutrient data as segment averages *(Figure 4)* shows little variation in total phosphorus among the sampling events. Total nitrogen tended to be highest in November, followed by May, August and February. The variation in chlorophyll levels by sampling event and segment is quite

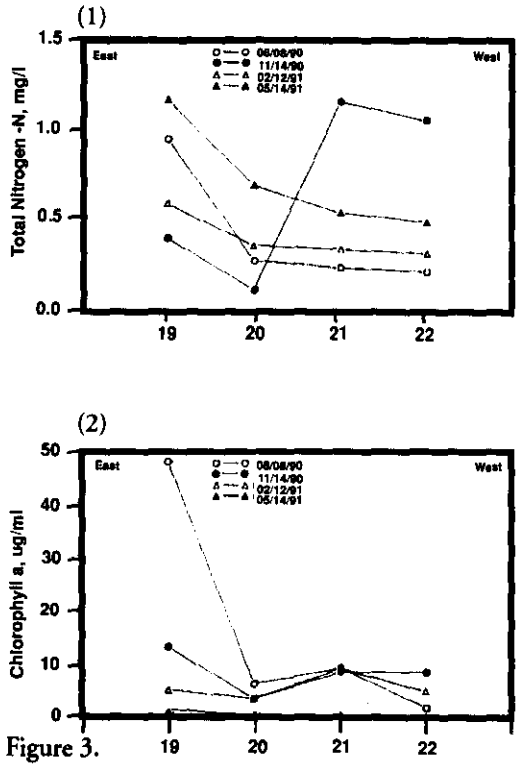


Figure 3. Nitrogen (1) and *chlorophyll a* (2) levels along an east-west gradient from Tidy Island to Longboat Pass.

Figure 3.

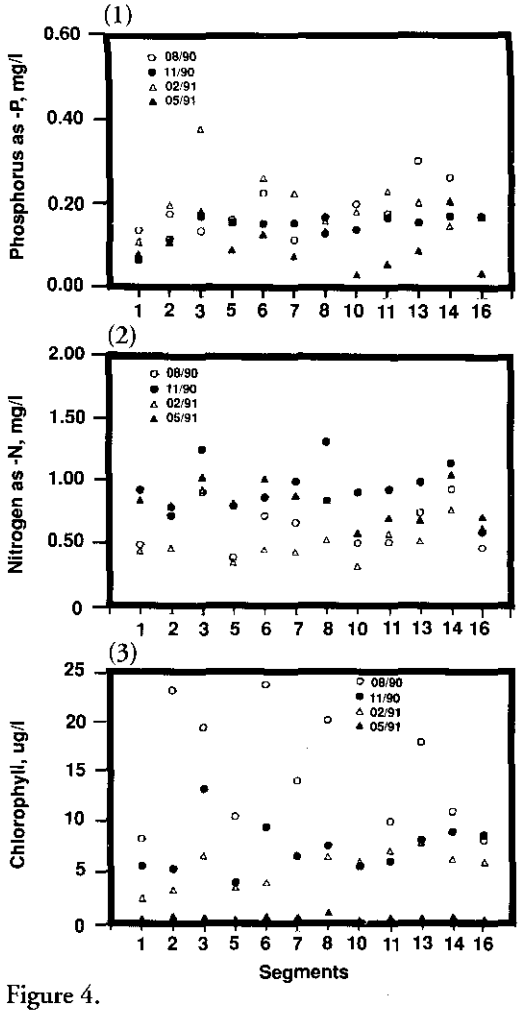


Figure 4.

Figure 4. Total phosphorus (1), total nitrogen (2), and *chlorophyll a* (3) for all Bay segments during each sampling event.

Salinity generally was lowest during the February monitoring event and highest during the August event *(Figure 5)*. Segment 14 (Little Sarasota Bay) exhibited the lowest salinities during all events, which is consistent with the relative size of the watershed, the number of tributaries contributing to smaller segments in the southern portion of the study area and reduced flushing rates in this area (Sheng and Peene, 1992). High color values were also prominent in the southern segments, due to the increased tannins from the tributaries and reduced flushing rates.

Comparison of Segments and Categories

The results of the first four Baywide monitoring events were compared by category using the Mann Whitney U test. Significant differences ($p > 0.05$) were found between category 5 (tributary) stations and all other categories (category 4 are stations with strong tributary influence; category 3 are near-shore stations with moderate tributary influence; category 2 are open water stations with minimum tributary influence; category 1 stations are open water) for the following parameters: depth; secchi depth; extinction coefficient; color; turbidity; total phosphorus; ortho phosphate; nitrate plus nitrite; total Kjeldahl nitrogen; total inorganic carbon; total organic carbon; and salinity. Significant differences between

pronounced, duplicating the pattern of increased *chlorophyll a* levels with increased rainfall found in Tampa Bay (Lewis and Estevez, 1988). The highest levels occurred during the first event in August, and the lowest in May. Organic carbon levels tended to be highest in February and lowest in May. These data are presented without inclusion of the Gulf and Pass segments to give a clearer representation of north-to-south variation within the Bay.

Secchi-depth seasonality, however, does not demonstrate the same pattern as nutrients and chlorophyll. Secchi depth in general is highest during February when chlorophyll levels are low. The Bay segments that are most influenced by water from the Gulf (segment 5, inside Longboat Pass, and segment 16, inside Venice Inlet) exhibit consistently higher secchi depths during May *(Figure 5)*. Segment 10 (inside New Pass and Big Pass) illustrates slightly increased secchi depths on average, but this area is influenced by proportionately more stations in areas of lower flushing. Secchi depth generally tended to be higher in the northern segments than in the southern segments.

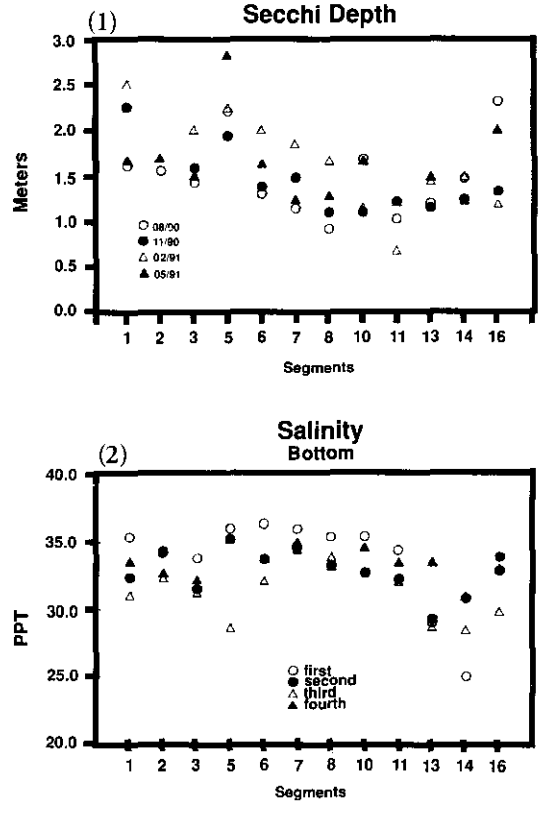
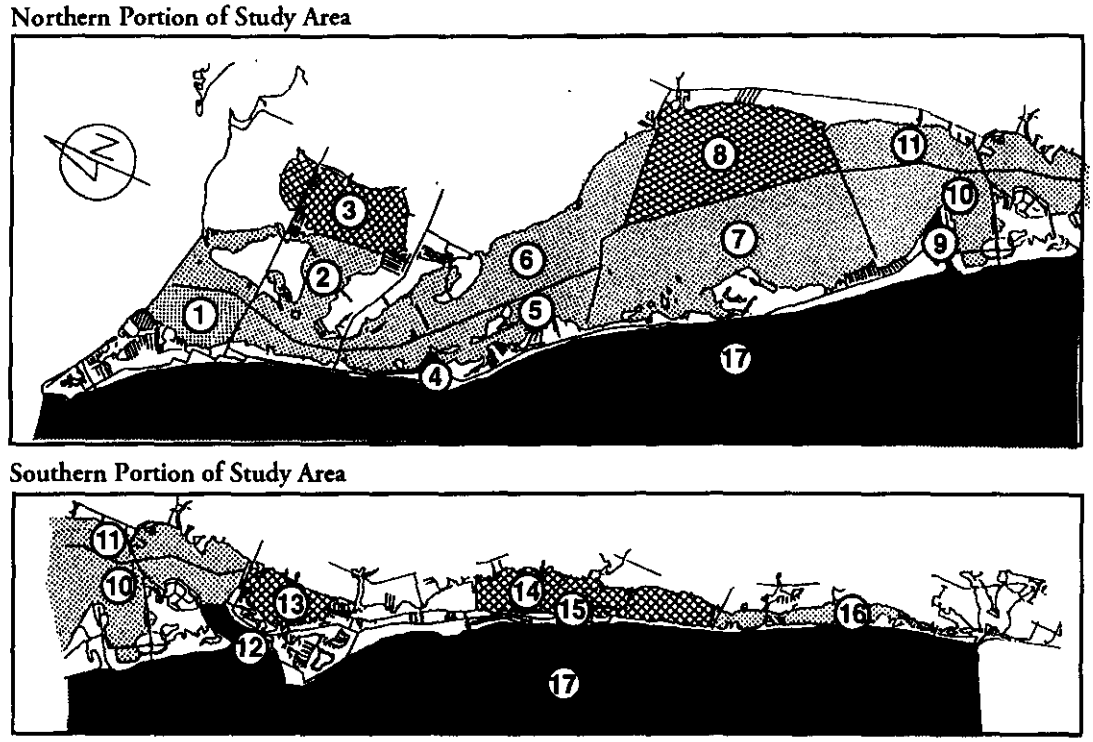


Figure 5. Secchi depth (1) and salinity (2) for all Bay segments during each sampling event.

Figure 6. Relative water quality for Sarasota Bay segments. Shaded areas have the best; stipled areas have intermediate; cross-hatched areas have the poorest.



categories also existed for particle counts, total suspended solids, volatile suspended solids and *chlorophyll a.* No significant differences between categories existed for ammonia, chlorophyll b or c, or phaeophytin. The tributary stations also had the highest average values for all parameters, except depth and secchi disk depth.

The 17 segments in the Sarasota Bay study area were compared to determine if significant differences existed between them by parameter. Due in part to the seasonal variation in many parameters, no significant differences existed for ammonia, chlorophyll b, chlorophyll c and phaeophytin. The remaining parameters showed significant differences between segments at the 95-percent confidence interval.

Segment Ranks

Establishing parameter means for the segments allows ranking and grouping the segments based on these rankings. Segments were ranked by mean value for the following light-related parameters: total Kjeldahl nitrogen, nitrate plus nitrite nitrogen, orthophosphate, total phosphorus, extinction coefficient, turbidity, color, total organic carbon, total inorganic carbon, *chlorophyll a,* particle count, total suspended solids and volatile suspended solids. The highest average value was ranked one, the lowest 17. All segments were ranked twice, once with and once without tributary stations included. Comparison of these rankings illustrates the contribution of tributary stations, particularly in segment 13.

The ranks were summed for all parameters, and three groups of segments became apparent. The groups *(Figure 6)* were the top 25 percent, the bottom 25 percent and the middle 50 percent of the segments. The bottom 25 percent, with the highest concentration of nutrients and the poorest water quality overall, included segments 3 (eastern Palma Sola Bay), 13 (Roberts Bay), 14 (Little Sarasota Bay), 15 (Midnight Pass) and 8 (eastern Sarasota Bay between Bowlees Creek and Stephens Point). The top 25 percent, with the lowest concentrations of nutrients and the best water quality, were segments 4 (Longboat Pass), 9 (New Pass), 12 (Big Pass) and 17 (Gulf of Mexico). Segments 1 (Anna Maria), 2 (western Palma Sola Bay), 5 (north Longboat Key), 7 (middle Longboat Key), 10 (City Island), 11 (downtown Bayfront) and 16 (Blackburn Bay) were in the middle 50 percent of the overall ranking.

The segments in the bottom-25-percent group, with the exception of Midnight Pass, are receiving waters for one or more tributaries. Even when the stations upstream of the mouths of the tributaries were excluded from the ranking, the influence of the tributaries was apparent, with the same segments in the bottom-25-percent group either with or without tributary stations included. The degraded water quality in the tributaries also affects the segments that receive these waters. The effects are most apparent in areas of low flushing and high residence times (i.e., poor circulation).

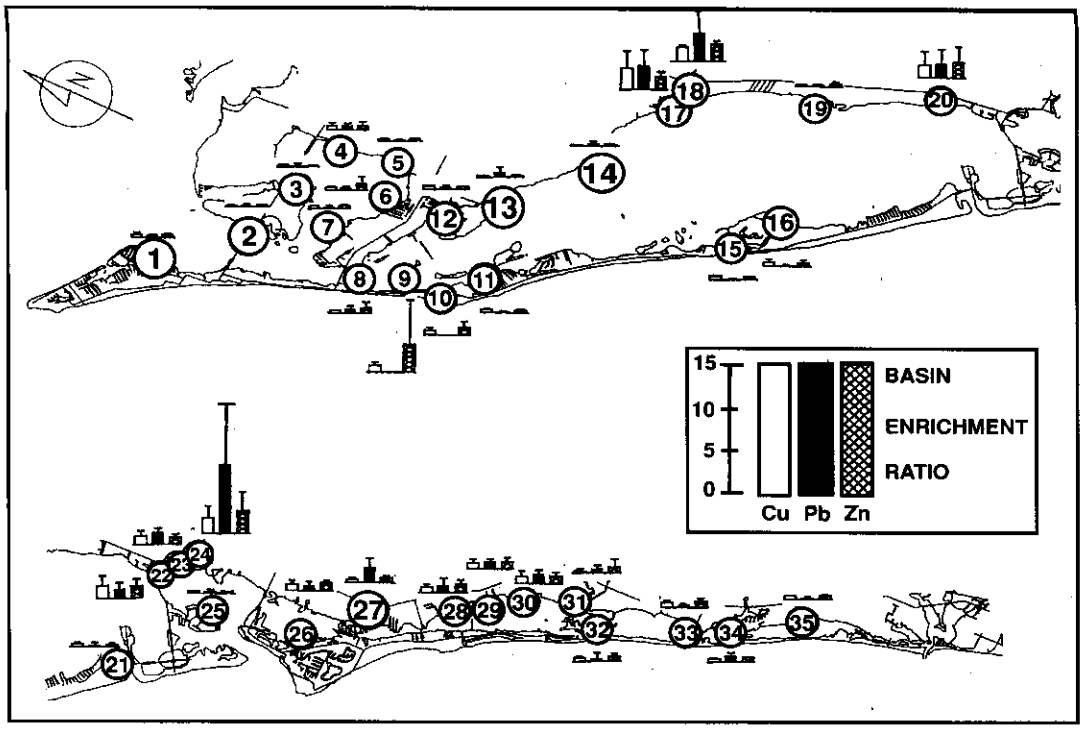


Figure 7. Enrichment ratios for copper, lead and zinc in Sarasota Bay sediments.

Trophic State Index

The trophic state index, or TSI, procedure is used routinely by the FDER in the biannual 305(b) water-quality assessment to determine the trophic state of waterbodies throughout Florida. The procedure uses annual averages of *chlorophyll a,* secchi depth, total nitrogen and total phosphorus to determine trophic states. For estuaries, values of 0-49 are "good," 50-59 are "fair" and 60-100 are "poor" (Hand *et al.*, 1990). Although this procedure can lead to overly optimistic evaluations of water quality, it can be useful in comparing areas.

Overall the TSI for Sarasota Bay is "good." Segment TSI ranges from 33 (good) for segment 17 (Gulf) to 52 (fair) for segment 8 (east Sarasota Bay). Segments 3, 8, 13, 14 and 15 have TSI values in the "fair" range when tributary stations are included in the calculation. Without tributaries included, only segment 15 (Midnight Pass) is still "fair;" the other segments are "good."

TSI values in Tampa Bay range from 74 (poor) in Delaney Creek to 39 (good) at the mouth of the Manatee River. TSI values in Charlotte Harbor range from 57 (fair) at the Caloosahatchee River mouth to 28 (good) in the north fork of Alligator Creek. Based on this index, water quality in Sarasota Bay is better than Tampa Bay and about the same as Charlotte Harbor.

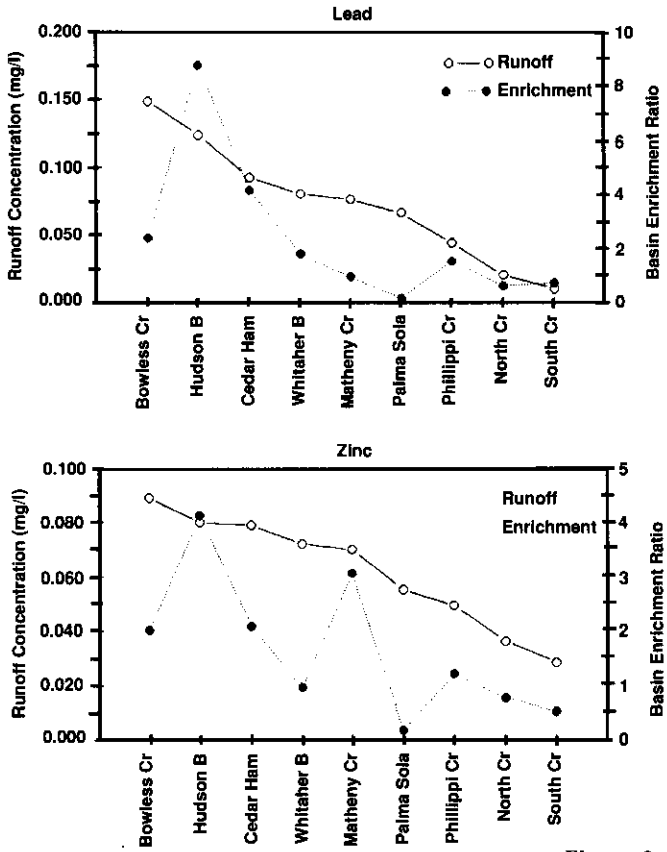


Figure 8. Relationship between runoff concentrations and basin-enrichment ratios for lead and zinc.

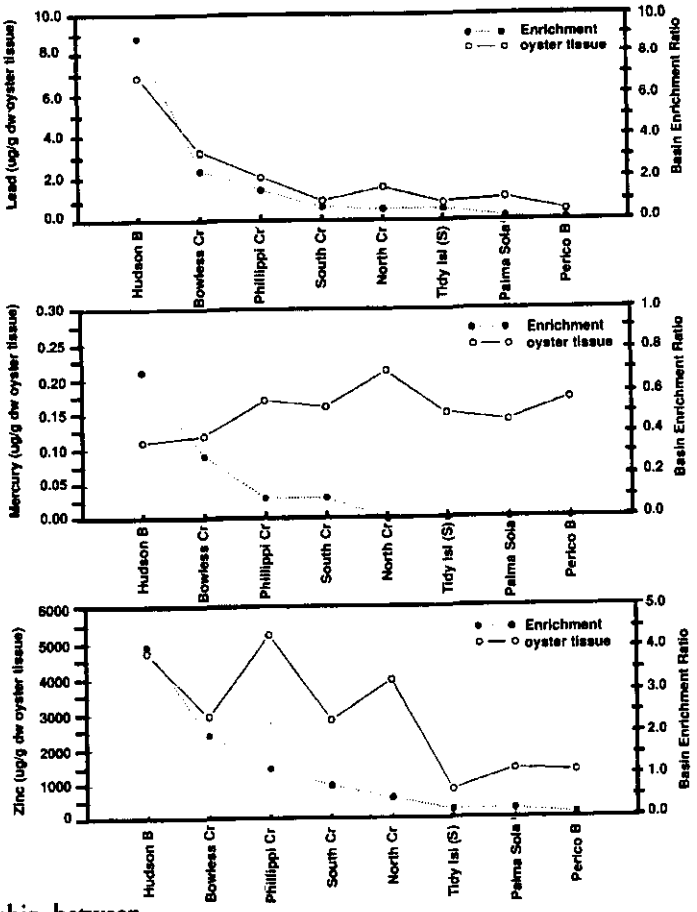


Figure 9. Relationship between sediment enrichments and shellfish tissues for lead, copper and zinc.

Sediment Contamination Assessment

Station Selection and Sample Collection

The scan was designed to emphasize potential areas of maximum contamination, and so the majority of the sites were on the eastern shore of the Bay. Station selection for the sediment scan emphasized Bowlees Creek, Hudson Bayou, Whitaker Bayou and Phillippi Creek, and considered the location of water-quality sampling locations, stations sampled for tissue contaminants during the Shellfish Contamination Assessment or areas of interest to the Point and Non-Point Source Assessment Projects. A total of 35 areas were sampled in the same locations, as shown in *Figure 7*. At each of the 35 areas, a suspected gradient in sediment quality was established and three stations were sampled at intervals along a transect.

Samples were collected from the upper 5 cm of the sediments, representing recent accumulations using a Ponar grab sampling device. Replicate samples from separate grabs were collected at each site to establish some measure of station variability.

Sediment deposition is typically heterogeneous, and small-scale variations in bathymetry, together with station location and sediment transport dynamics within a particular tributary, can produce widely ranging concentrations of contaminants in bulk sediments. Although researchers have taken various approaches to the problem of interpreting sediment data, most have relied on mathematical normalization techniques, such as presenting pollutant concentrations as a function of percentage of fines, percentage of organics or amounts of geochemical tracers.

However, even normalized sediment data should be considered an approximate technique in the absence of detailed physical analysis of the estuary to identify deposition patterns and an intensive spatial sampling for contaminants. Sediments typically exhibit a gradient in pollutant content, which is produced by equilibrium partitioning and mobility of contaminants as controlled by sediment type, salinity, pH and other water-quality parameters. In addition, sediment transport and deposition will affect the eventual fate of contaminants. The position of the gradient established reflects not only the composition and load of sediment and pollutants supplied, but also the net and tidal flows effecting the transport. Gradients will differ for different contaminants.

The position of pollution gradients varies between tributaries. In some instances, the most-upstream station is the most contaminated, but this is certainly not always the case. Within the three stations for a basin, for example, different metals may have maximum enrichment ratios at different stations. Some portion of the apparent difference in gradient position must undoubtedly be attributed to the presence of concentrations of non-point-source impacts such as stormwater drains and marinas. Other influences may be actual station location.

Examination of the sediments collected during this study with respect to the expected metal content reveals that the bulk of the sediments are uncontaminated by the six pollutant metals evaluated for this study (arsenic, cadmium, copper, lead, mercury and zinc). This is particularly the case for arsenic, cadmium and mercury, while more sediments are enriched with copper, lead and zinc (20 percent, 33 percent and 37 percent of the stations sampled, respectively). *Figure 7* represents the enrichment ratios by basin for copper, lead and zinc, and the most affected tributaries obviously are Hudson Bayou, followed by Cedar Hammock and Bowlees Creeks, followed by Whitaker Bayou.

The stations located farther upstream

than the mouths of the tributaries (in Hudson Bayou, Cedar Hammock Creek, Bowlees Creek, Whitaker Bayou and Phillippi Creek)) are all enriched for a number of metals and form much of the upper percentiles when individual stations are considered by mean rankings of all metals. The portion of the tributary sampled must therefore be considered when comparing basins.

Metals

In Florida, the bulk of the metallic content in uncontaminated sediments resides in the fine clay fraction that is comprised of alumino-silicate minerals, rather than in the larger-sized quartz sand fraction. Aluminum can be used as a tracer for naturally occurring metals because the concentrations in naturally occurring soils are known. Previous work (Schropp and Windom, 1988) has identified the expected range of metal content in uncontaminated sediments for given aluminum concentrations. Values falling above the upper-95th-percentile confidence interval for this relationship are considered anthropogenically enriched in the particular metals. Enrichment ratios for individual metals and stations were further computed as the observed metal concentration divided by the upper concentration that would be expected in pristine sediments, based on the observed aluminum concentration. Values of the ratio greater than 1.0 reflect data points outside the confidence intervals, and, therefore, enriched. The basin-enrichment ratios are presented in *Figure 7.*

The overall relationship of sediment metals with aluminum content is clear, as there is a clear central tendency in the distribution of the Sarasota Bay data. The apparent increase in the slope of the relationship, as compared to the 95-percent confidence interval for pristine sediments, is most likely a product of station selection for the study, as similar results have been seen in other work in contaminated areas (Pierce, *et al.*, 1988; Hofmann and Dixon, 1988; NOAA Tampa Bay Sediments, 1991). Analytical bias was eliminated using spiked matrix and reference materials.

Mercury

Mercury demonstrated a strong metal:aluminum relationship within the Sarasota Bay data set, in contrast to the statewide dataset that determined no significant relationship. Ranges of mercury and aluminum sampled were comparable in both the Sarasota Bay and pristine data sets. Relationships of mercury with percent organic content of the sediments were also apparent. The relationship observed in Sarasota Bay may reflect either a more uniform source of sediments or an enrichment process that is ubiquitous in the watershed, such as aerial deposition.

Relation to Basin Loadings

Basin loadings for lead and zinc together with land-use types, as given in the Point/Non-Point Source Pollution Loading Assessment, Phase I Report (CDM, 1992) were tabulated and summed by watershed and compared to metal-enrichment ratios for the basin, for the individual stations and for the station within a basin that was nearest the mouth of the tributary.

No statistically significant linkage appeared between either pounds, pounds per acre or runoff concentrations and the basin-enrichment ratios for either metal *(Figure 8).*

Based on the figures of runoff concentrations and basin enrichments, Hudson Bayou, and to a lesser extent, Cedar Hammock and Phillippi Creek, appear to have more lead in the sediments than might readily be explained by predicted loadings. The sediments in these same three basins also appear to be elevated, in comparison to runoff concentrations, with respect to zinc. The above comparisons again depend on the assumption that comparable areas of the pollution gradient within each watershed have been sampled.

Relation to Oyster-Tissue Contaminant Levels

A number of the sediments sampled during this study were also from quite near the location of oysters collected during the Bivalved Shellfish Contamination Assessment. For the comparison of shellfish tissues with sediment data, the same cautions apply as for the comparison with basin loadings. For correspondence to be expected, both samplings (sediment and tissue) at all stations must represent similar portions of the pollution gradient.

In *Figure 9*, the correspondence between sediment enrichments and shellfish tissues appears quite high for lead, copper and, to a lesser extent, zinc. Cadmium, arsenic and mercury in shellfish appear to be dominated by factors other than sediment enrichment. Cadmium and mercury are two elements that frequently have high relationships with organic content in the sediment, and the apparently varying bioavailability may well be related to between-basin differences in this parameter. These results indicate that the bioaccumulation of lead and copper in oysters is the most reflective of sediment-enrichment ratios.

Bioavailability of these two elements may be least affected by other sediment or water-quality variables, and they may therefore be the most readily used for interbasin comparisons and toxicity evaluations.

Potential Biological Impacts

Recent work (Long and Morgan, 1990) has synthesized the information available from various approaches determining biological impacts to provide a single "yardstick" for use in evaluation of the National Oceanic and Atmospheric Administration's National Status and Trends sediment data. Data from many species, including freshwater and marine organisms, were compiled together whenever toxic effects were determined. The synthesis was not intended to represent official standards or regulatory criteria. The lowest 10th percentile was designated an Effects Range - Low (ER-L), or that concentration of contaminant above which adverse biological effects may first be expected. The 50th percentile was selected as the Effects Range - Median (ER-M), or that concentration above which adverse effects almost always would be expected.

The Effects Range Approach may be considered conservative, in that studies that determined no effects were not included in the ranking, resulting in the use of the most sensitive species, or of the sediments providing the highest degree of bioavailablity. The table below summarizes the ER-L and ER-M values for the metals determined in this study, together with the percentage of the sediment samples from this study which exceeded those threshold values.

Arsenic and cadmium do not appear to be severe contaminants within the Sarasota Bay system. No samples exceeded the low effects range, as determined Long and Morgan (1990), and the maximum concentrations observed in Sarasota Bay sediments (14.9 for arsenic and 1.94 for cadmium) were less than the lowest value used to determine the ER-L and ER-M values.

A number of stations exceed the effects range-low for lead, with slightly fewer exceeding the ER-L for copper, mercury and zinc. These stations were all within the basins of Cedar Hammock Creek, Bowlees Creek, Whitaker Bayou and Hudson Bayou. Stations within Marina Jack were above the ER-L for lead and mercury, while some in Phillippi Creek were above the ER-L for lead and zinc.

A few stations exceeded the ER-Ms for lead and zinc, the concentrations above which adverse effects may almost always be expected. Stations in Hudson Bayou and Cedar Hammock Creek were in this category for lead, and stations in Hudson Bayou and Whitaker Bayou for zinc. One of the samples from Hudson Bayou (Station 24A) was almost three times the ER-M for lead, and over two times the ER-M for zinc. The biological effects noted in the studies used to establish the ER-Ms for these metals included toxicities to oyster larvae, amphipods, apparent effects thresholds noted for amphipods, bivalves and benthic organisms, 100-percent mortality of some polychaetes and reduced benthic species richness.

The stations that exceeded the various ER-L and ER-M levels were, in general, located upstream of the mouths of the various tributaries. While this indicates that the areal extent of contaminated sediments is comparatively small (with respect to the Bay bottom of the entire study area), the areas affected also represent some of the few low-salinity habitats available for the region. Any adverse biological impacts would also be directed against the more sensitive larval or juvenile life stages that typically utilize the low-salinity regions.

An additional concern is raised by the pattern of stations that exceeded the various effect ranges. Only five areas of the 35 sampled included stations that extended upstream of the mouths of the various tributaries; the bulk of the stations were directed towards evaluating the sediments within the Bay proper. There may potentially be additional low-salinity habitats that are impacted and yet were unsampled. The sediment status of the upstream reaches of the remaining tributaries is unknown.

Organics

The survey of sediment samples from Sarasota Bay demonstrated that most areas had low concentrations of the target compounds. Usually, stations with moderate to high levels of contamination were within the more urbanized bayous and creeks. Organics data, due to the hydrophopic nature of the components, is often presented as normalized to the organic or carbon content of the sediment.

Table 2. ER-L and Er-M levels of six metals and relation to Sarasota Bay sediments.

Metal	Effects Range -Low (ug/g)	Percent Exceeded (%)	Effects Range -Median (ug/g)	Percent Exceeded (%)	Maximum Sarasota Bay ug/g
Arsenic	33.0	0.0	85.0	0.0	11.75
Cadmium	5.0	0.0	9.0	0.0	1.66
Copper	70.0	6.7	390.0	0.0	160.00
Lead	35.0	12.9	110.0	5.0	283.00
Mercury	0.15	6.3	1.3	0.0	0.325
Zinc	120.0	7.5	270.0	1.7	500.00

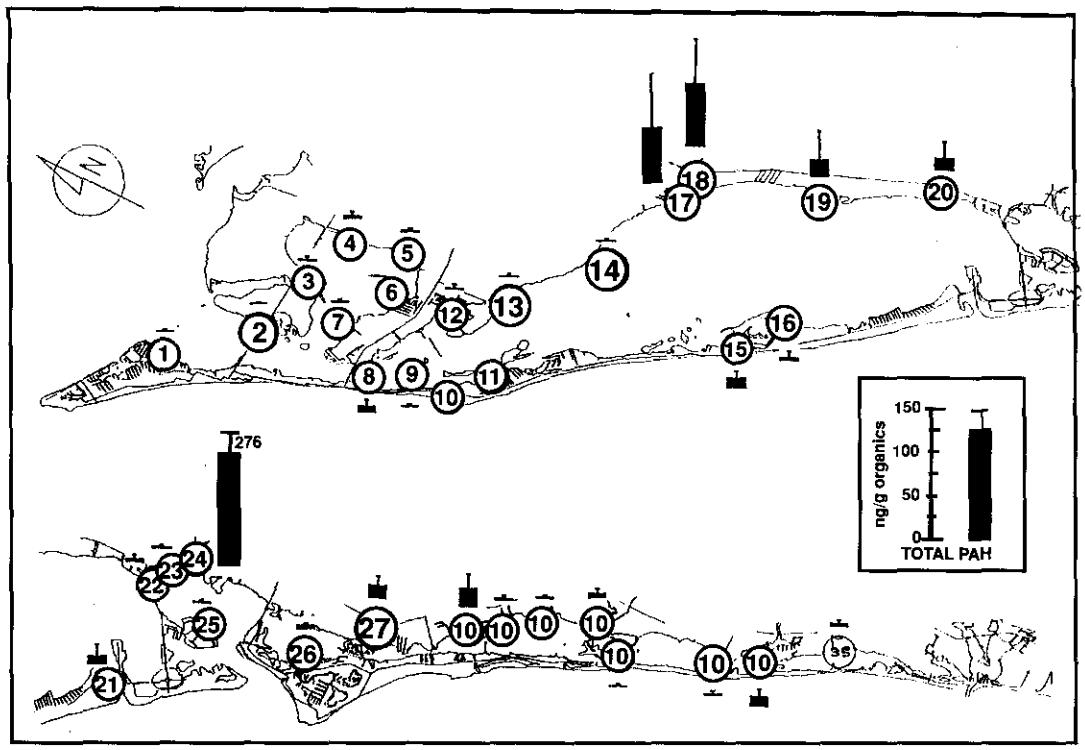


Figure 11. Total PAH in Sarasota Bay sediments by area. Average PAH concentrations (normalized to sediment organic content) for stations were summed to obtain the area totals.

by the National Status and Trends Program (NS&T) conducted by NOAA, 1989. It should be noted, however, that stations for that program were selected with the specific aim of avoiding point sources or known areas of contamination. Total chlorinated pesticides in Tampa Bay NS&T samples ranged from below the limit of detection to 61.4 ng/g dw (including DDTs). Samples from Sarasota Bay also range from below the limit of detection for total chlorinated pesticide concentrations, as do the Tampa Bay NS&T sites, but greatly exceed the Tampa Bay maximum at the most contaminated station (Hudson Bayou).

One area of concern for some of the more contaminated samples within this study was the observance of polychlorinated biphenyls (PCBs) as potentially interfering peaks. While PCBs were not target analytes in this study, PCB congeners were tentatively identified in several of the samples, and the toxicity of these compounds well known. They should be specifically targeted for analysis in selected samples.

Polynuclear Aromatic Hydrocarbons (PAH)

Polynuclear aromatic hydrocarbons (PAH) have both natural and anthropogenic sources to the marine environment, although among the manmade sources, petroleum spills and combustion by-products predominated. Combustion-derived PAH could enter the Bay through atmospheric deposition, surface runoff, effluents and direct exposure to vehicular exhaust (e.g., motor boats). Uncombusted petroleum products could enter the Bay via the same routes, with the additional route of spillage or leakage of petroleum products. Used motor oil contains significant concentrations of PAHs, both alkylated and parent low and medium molecular weight (Pruell and Quinn, 1988; Takada *et al.*, 1991) and can be introduced to the Bay through surface runoff or illicit disposal. The relative significance of each of the sources mentioned would vary with location in the Bay.

In Sarasota Bay sediments, the highest total PAH concentration (as a station mean) occurred at station 17A in Cedar Hammock Creek (26.8 ug/g dw), followed by stations 24A and 24B in Hudson Bayou (18.1 and 8.3 ug/g dw). Stations in Whitaker Bayou (20A) and Bowlees Creek (18B) also had elevated concentrations of these compounds. Normalizing total PAH to organic content produced a ranking of areas, with Hudson Bayou, Bowlees Creek and Cedar Hammock Creek far ahead of other areas of the Bay. Total PAH values adjusted for organic content are illustrated as basin means (the average of all three stations) in *Figure 11.* This figure demonstrates the variability of PAH contamination in the Bay, and the fact that extremely high concentrations were restricted to relatively few of the stations and areas sampled (Hudson Bayou, and to a lesser extent, Bowlees and Cedar Hammock Creeks).

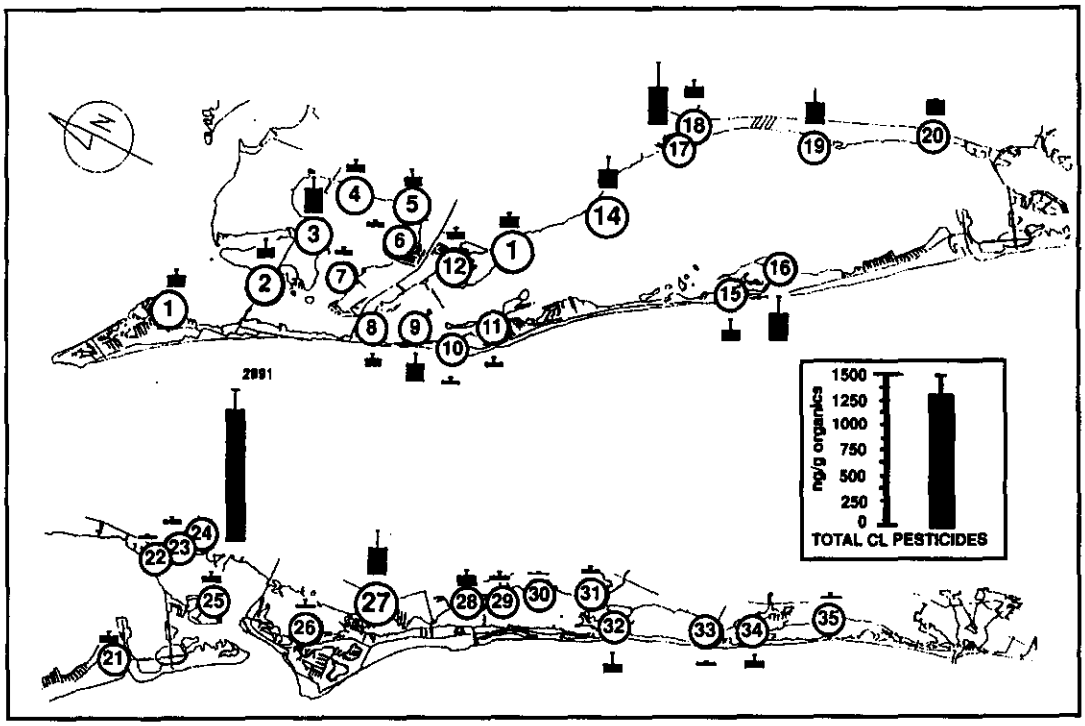


Figure 10. Total chlorinated pesticides in Sarasota Bay sediments by area. Average pesticide concentrations (normalized to sediment organic content) for stations were summed to obtain the area totals.

Pesticides

The highest mean total pesticide concentration, 192 ng/g dw, measured during this study was in Hudson Bayou station 24A. This station had individual and total pesticide concentrations as much as three to four times those measured at any other station. Mean total pesticide concentrations of roughly 70 ng/g dw were measured at both Hudson Bayou station 24B and Cedar Hammock Creek station 17A. *Figure 10* represents the total chlorinated pesticides found in sediments for each of the areas sampled as a function of organic content. Using normalized data, Hudson Bayou is by far the most contaminated area. Cedar Hammock Creek, Phillippi Creek, Perico Bayou and Bishop's Point (Harborside) also show elevated levels of total chlorinated pesticides. The most abundant chlorinated pesticides were the DDT derivatives, DDE and DDD, the cyclodiene pesticides, aldrin, dieldrin and heptachlor epoxide, and the chlorinated organophosphate, chlorpyrifos.

Potential Biological Effects

The potential for adverse biological effects resulting from the concentrations of pesticides in Sarasota Bay sediment can also be assessed by comparison with the Effects Range approach described above. Although effects have not been determined for all the pesticides, the following are presented to assess potential adverse biological effects.

Relation to Shellfish Contamination Assessment

A comparison of pesticide levels in sediments with pesticide levels in Sarasota Bay shellfish, where both studies had common sites, indicates only one site where pesticides reached appreciable quantities in both shellfish and sediments. At this site (Hudson Bayou), a wide array of pesticides was measured in the sediment samples, while shellfish had quantifiable levels of p,p'-DDE and p,p'-DDD. The observed differences in the number of pesticides found in the two sample types likely either reflect the different time scales integrated by measurements in sediment and shellfish, or differences in the bio-availability of the pesticides being measured.

Relation to Tampa Bay Sediments

With no other major surveys of pesticides in the sediments from Sarasota Bay, the best-available comparisons are pesticide concentrations observed in Tampa Bay sediments

Table 3. ER-L and ER-M levels for selected pesticides and relation to Sarasota Bay sediments.

Pesticide	Effects Range-Low (ng/g)	Percent Exceeded %	Effects Range-Median (ng/g)	Percent Exceeded %	Maximum Srasota Bay (ng/g)
DDT	1.0	5.7	7.0	1.0	13
DDE	2.0	6.7	15.0	3.8	27
DDD	2.0	5.7	20.0	1.9	43
Total DDT	3.0	11.4	350.0	0.0	70
Dieldrin	0.02	5.7	8.0	2.8	17
Endrin	0.02	1.0	45.0	0.0	1

Five of the 35 study sites exhibited no quantifiable PAH at any of the three stations. Ten stations showed moderate to high PAH concentrations and usually contained not only methly-substituted PAH but also ethyl- and propyl-substituted PAH, indicative of gross petroleum contamination. These stations included those in Cedar Hammock Creek (2), Bowlees Creek (2), Hudson Bayou (2), Matheny Creek (2) and Whitaker Bayou (1).

Potential Biological Effects

As for the pesticides, the toxic levels of PAH can also be assessed from the sediment-effects ranges defined by Long and Morgan (1990), which are listed at right below for the PAH compounds identified in this study *(Table 4).*

A comparison of PAH concentrations in Sarasota Bay sediment with their effects thresholds shows that although several stations throughout the Bay exhibited PAH levels above "background" levels, most concentrations are below that considered to pose an adverse biological effect.

Three sites were found to contain sufficient concentrations of PAH to represent an adverse biological effect on organisms in contact with sediment. These sample sites, including Cedar Hammock Creek, Bowlees Creek and Hudson Bayou, should be considered "hot spots" for PAH contamination.

Stations exhibiting PAH concentrations above the ER-L, but below ER-M concentrations for one or more PAH, include sediments from Whitaker Bayou, Marina Jack's, Island Park, Matheny Creek and Cedar Creek *(Figure 11).*

Relation to Shellfish Contamination Assessment

Comparison of the sediment PAH concentrations with the concentrations determined in shellfish from Sarasota Bay showed that all but one of the sites where shellfish were reported to have trace levels of PAH also contained measurable quantities of PAH in sediment.

Relation to Tampa Bay Sediments

A comparison of the average mean total PAH concentrations of Sarasota Bay sediments (941 ng/g dw) with the concentrations reported for Tampa Bay NS&T sites (NOAA, 1989) places Sarasota Bay sediments in the middle range of concentrations observed at the six NS&T Tampa Bay sites (90 to 1900 ng/g dw). Since the Sarasota Bay average mean is significantly affected by the few extremely high stations, we may conclude that Sarasota Bay sediment concentrations compare favorably with concentrations observed in Tampa Bay.

Fecal Sterols

Coprostanol is primarily produced by the enteric bacteria of higher animals (Walker *et al.*, 1982), and little decay of this material occurs in anaerobic sediments. Anthropogenic contamination is more readily visible in coprostanol concentrations as a function of sediment organic content.

Both coprostanol and epicoprostanol are produced during anaerobic microbial action on sewage sludge (McCalley *et al.*, 1980, 1981), and could potentially be produced in anaerobic sediments. During the anaerobic incubation of sludge, ratios of coprostanol to epicoprostanol were also reported to change, with epicoprostanol the favored product.

Some indications exist that coprostanol can be produced *in situ* under anaerobic conditions in areas uncontaminated by mammalian fecal wastes (Taylor *et al.*, 1981; Toste, 1976; Smith *et al.*, 1982, 1983; Mackenzie *et al.*, 1982) from cholesterol precursors. The relative magnitude of this "environmental" production of coprostanol has yet to be determined, but is likely to be strongly controlled by sediment composition and bacterial population. Comparable levels of coprostanol and epicoprostanol with depth in anthropogenically uncontaminated sediment cores (Vankatesan and Santiago, 1989) would seem to indicate that the process of either total coprostanol production or shift in epimere dominance does not continue indefinitely.

Table 4. ER-L and ER-M levels for selected PAHs and relation to Sarasota Bay sediments.

PAH	ER-L (ng/g)	Percent Exceeded %	ER-M (ng/g)	Percent Exceeded %	Sarasota Bay max. (ng/g)
Acenaphthene	150	0.0	650	0.0	BDL1
Anthracene	85	2.8	960	0.0	262
Benzo (a) anthracene	230	5.7	1600	1.9	1961
Benzo (a) pyrene	400	7.6	2500	0.0	2339
Chrysene	400	6.7	2800	1.9	3350
Dinezo (a, h) anthracene	60	ND2	260	ND2	ND2
Fluoranthene	600	5.7	3600	1.9	4740
Fluorene	35	1.0	640	0.0	38
Naphthalene	340	ND2	2100	ND2	ND2
Phenanthrene	225	4.7	1380	0.0	1176
Pyrene	350	5.7	2200	1.9	4540
Total PAH	4000	6.7	35000	0.0	26771

1 BDL = Below Detection Limit
2 ND = Not Determined

Treatment plants for domestic effluents rely on a variety of processes for solids, biochemical oxygen demand and nutrient removal. Advanced waste-treatment plants (AWT) in particular use a series of anaerobic digestions of clarified effluents for nitrogen removal. For secondary treatment, anaerobic conditions may be less frequent, but both processes experience anoxia in the initial stages of sludge settling. The formation of epicoprostanol is apparently favored by the anaerobic digestion process based on the analysis of sludges from a variety of treatment plants (Eganhouse *et al.*, 1988).

Sarasota Bay sediments displayed a wide range in both epimere and total coprostanol concentrations. Stations in the upper 10th percentile (>500 ng/g dw) included one each from the Grand Canal, Cedar Creek, Whitaker Bayou and the area immediately to the north of Tidy Island, and two stations from each of Cedar Hammock Creek and Bowlees Creek areas. Over half the stations in the upper 10th percentile were located near the mouths of the various tributaries. Bulk coprostanol concentrations, as for metals and other organics, undoubtedly reflect the distribution and relative organic content of sediments.

In Sarasota Bay, the relationship of total coprostanol with organic content of the sediments was highly significant ($r^2 = 0.556$, n=76). The station in Clower Creek (station 29A) appears to have lower total coprostanol concentrations than would be expected from studywide norms (at the 95-percent confidence intervals), while stations to the north of Tidy Island (12A) and at the Grand Canal (26C) appear to have an enrichment in coprostanol beyond that expected for the remainder of the study area.

Before concluding, however, that the remaining stations are unimpacted, it should be restated that the sampling design emphasized stations suspected to have substantial amounts of contaminants. Access to a data base from pristine areas with similar sources and loads of organic matter and climatological conditions could develop an "enrichment ratio" approach similar to that used for metals contamination. Any selection of a "pristine" subset of stations with respect to coprostanol from this study would be very subjective. The use of the other contaminants to identify "impacted" and "unimpacted" stations was not considered to be useful, since domestic effluents and the major contributors of metals and synthetic organics do not necessarily coincide.

Normalization of total coprostanol data resulted in a differing suite of stations in the upper 10th percentile, and the distribution of fecal sterols in Sarasota Bay is shown in *Figure 12*. Plotted are the mean total coprostanol (summed means of coprostanol and epicoprostanol) by region. A station to the north of Tidy Island, the upstream station in Bimini Bay (Anna Maria), one at Long Bar Point, Buttonwood Harbor and two stations from the Grand Canal and Palma Sola Creek had the highest total coprostanol concentrations per weight of organic matter. The stations to the north of Tidy Island and at the Grand Canal were both apparent outliers to the coprostanol/ organic relationship determined for Sarasota

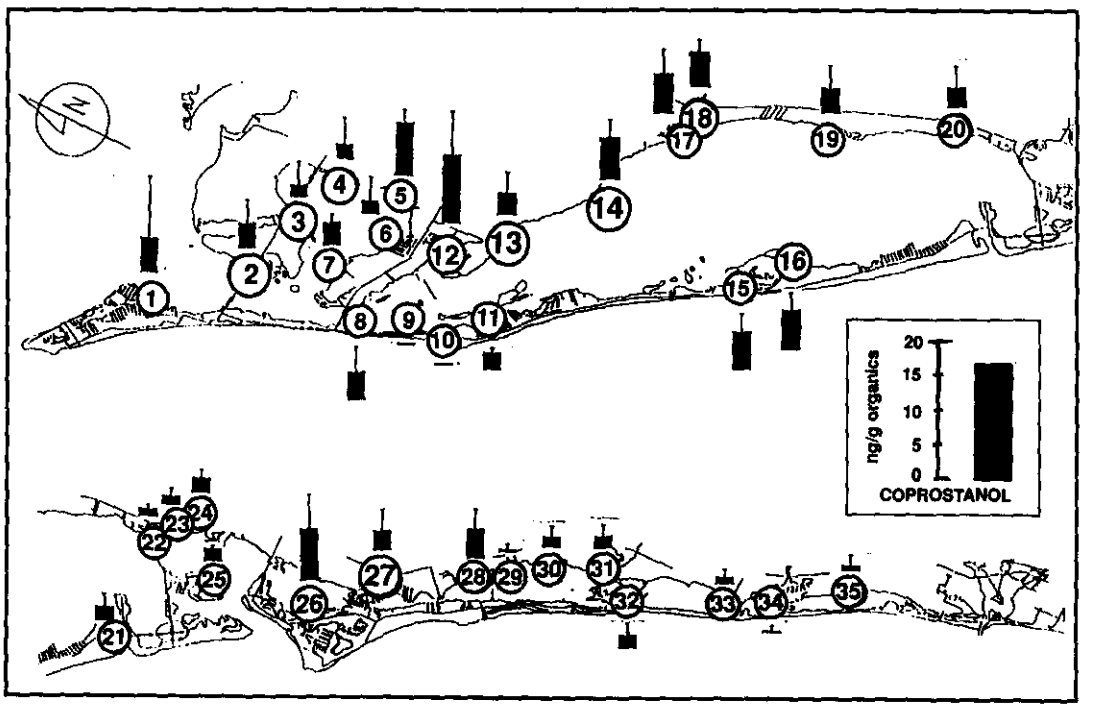


Figure 12. Total coprostanol in Sarasota Bay sediments by area. Average coprostanol (normalized to sediment organic content) for stations were summed to obtain the area totals.

Bay sediments (more coprostanol than expected).

The coprostanol-to-epicoprostanol ratios were determined for Sarasota Bay sediment samples where both compounds were quantified. The values of this ratio in Sarasota Bay sediments ranged from 0.1-1.5 with almost all values below 0.3. Coprostanol was typically one-third of the epicoprostanol levels.

The two notable exceptions to this relationship were for stations at Cedar Hammock Creek (more coprostanol than would be expected) and to a lesser extent at station 18B at Bowlees Creek (more epicoprostanol than predicted).

The predominance of low ratio values determined in these samples could suggest several processes for coprostanol in Sarasota Bay sediments. Coprostanol and epicoprostanol may be produced *in situ* by the anaerobic microbial degradation of cholesterol. Cholesterol sources include not only animal wastes, but plant detritus as well, although in lesser proportions. Alternatively, the waste sources discharging directly to the Bay consist of AWT discharges under which anaerobic conditions favor epicoprostanol production. Subsequent incorporation into reduced sediments maintains the favored status of epicoprostanol. In this instance, higher coprostanol/epicoprostanol ratios may indicate more recent inputs of aerobically or relatively untreated wastes. To examine and rank areas which receive domestic effluents, the use of total cholesterol normalized to sediment organic content appears to be more useful.

Options

Although temporal trends by segment indicate that water quality in Sarasota Bay is improving, water-quality problems still exist in the tributaries and the segments receiving water from the tributaries. Tributary stations were significantly higher in nutrients, chlorophyll, turbidity and light attenuation than any other category of station. Sediment collection and analysis, designed to assess recent inputs of contaminants to the benthos, revealed sediments enriched in pollutant metals and containing sufficient chlorinated pesticides, PAHs or metals to make impacts on organisms likely.

Management

In order to control water quality in the tributaries, the quality of water entering the tributaries must be controlled. Water enters the tributaries as rainfall, either directly or indirectly as runoff from the land. Water also may come from point sources such as wastewater discharge or brine effluent. Groundwater also enters the tributaries.

Rainfall entering tributaries directly can carry a wide range of atmospheric pollutants with it; these may include nitrogenous compounds and metals from automobile exhausts. Treating rainfall before it enters the tributaries is not feasible, but controlling levels of atmospheric pollutants is possible.

Runoff carries nutrients, oil, grease, solids and debris into tributaries. All stormwater should be treated before it enters either the tributaries or the Bay. Vegetated buffers along creeks slow the rush of water, allowing particulates to settle. Stormwater-detention areas provide similar functions.

Sediment quality in the tributaries is subject to the same inputs as water quality, and can benefit from the same management approaches. Contaminated sediments also could be removed or capped.

Additional Research Needs

Areas where additional information is needed include:

1) Water- and sediment-quality studies in the tributaries that extend further upstream than current efforts.
2) The quantity of freshwater entering the system and the timing of those inputs, particularly as it relates to historical inputs.
3) Investigating the possibility that PCBs exist in the sediments of Sarasota Bay.
4) Developing a database from "pristine a reas" for coprostanol so an enrichment ra tio approach (as used for metals) could be used for coprostanol.

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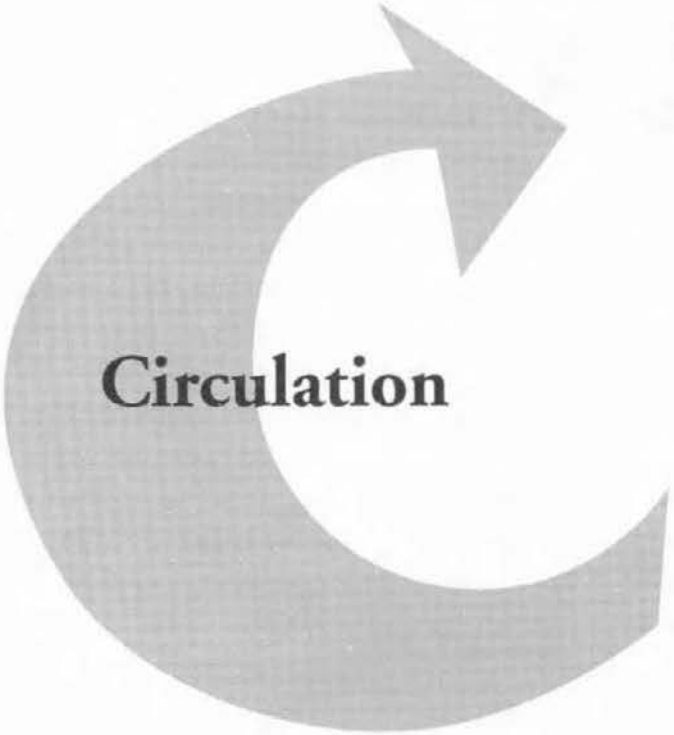

Circulation

- Circulation and Its Effect on Water Quality
- Tidal Inlet Dynamics
- Inlets and Shorelines

Circulation and Its Effect on Water Quality

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Executive Summary

Circulation is of utmost importance in that it plays a dominant role in transporting and diluting various species (e.g., salt, dissolved oxygen) and contaminants (e.g., sediments, nutrients, metals, etc.) from their sources to faraway locations. Thus, understanding and quantifying the circulation in an estuary is the first step toward developing a management plan for estuarine resources. Until recently, little has been done to quantify the circulation of the Sarasota Bay system.

Currents and salinity data in Sarasota Bay have recently been collected by the University of Florida, while water-level data have been collected by the U.S. Geological Survey. A three-dimensional model of circulation and salinity transport has been developed by the University of Florida. The model is based on the CH3D model originally developed by Sheng (1989a) for Chesapeake Bay and the James River.

Circulation and transport within the Sarasota Bay system are primarily driven by the interaction of tidal waves propagating through the multiple inlets connecting the Bay with the Gulf of Mexico and Tampa Bay. Circulation and transport are also influenced by wind, as well as by density gradients associated with salinity and temperature variations.

Sarasota Bay is characterized by areas of strong currents in and around the passes, and by null zones (areas of very low currents) located at dead-end zones or where two tidal waves propagating in from different inlets meet. Analysis of measured currents and computer simulations show that the primary null zones are located in Little Sarasota Bay just south of Stickney Point, in the middle portion of Sarasota Bay, in the region west of Hudson Bayou and in Palma Sola Bay.

The amount of water that flows through the various passes during each tidal cycle varies significantly, with Big Pass having the largest tidal prism.

The locations of the null zones within the system have a significant effect on the flushing characteristics of the different segments within the Bay

and therefore the water quality. Based upon the present segmentation scheme within the Bay, a computer simulation to determine the flushing characteristics by segments was conducted. For a 10-day simulation in August 1991, the results showed that segments containing null zones exhibited poorer flushing when compared with other segments. For example, segments 3 (Palma Sola Bay), 7 and 8 (middle of Sarasota Bay) and 14 and 15 (Little Sarasota Bay) showed only 20-30 percent flushing after 10 days, while the other segments were on the order of 70-80 percent flushed.

An additional simulation in which Midnight Pass was opened showed that flushing within segments 14 and 15 increased by 50 percent, flushing within segment 16 (Blackburn Bay) increased by 10 percent and flushing within segment 13 decreased by 30 percent. The result of the opening was to improve overall flushing, but the null zone was moved from segments 14 and 15 into 13, resulting in poorer flushing within that segment. The results given are highly dependent upon the choice of the cross-sectional area and therefore the flow through the pass.

Residual circulation patterns can have a significant effect on water quality within the system through the transport of loadings to areas not necessarily near the source. Measurements of currents and salinity near the constriction at Cortez Bridge during July and August 1991 indicated a net residual flow to the south. The measurements also showed that when the currents were flowing to the south, the salinity at the constriction dropped, thus indicating a fresher water source to the north. Since the most significant flow in that area comes from the Manatee River, it is reasonable to expect that the net southerly residual flow entrains water from the Manatee River into Sarasota Bay through Anna Maria Sound. A comprehensive study is presently being conducted to verify this assumption.

The circulation and transport patterns within the system have a significant effect on how, when and where the loading effects will be noticed. For example, it has been observed that water quality in Anna Maria Sound is generally poorer than expected for a pass-influenced segment. Water quality in the area behind Midnight Pass is very poor due to the lack of flushing there and pollutant loadings from other areas.

Another effect circulation can have on water quality is through its interaction with sediment transport dynamics, e.g., the uptake and release of nutrients by sediment particles, the transport and settling of fine sediment particles in areas of low energy (null zones) and the resuspension during storm events. Sediment-related events can significantly affect the water quality, while the increased turbidity can also reduce light penetration affecting seagrass growth. Thus to improve our understanding of the water quality of Sarasota Bay, it is important to further study the interaction between circulation and sediment and water-quality dynamics.

The circulation patterns within the Sarasota Bay system are highly dependent upon the cross-sectional areas and the locations of the multiple inlets connecting the Bay to the Gulf of Mexico. Any changes to the cross-sections through dredging or the addition of new inlets will alter the flushing characteristics, and therefore the water quality. Presently, three primary null zones have reduced flushing capabilities.

The opening of new inlets such as Midnight Pass would alter the flushing characteristics in the nearby segments and increase the overall flushing rates of the system, but at the same time cause reduced flushing capabilities in some other segments. Present model simulation of circulation and tidal flushing indicated that the opening of Midnight Pass would significantly improve the water quality in the area behind the Pass (segments 14 and 15), with degradation of water quality in Roberts Bay as a side effect. However, tidal fluxes at Midnight Pass would allow red tide to come into Little Sarasota Bay during the summer months.

For more quantitative estimation on the impact of proposed opening of passes and/or reduced loading of nutrients, it is essential to develop a coupled circulation-water quality model for Sarasota Bay.

Basic Principles of Circulation and Its Influences on Water Quality in Estuaries

Effect of Tide, Wind and Freshwater/ Ocean Water on Estuarine Circulation

Estuaries are semi-enclosed water bodies where salt water from the ocean is measurably diluted by fresh water from tributaries (Cameron and Pritchard, 1963). Estuarine circulation is driven by tide, wind and density variation in the water, while influenced by the geometry and bathymetry of the basin and the rotation of the earth.

Tides in estuaries are primarily forced by the ocean tides at the entrance of the estuaries, while tides in large coastal waters (e.g., the Gulf of Mexico) result from direct gravitational forcing by the sun and the moon as well as forcings at the open boundaries (Yucatan Channel and Florida Straits). Field monitoring of estuarine circulation and transport is very costly. Hence, it is also necessary to utilize numerical models to fully quantify the complex estuarine circulation and transport driven by tide, wind and density gradient. Physical modeling, due to inherent scaling problems, cannot represent the circulation and transport in turbulent field conditions. The cost for building and maintaining a physical model is also prohibitive.

Tides propagate as long waves in the ocean and estuaries and are reflected and dissipated by the boundaries. In an estuary (e.g., Tampa Bay and Sarasota Bay) where the basin length is less than the quarter-wavelength of tidal propagation (tides propagate as long waves at a speed equal to the square root of the product of gravitational acceleration and the local depth), the water level in the entire estuary fluctuates up and down simultaneously (i.e., in phase) during the "flood" cycle (water level rises in the estuary as ocean water flows into the estuary) and the "ebb" cycle (water level decreases in the estuary as estuarine water flows into the ocean). When the basin length is near one-quarter of the tidal wavelength (e.g., Long Island Sound), near resonance occurs such that tidal amplitude increases while tidal current decreases from the ocean entrance towards the river (Ippen and Harleman, 1966). If the basin length exceeds the quarter-wavelength of tidal propagation (e.g., James River estuary in Virginia), part of the bay may be in "flood" cycle while other parts of the bay is in "ebb" cycle.

When the natural period of a basin (e.g., the Gulf of Mexico) is comparable to a tidal period (e.g., the diurnal period), the tidal constituent is amplified. This is why tides on the Gulf coast of Florida are composed of a mixture of the semi-diurnal tides (lunar and solar tidal constituents that have periods on the order of 12 hours) and the diurnal tides (lunar and solar tidal constituents with periods on the order of 24 hours), while tides on the Atlantic coast of Florida are semi-diurnal. Tidal currents are in phase with the tidal elevation when tides are purely "propagating waves," while tidal currents and elevation are out of phase in "standing waves."

Tidal circulations are modified due to the effects of wind and density structure in the water. The wind enhances vertical mixing, creates vertical flow structure (e.g., surface flow in the downwind direction and bottom flow in the upwind direction), causes set-up and set-down in water level and alters the long-term circulation patterns. While the wind- and tide-driven currents affect the distribution of temperature and salinity in estuaries, the resulting density structure can induce baroclinic circulation to significantly modify the flow field.

The classical tidally averaged estuarine circulation consists of seaward flow of fresh water near the surface and landward flow of ocean water near the bottom (Hansen and Rattray, 1965). Depending on the relative importance of tidal mixing with respect to the river flow, vertical salinity structure in estuaries may be highly stratified (low tidal mixing), well-mixed (strong tidal mixing) or partially stratified (intermediate). However, circulation patterns in estuaries are highly dynamic. Significant vertical stratification may occur even in well-mixed estuaries. When studying the long-term residual circulation in estuaries (Zimmerman, 1978), the effect of density gradient on estuarine circulation must be considered. Saltwater

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from the sea often penetrates far upstream in rivers as a salt wedge. During periods of drought or expected sea-level rise, salt intrusion can significantly penetrate rivers, thus affecting freshwater supply (Hull and Titus, 1986). In short estuaries (Sarasota Bay and Indian River Lagoon), saltwater can intrude the ground water.

Most U.S. estuaries are coastal plain (drowned valley) estuaries and are quite shallow, typically consisting of a deep navigation channel where significant stratification exists and shallow adjacent flats where salinity and temperature are generally well-mixed. Salt intrusion takes place primarily within the bottom water of the deep navigation channel. Recent studies in Chesapeake Bay (Sheng *et al.*, 1989a; Johnson *et al.*, 1989) and Tampa Bay (Peene *et al.*, 1991; Yassuda *et al.*, 1992) showed that currents in the navigation channel are generally parallel to the channel and gradients in salinity and velocity exist across the channel. Transports of momentum and salinity along the channel are generally more important than the cross-channel transports.

Estuaries are connected to oceans through numerous tidal inlets (passes). The geometry and bathymetry of these passes can have significant effect on estuarine circulation (tidal currents, tidal prism, tidal flushing, residual flow), inlet stability and water quality. Salt intrusion is also influenced by "tidal pumping" and "tidal trapping" (Fischer *et al.*, 1979), which often lead to interesting residual circulation patterns and gyres in estuaries with complex geometry and bathymetry.

In the vicinity of large freshwater discharge (e.g., river plume), a front (Garvine, 1974) can be formed across which large gradients in density and other properties exist. The front can be destructed by intermittent vertical mixing modulated by tidal circulation over scales much larger than the river width (O'Donnell, 1990). Estuarine circulation and transport are also influenced by the circulation of the adjoining continental shelf.

Studies on estuarine circulations have utilized field experiments, laboratory physical modeling and numerical modeling.

Field experiments involve the measurements of various meteorological parameters (e.g., wind, air temperature, atmospheric pressure and solar radiation, etc.) and hydrodynamic parameters (e.g., water level, water currents, temperature and salinity, etc.) over long time periods.

Laboratory physical models were developed to study wave propagation and circulation in real estuaries (e.g., Chesapeake Bay and San Francisco Bay). However, due to inherent scaling problems associated with physical models in representing turbulent flow, it has been recognized that physical models are suitable for studying wave propagation but not circulation and transport problems. Because of this scaling problem and because of the high maintenance and modification cost, physical models have been gradually replaced by numerical models as one of the primary tools for estuarine studies.

Numerical models of estuarine circulation are based on well-known principles of physics and consist of equations that can be solved numerically with relative ease. Numerical models can be developed to represent turbulent motion in field conditions, and hence do not have the scaling problem of physical models. Numerical models, after rigorous calibration and validation processes, can be modified with relative ease to allow "prediction" of "what if" scenarios.

Numerical models of estuarine circulation of various (one, two or three) dimensions have been developed. Sheng (1986) and Sheng (1989a) provided comprehensive reviews of numerical models of estuarine circulation and transport. To allow simulation of estuarine circulation and transport in shallow estuaries, numerical models must contain the following features: (1) ability to represent the various forcings of wind, tide and density gradient as modified by earth rotation, (2) ability to represent the various temporal (tidal periods, seiche, synoptic events) and spatial (boundary layer, channel width) scales of motion of interest, (3) ability to represent turbulent flow in field conditions, (4) ability to be run efficiently. Although two-dimensional, vertically averaged models could be used to simulate tide-induced water-level fluctuations, a three-dimensional model is generally required for accurate simulation of the flow field, particularly in the case of horizontal and/or vertical variation in salinity and/or temperature.

The latest estuarine circulation models, e.g., the Chesapeake Bay model (Sheng *et al.*, 1989a, Johnson *et al.*, 1989), utilize a curvilinear grid that conforms to the complex shorelines and bathymetry of estuaries, thus giving more accurate results than the rectangular-grid models. This model is the basis of the Sarasota Bay circulation model (Sheng and Peene, 1991).

Effect of Circulation on Water Quality

Increased external loading of nutrients through tributaries and rivers had led to

accelerated eutrophication and reduced fishery production in many estuaries and lakes in the U.S. For example, three decades of increased loading of nutrients have resulted in an extensive area of anoxia (zero oxygen concentration) in Chesapeake Bay during the summer months. Hillsborough Bay in Florida has also been found to have an extensive area of hypoxia (low oxygen concentration) in the summer (Johannsson, 1991). Since dissolved oxygen is vital to the fishery species, hypoxia and anoxia (zero dissolved-oxygen level) often lead to fishkills.

The distribution of water-quality parameters (e.g., temperature, salinity, sediment, nutrients such as nitrogen and phosphorus, dissolved oxygen, etc.) in an estuary are significantly influenced by estuarine circulation. Sediment transport in estuaries is very complex and consists of the following processes: advection, turbulent mixing, flocculation, settling, erosion/resuspension and deposition (Krone, 1979; Sheng 1986). River sediments that enter into an estuary may undergo a series of advection-deposition-resuspension sequences before entering into the ocean or residing at a low-energy location in the estuary. Nutrients that enter into an estuary from rivers and tributaries may exist in both dissolved and particulate forms. While both the dissolved and particulate nutrients are influenced by the advection and turbulent mixing of the flow field, particulate nutrients are closely related to sediment transport and undergo the processes of flocculation, settling and erosion and deposition. Nutrients also undergo complex chemical transformation processes. For example, nitrogen can undergo mineralization, nitrification, volatization, denitrification, desorption/adsorption and fixation.

Many of the nutrient transport processes can be influenced by physical and biological processes. For example, organic nitrogen contained in soil particles can be brought into the water column due to resuspension of sediments during high-energy episodic events such as the passage of a storm front. Once in the water column, part of the organic nitrogen on the particles can be desorbed into the water until an equilibrium is reached between the organic nitrogen in soil and the soluble organic nitrogen in water. Likewise, ammonium adsorbed onto resuspended sediment particles can be desorbed into the water and later nitrified to nitrate due to the presence of oxygen in water. Recent studies in Chesapeake Bay (Simon, 1989) and Tampa Bay (Sheng *et al.*, 1992a) found that resuspension flux of ammonium is typically one to three orders of magnitude larger than the diffusive flux. Vertical transport of dissolved nitrogen is affected by the turbulent diffusion in the water column, while vertical transport of particulate nitrogen is affected by the turbulent diffusion as well as settling/deposition of suspended sediments. Transport of nutrients in the sediment column is affected by the molecular diffusion as well as the feeding activities of benthic organisms.

From the above description, it is clear that sediment and water-quality dynamics in estuaries are quite complex. As an example, the various mechanisms of circulation, sediment transport and nutrient (nitrogen) transport in an estuary are shown in *Figure 1*. It should be pointed out that sediment and nutrient processes are highly time-dependent and may vary significantly from one estuary to another or from one site to another. The relative importance of these various processes may also change significantly with location and time. To develop a comprehensive model of nutrient transport, much understanding of the sediment and nutrient processes must be acquired from field observation and laboratory experiments.

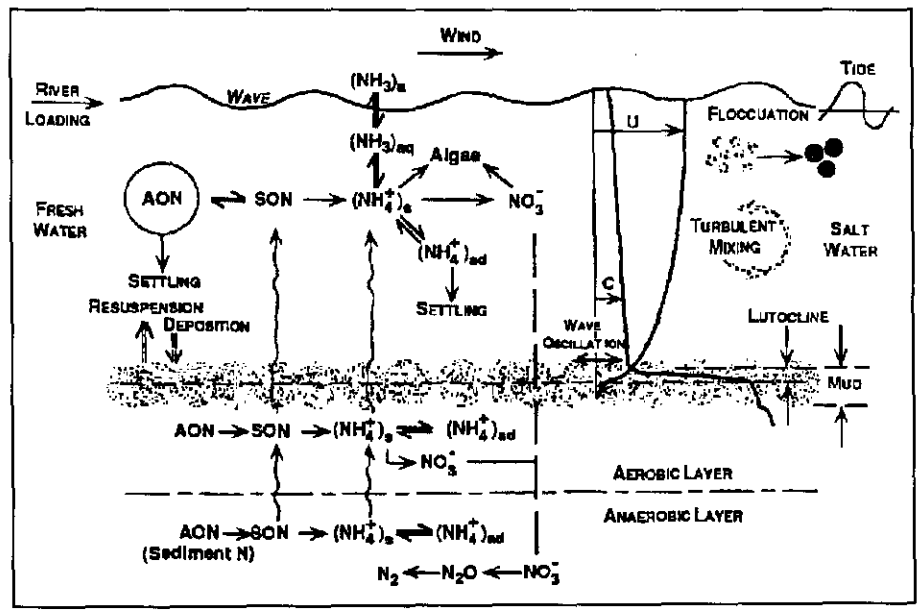


Figure 1. Mechanisms affecting the transport of sediments and other water-quality parameters in estuaries.

Effect of Circulation on Habitat and Fishery

Estuarine circulation can significantly affect fishery habitat and fishery production. For example, increased loading of sediments or particulates from tributaries or increased storm-induced resuspension events may lead to increased turbidity and reduced light penetration into the bottom water of an estuary, thus resulting in a decline in the seagrass population. Florida estuaries have suffered a significant loss of seagrasses (e.g., Livingston, 1987), which may have in turn contributed to the reduction in fisheries. Many Florida estuaries have

also received increased fresh water from tributaries and canals, which caused reduced salinity levels and increased salinity fluctuations, thus leading to increased mortality of shellfish and larvae of recreational and commercially important species.

Artificial reefs are becoming increasingly popular in Florida, including Sarasota Bay, as a way to enhance fishery production. The performance of artificial reefs can be significantly affected by estuarine circulation. Understanding the circulation and its local interaction with the reef will definitely lead to better reef design and enhanced fishery production at the reef sites. Currently, Sheng (1992) is monitoring the physical processes at several reef sites of the Suwannee Regional Reef System (Lindberg *et al.*, 1992) offshore from Cedar Key.

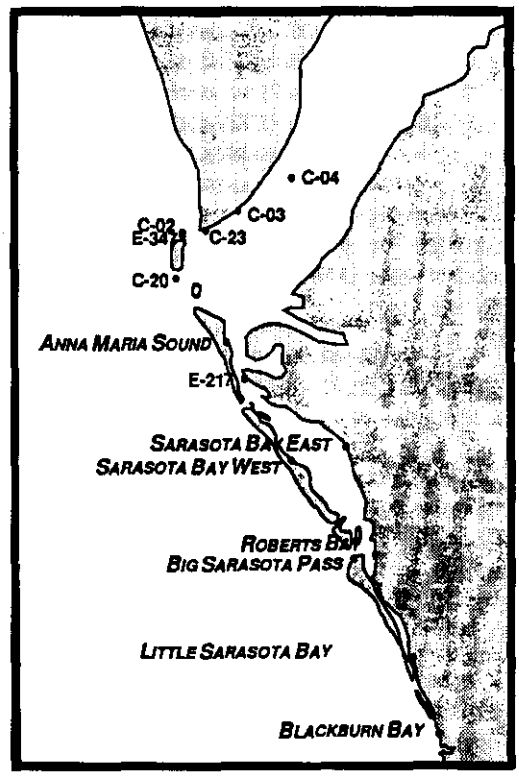


Figure 2. A map of the Sarasota Bay system and part of Tampa Bay, including the USGS and NOAA/NOS data station locations.

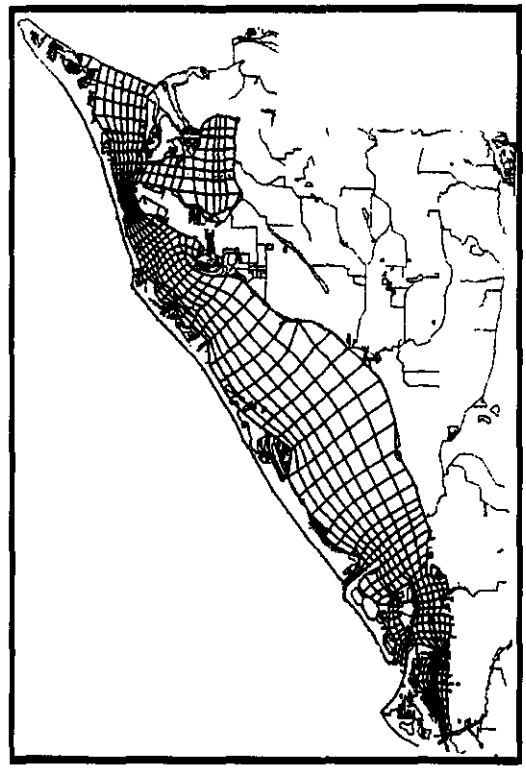


Figure 3. A numerical grid for the main portion of Sarasota Bay.

How to Utilize Circulation Information to Assess the Effects of Loading on Water Quality

As discussed earlier, nutrients that enter an estuary may undergo a series of advection-deposition-resuspension-transformation processes before residing at a low-energy location or entering the ocean. Nutrients entering an estuary may actually affect the water quality at a location distant from the source of input. To develop a rational management plan for estuarine resources, it is essential to be able to first quantify the transport of nutrients and other water-quality parameters in an estuary under present conditions. This requires an extensive amount of field data, laboratory experiment and numerical modeling.

Due to the site-specific nature of the numerous transport processes, an existing water-quality model for one estuary may not be applicable to another estuary. Models developed for the deeper, temperate estuaries in the north are not expected to work in the shallow Florida estuaries where physical processes have a much stronger effect on the water-quality processes. To develop a more useful product for estuarine resources management, however, it is essential to quantitatively understand all aspects of nutrient cycling (including transport and transformation) in addition to benthic fluxes in a particular estuary. An extensive amount of field data over various spatial and temporal scales is required before one can produce a reliable water-quality model. In addition to the traditional water-quality data collected by the Sarasota Bay Program as "snapshots" every season, continuous water-quality data collected over several tidal cycles and episodic events are urgently needed.

With sufficient data, it is possible to develop an overall nutrient budget for an estuary or part of an estuary that requires the quantification of the following components: 1) external loading from tributaries, non-point sources and atmospheric deposition, 2) exchange flux between the estuary and the ocean, 3) internal loading of nutrients from/to the bottom sediments, 4) cycling (transport and transformation) of nutrients within the water and sediment columns.

A recent study of the Tampa Bay nutrient

budget (Morrison, 1992) revealed little or no existing information on the internal loading (i.e., resuspension flux and diffusive flux) and cycling of nitrogen in Tampa Bay. This is also true for many other estuaries in Florida, including Sarasota Bay, Indian River Lagoon, St. Johns River, Biscayne Bay and Appalachicola Bay.

Following the development and validation of a water-quality model for an estuary, the model may be used to predict the impact of reduced or increased external loading to the distribution of nutrient concentrations and other water-quality parameters in the estuary.

Circulation in the Sarasota Bay System

The Sarasota Bay system is an elongated coastal lagoon located to the south of Tampa Bay, extending from Anna Maria Sound in the north to Venice Inlet in the south. It is connected to Tampa Bay through Anna Maria Sound, and to the Gulf of Mexico through Longboat Pass, New Pass, Big Pass and Venice Inlet. An additional connection between the Gulf of Mexico and Little Sarasota Bay, called Midnight Pass, was closed in 1983.

The average depth of Sarasota Bay is on the order of 2 m with the southern portion, i.e., Little Sarasota Bay and Blackburn Bay having many tidal flats. The depth within the navigation channel is between 3-4 m. A bathymetric survey was recently conducted by the University of Florida, and a report is being prepared.

Tidal Circulation

Tidal circulation in the Sarasota Bay system is forced by the tides at Anna Maria Sound, Longboat Pass, New Pass and Big Pass. Tidal circulation in Little Sarasota Bay is forced by tides at Venice Inlet and a small channel, the Intracoastal Waterway, running south of Roberts Bay.

Tides at the open boundaries are composed of semi-diurnal and diurnal components with relatively low tidal amplitudes (40-80 cm) and slight shifts in the tidal phases. Tidal amplitudes and tidal phases do not vary significantly within the Sarasota Bay system. However, tidal currents show significant spatial variation. The shallower depth and more constricted geometry of Little Sarasota Bay result in more tidal dissipation than is found in Sarasota Bay.

During flood tide, ocean water enters into Sarasota Bay through all the passes and Anna Maria Sound, creating strong flood currents, particularly in Big Pass. During ebb tide, estuarine water recedes into the Gulf and creates strong ebb currents. Currents in areas between the passes are generally much weaker than currents in the passes, due to the presence of null zones. This point is further discussed elsewhere in this chapter.

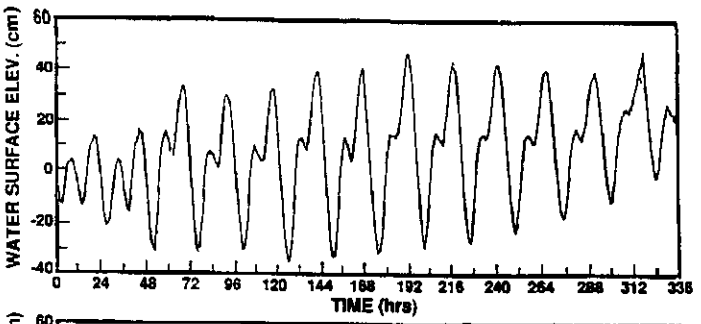


Figure 4a.

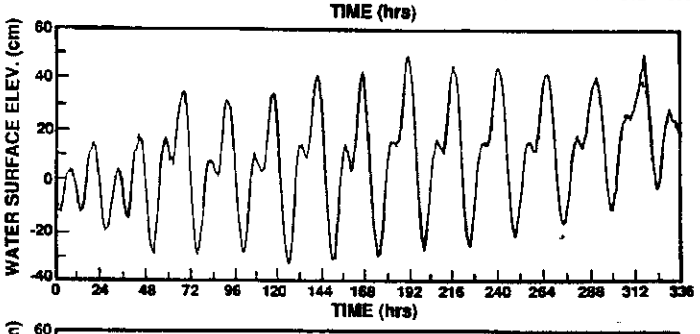


Figure 4b.

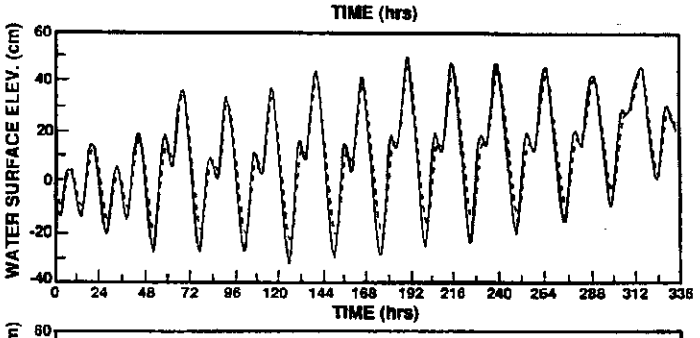


Figure 4c.

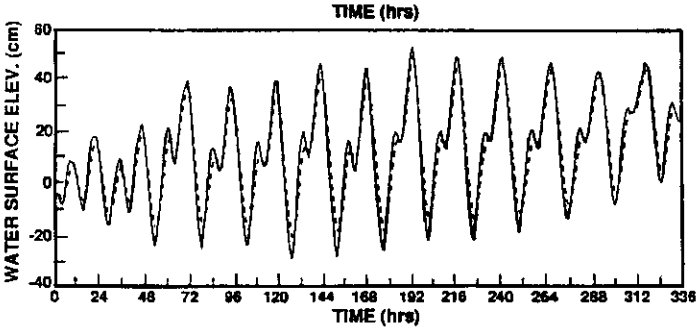


Figure 4d.

Figure 4. Water level at (a) Big Pass, (b) Longboat Pass, (c) Sarasota Bay East and (d) Sarasota Bay West during September 24, 1990. Solid lines: data. Dashed lines: model results.

Tides in the Sarasota Bay system were measured by the United States Geological Survey at seven stations (Anna Maria Sound, Sarasota Bay East, Sarasota Bay West, Roberts Bay, Big Pass, Little Sarasota Bay and Blackburn Bay– see *Figure 2)*, while tides in Tampa Bay were measured by National Oceanographic and Atmospheric Administration/National Ocean Service during 1990 and 1991 (Hess, 1991).

Sheng and Peene (1991) developed a three-dimensional model of tidal circulation in Sarasota Bay, based on the CH3D model (Sheng, 1989a) developed for Chesapeake Bay (Sheng *et al.*, 1989a) and James River (Sheng *et al.*, 1989c). Using the numerical grid shown in *Figure 3* and the forcing at open boundaries *(Figures 4a* and *4b)*, they success-

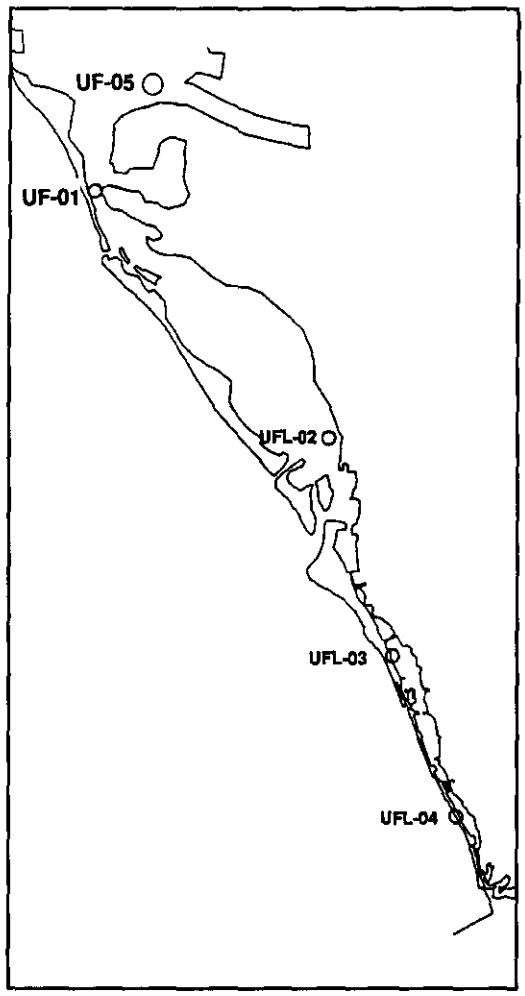


Figure 5. Locations of University of Florida data stations.

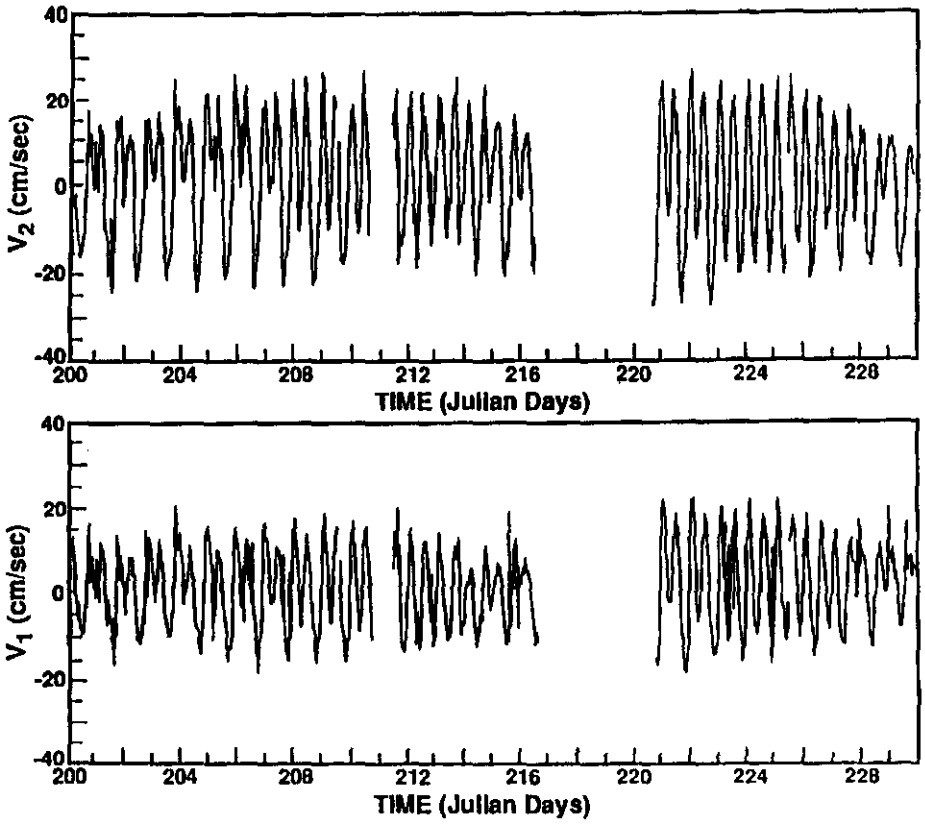


Figure 6. Measured north (postitve)-south (negative) surface (V_2) and bottom (V_1) currents at East Sarasota Bay (UF station 2) during July-August 1991.

fully simulated the tidal water-level fluctuation within the system *(Figures 4c* and *4d)*. Tidal currents were measured by the University of Florida (Sheng *et al.*, 1992b) at four locations in the Sarasota Bay system *(Figure 5)* during July-August 1991, with a similar study conducted during May-June 1992 at five locations (including a new station outside the Manatee River).

Harmonic analysis of the current data showed that, for the period measured, tides were the dominant mode of forcing, with the harmonics representing on the average 90 percent of the current signal at all stations. Measured currents at station 2 near Whitaker Bayou over 30 days, shown in *Figure 6*, indicate that north-south components (10-30 cm/s) dominate over the east-west components (5-10 cm/s). Tidal harmonics constitute more than 90 percent of the north-south current signal, but less than 50 percent of the east-west current signal.

Tide- and Wind-Driven Circulation

Wind can effect the tidal circulation by enhancing vertical and horizontal mixing in the water column, creating set-up and set-down in water level and modifying the vertical current structure (e.g., creating return current and modifying the surface and bottom boundary layers). Peene *et al.* (1992) simulated the tide- and wind-driven currents in the Sarasota Bay system during the passage of Tropical Storm Marco in October 1990 using the numerical grid shown in *Figure 7*. Water-level fluctuations at the USGS stations in Sarasota Bay and the NOAA/NOS stations in Tampa Bay were correctly simulated by the numerical model *(Table 1)*. The simulated and measured storm surges in Sarasota Bay compare very well and are correlated with wind stress during the storm passage. As shown in *Table 2*, the simulated currents at the Egmont Key (C-02) and Skyway Bridge (C-03) stations were somewhat lower than the measured data, due to the fact that the NOAA current meters were deployed in the deep navigation channel, which was not sufficiently resolved by the numerical grid. Yassuda *et al.* (1992) refined the grid in Tampa Bay to resolve the navigation channel and reduced the error by 50 percent. The overall satisfactory agreement between model results and measured water level and currents suggests that the model can be used for reliable predictions of tide- and wind-driven circulation.

Comparison between simulated and measured currents at the bottom layer of UF stations 2 and 4 in Sarasota Bay during July-August 1991 is shown in *Figure 8*. The

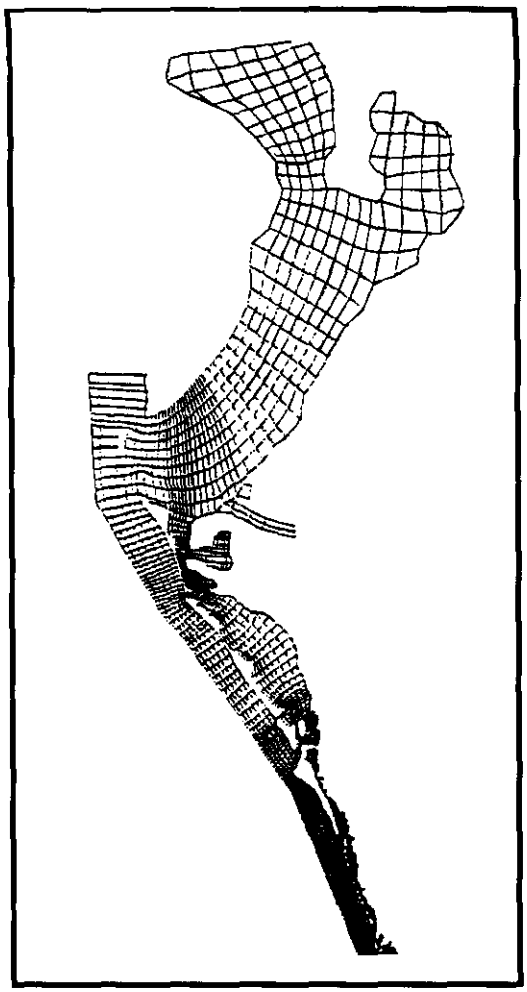


Figure 7.

Figure 7. The Boundary fitted grid used for the numerical simulation.

agreement is quite good. A previous Little Sarasota Bay circulation model developed by Dendrou *et al.* (1983) was not able to produce satisfactory results of currents, due to the use of a very simple one-dimensional model.

Salinity and Baroclinic Circulation

Salinity transport in Sarasota Bay is primarily driven by the currents, which can in turn be affected by salinity gradients in the vertical and horizontal directions. Currents and salinity measured at the four University of Florida stations during July-August 1991 have been analyzed (Sheng *et al.*, 1992b).

Salinity at UF station 2 near Whittaker Bayou is rather well mixed vertically and fluctuates between 32-34 ppt during this time period.

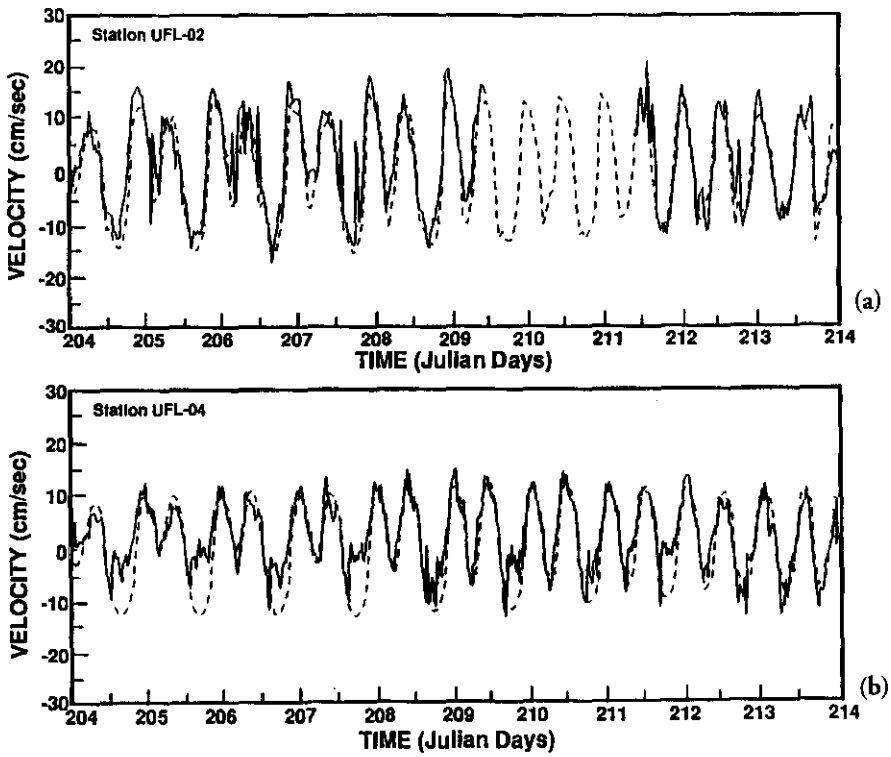
Salinity and north-south current at station 1 in Anna Maria Sound *(Figure 9)* showed that low salinity followed the southerly current, thus suggesting the movement of Manatee River water into Sarasota Bay.

At station 3 in Little Sarasota Bay, salinity showed significant temporal variation (24-29 ppt) due to the influence of freshwater input from river and rain *(Figure 10)*. Both stations 2 and 3 are in shallow waters. Within the navigation channel, however, vertical salinity stratification can be expected. Salinity simulations are presently being performed.

Effect of Passes on Circulation and Water Quality

The interaction between the tidal waves entering in the various passes creates a complex circulation pattern characterized by areas of strong currents near the passes and null zones (areas with very low currents) between the passes. *Figures 11a-11d* show the simulated water level and currents at four instants over a

Figure 8. Simulated (dashed line) and measured (solid line) north-south currents at the bottom layer at UF stations (a) near Whittaker Bayou and (b) in Blackburn Bay.



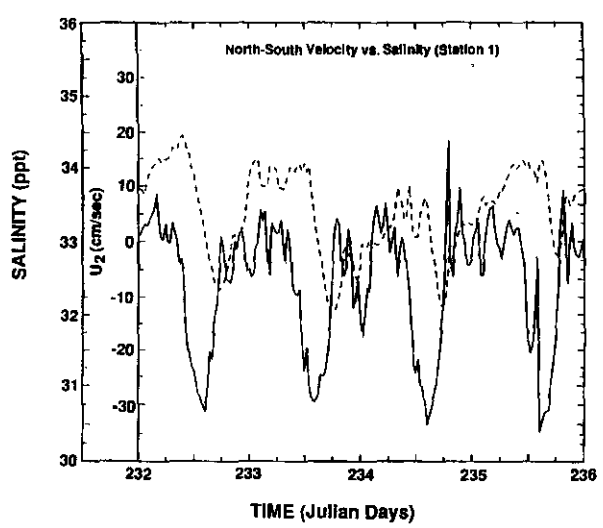


Figure 9. Measured near-surface north-south current and salinity at UF Station 1 (Anna Maria Sound) during a four-day period in July 1991. Solid line: velocity. Dashed line: salinity.

Statistical Comparisons of the Simulated vs. Measured Water Surface Elevation							
Station	No. Sample	Range (cm)	Drms (cm/s)	D'	Gw	Erms (cm/s)	Lrms (hr)
Anna Maria	481	57.2	3.40	0.06	0.91	2.03	0.43
Cortez	481	55.0	2.58	0.05	1.01	3.10	0.43
Egmont	481	52.6	2.74	0.05	0.97	2.00	0.48
S.B.E.	481	52.7	5.40	0.10	1.04	5.03	0.52
S.B.W.	481	54.0	5.68	0.11	1.00	5.63	0.57
Roberts Bay	481	47.4	6.68	0.14	1.17	5.12	0.72
Big Pass	481	56.0	3.41	0.06	1.02	3.31	0.55

Drms: non-normalized Root-Mean-Squared (RMS) error of time series of data
D': normalized RMS error
Gw: ratio of simulated vs. measured peaks/troughs
E rms: RMS error of peaks/troughs
Lrms: RMS error of the times of peaks/troughs

Table 1.

Statistical Comparisons of Simulated vs. Measured Velocity Components								
Station	Compo nent	No. Sampl.	Range (cm/s)	Drms (cm/s)	D'	Gw	Erms (cm/s)	Lrms (hr)
C-02	U	481	135.7	23.98	0.18	1.07	13.57	1.06
	V				0.12	0.97	12.46	0.94
C-04	U	481	83.0	10.35	0.18	0.58	16.13	0.94
	V				0.15	0.78	9.56	0.77
C-20	U	481	67.1	12.23	0.17	0.77	20.10	0.78
	V				1.24	3.46	10.85	1.51
C-23	U	481	85.0	12.83	0.18	0.56	23.33	1.00
	V				0.23	0.65	8.35	1.16
C-03	U	481	100.8	17.51	0.19	0.56	26.87	0.75
	V				0.15	0.85	7.02	0.78

Table 2.

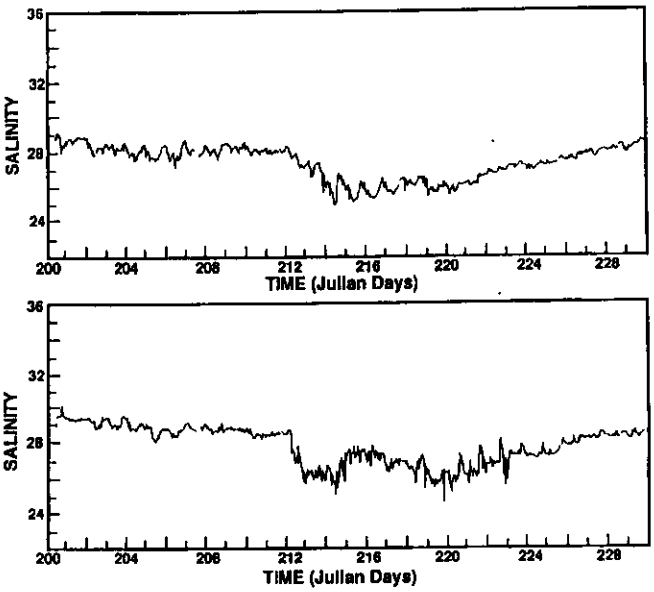


Figure 10. Measured near-surface (top) and near-bottom (bottom) salinity in Little Sarasota Bay (UF Station 3) during July-Auguat 1991.

single diurnal tidal cycle in central Sarasota Bay after a 10-day simulation.

The areas of strong flow around the passes and directed along the channels can be seen along with the null zone located near Hudson Bayou. This null zone is characterized by near-zero flow and the presence of a point of inflection on the water-level contour plots. The location of the null zone depends significantly on the location and configuration of the passes, and may be shifted if a new pass is opened or an existing pass is closed. The numerical grid used in this simulation and those to be described later is shown in *Figure 7*. The grid was extended into Tampa Bay to allow the simulation of the exchange processes between the two water bodies.

Transport of water-quality parameters is affected by residual flow and tidal flushing. Tidal flushing in Sarasota Bay was simulated by dividing the model domain into eight sections based on the 16 segments of the segmentation study *(Figure 12)*. A conservative substance of 30 ppt (parts per thousand) is released into all the numerical cells within a section at the beginning of a numerical simulation (e.g., a 12-day period, in July 1991 in this case), while concentration in other sections are given zero values. As the simulation proceeds, the relative amount of the conservative substance remaining in the section can be calculated. A quick drop in the relative mass indicates good flushing in the section, while a slow drop in the relative mass indicates poorer flushing. Tidal-flushing rates within the eight sections are shown in *Table 3*. It is clear that Palma Sola Bay, Middle Sarasota Bay and Middle Little Sarasota Bay have rather poor flushing rates.

Effect of Closure of Midnight Pass on Little Sarasota Bay Circulation and Water Quality

Midnight Pass was closed in 1983. To examine the effect of closure of Midnight Pass on circulation and water quality, we performed model simulations to compute the flushing rates in different sections of the Bay with 1) Midnight Pass closed, i.e., the post-1983 bathymetric condition, and 2) Midnight Pass opened, i.e., the pre-1983 bathymetric condition.

Tidal-flushing rates in the three southernmost sections of the system computed with the post-1983 bathymetry are shown in *Figure 13*. Tidal-flushing rate was fastest in the middle section but slowest in the northern section due to the null zone. Flushing rates for the same three sections with an open Midnight Pass, i.e., the pre-1983 bathy-

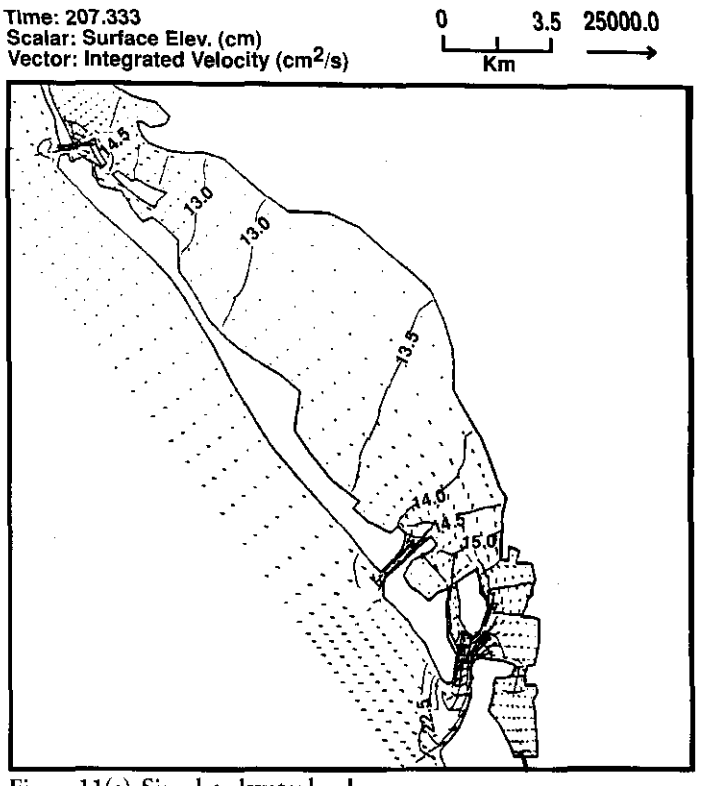


Figure 11(a). Simulated water level and horizontal currents in Sarasota Bay at 8 a.m. on Julian Day 207 in 1991.

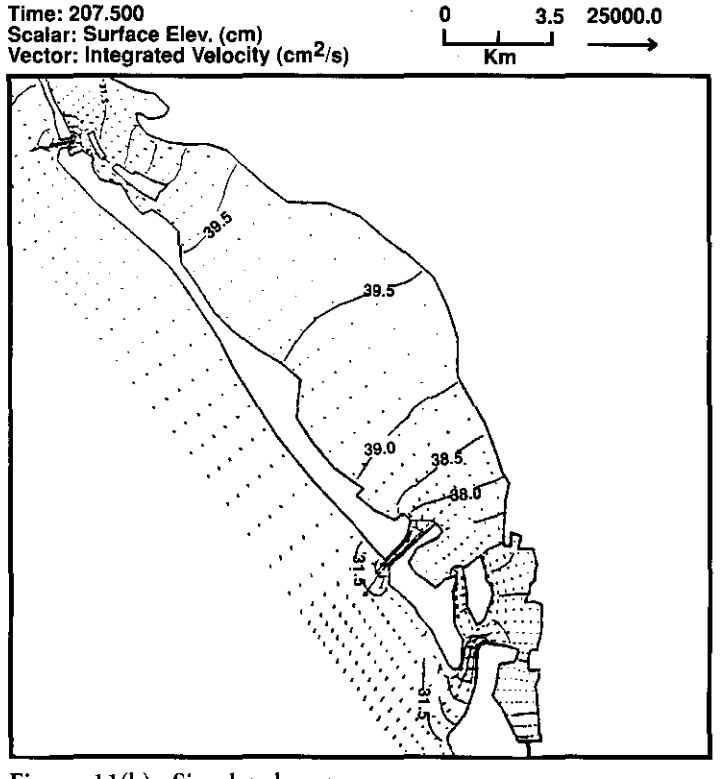


Figure 11(b). Simulated water level and horizontal currents in Sarasota Bay at noon on Julian Day 207 in 1991.

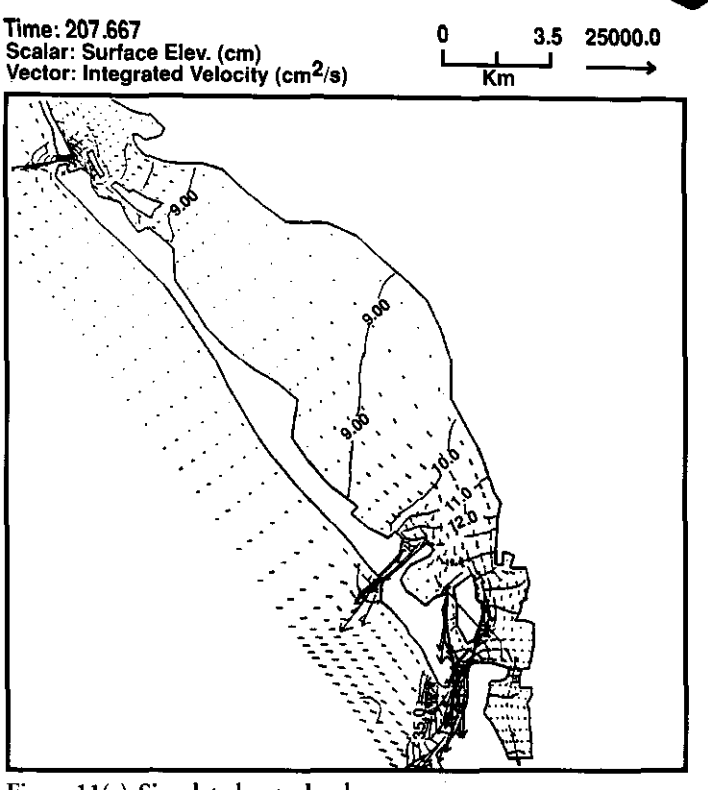


Figure 11(c). Simulated water level and horizontal currents in Sarasota Bay at 4 p.m. on Julian Day 207 in 1991.

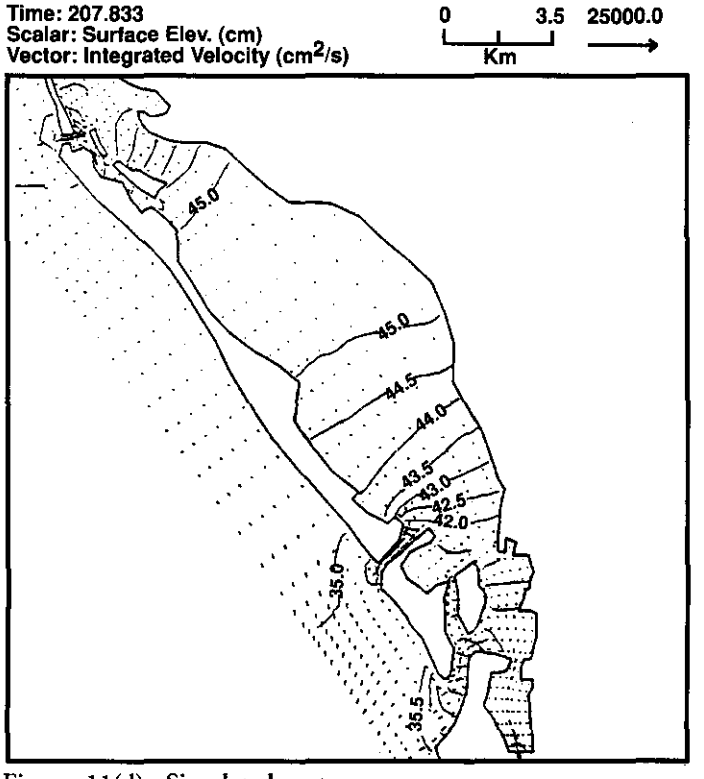


Figure 11(d). Simulated water level and horizontal currents in Sarasota Bay at 8 p.m. on Julian Day 207 in 1991.

Table 3.

Flushing Rates of Conservative Constituent in Eight Sections of Sarasota Bay System					
Section	Segments	Location Descriptions	Percent Flushed After 10 days		
			Before ICW	Present Condition	Pass Open
1	1, 2	Anna Maria Sound Cortez Bridge	81	81	81
2	3	Palma Sola Bay	31	31	31
3	4, 5, 6	Longboat Pass Tidy Island	64	64	64
4	7, 8	Middle Sarasota Bay	32	32	32
5	9, 10, 11, 12	New Pass, Big Pass Southern Portion of Sarasota Bay	81	81	81
6	13	Roberts Bay Midnight Pass	52	76	48
7	14, 15	Little Sarasota Bay Midnight Pass	71	27	74
8	16	Blackburn Bay	70	72	83

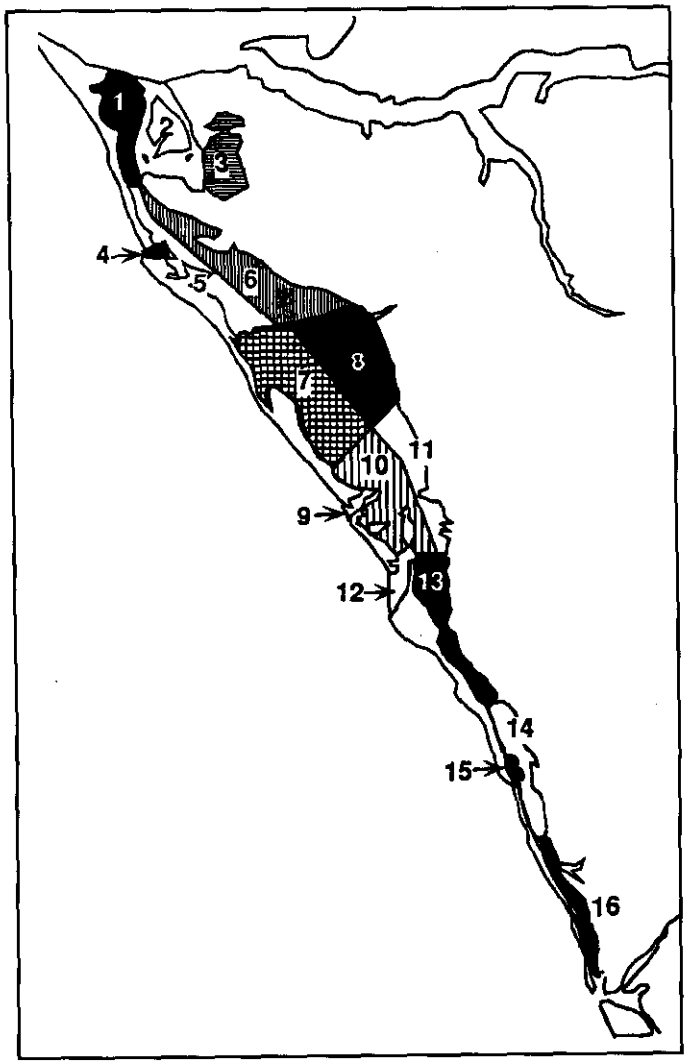


Figure 12. Sarasota Bay NEP study area segments.

metric condition, are shown in *Figure 14*. Comparison between *Figures 13* and *14* showed that closure of Midnight Pass led to poorer tidal flushing in the middle section but enhanced flushing through the northern section due to the elimination of the null zone there. Flushing through the southern section was somewhat reduced. Measurement of dissolved oxygen concentration in the area behind Midnight Pass in 1991 by the University of Florida showed abnormally low values (i.e., < 1 ppm).

Effects of the Navigation Channel on Little Sarasota Bay Circulation

Prior to 1956, the Sarasota Bay system had no navigation system. In order to examine the impact of navigation channels on circulation in the Sarasota Bay system, we performed model simulations of the rates of tidal flushing in various segments of the Bay, first with the pre-1956 bathymetry (with Midnight Pass but no channel) and then with the post-1956 but pre-1983 bathymetry (with channel and Midnight Pass).

Flushing rates for the three sections computed with the pre-1956 bathymetry (without navigation channel but an open Midnight Pass) are shown in *Figure 15*. It is clear that the navigation channel led to increased flushing rates in the middle and southern sections, with little change in the northern section. Although it was speculated that the Intracoastal Waterway (ICW) reduced the tidal exchange through Midnight Pass relative to the tidal exchanges at

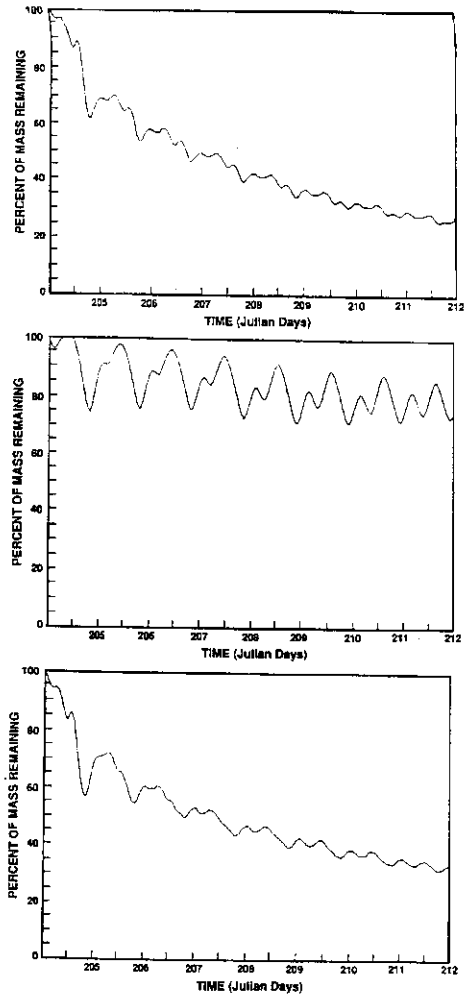


Figure 13. (a) Relative tidal flushing at Segment 13, (b) Segments 14 and 15, and (c) Segment 16 during a 12-day period with present bathymetry and geometry.

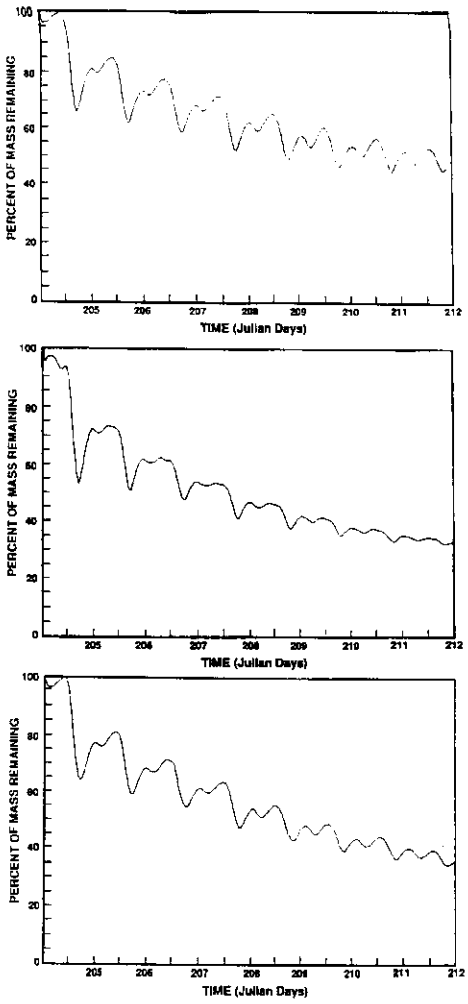


Figure 14. (a) Relative tidal flushing at Segment 13, (b) Segments 14 and 15, and (c) Segment 16 during a 12-day period with pre-1983 bathymetry and geometry (with Midnight Pass open).

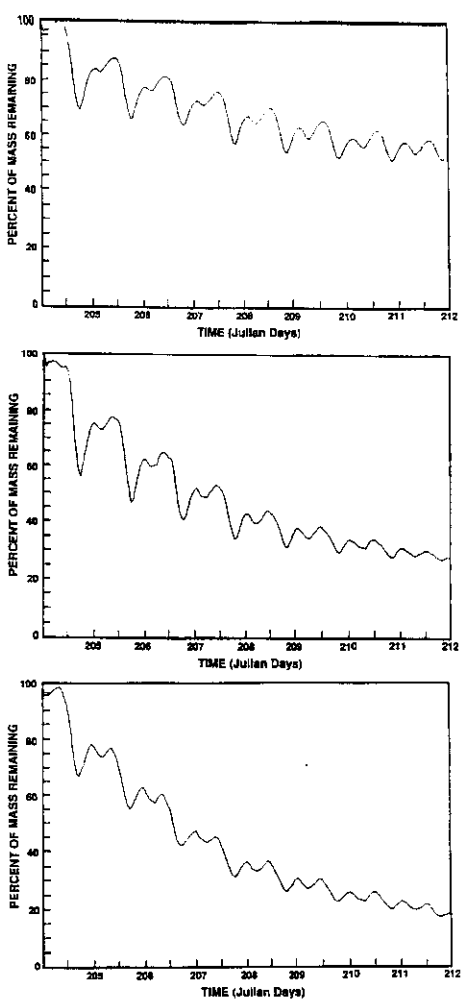


Figure 15. (a) Relative tidal flushing at Segment 13, (b) Segments 14 and 15, and (c) Segment 16 during a 12-day period with pre-1956 bathymetry and geometry.

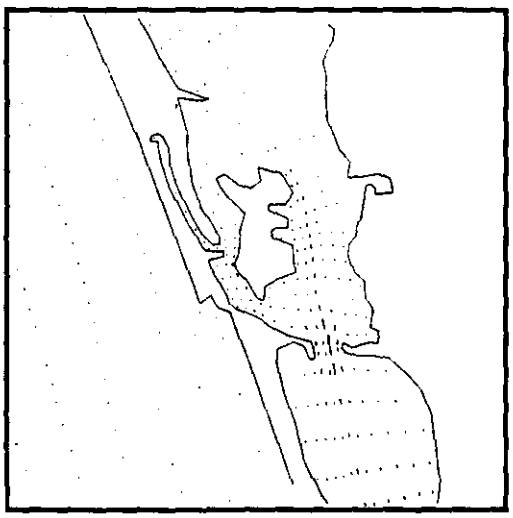
Stickney Point and Blackburn Point (Sarasota County, 1985), this effect is not apparent in our results, because the bathymetry used in the mode simulation may be somewhat deeper than the true 1956 bathymetry. Our results suggest that the ICW probably did not have any significant effect on the reduced tidal prism through Midnight Pass and the instability of the Pass in 1983. However, it is reasonable to expect that the construction of the ICW probably contributed to the instability of the pass.

Table 3 shows a comparison of flushing rates for three conditions (before ICW, present condition and Pass open) in terms of the percent of mass flushed after 10 days of the release of dye in the numerical model.

Effect of Tampa Bay and Manatee River on Circulation in Sarasota Bay

Currents measured by Sheng *et al.* (1992c) at the Anna Maria Sound station showed significant residual current (10 cm/s) from Tampa Bay into Sarasota Bay during July-August 1991. As discussed elsewhere, a close examination of the current and salinity data from the area suggests the transport of low-salinity Manatee River water into Sarasota Bay.

The southward residual current appears to be produced primarily by nonlinear tidal action, but also correlates with the local wind, which actually shows a small residual component to the north. Detailed mechanisms for the creation of this residual current are being further studied. The residual transport of Manatee River and Tampa Bay water into Sarasota Bay has significant implication on



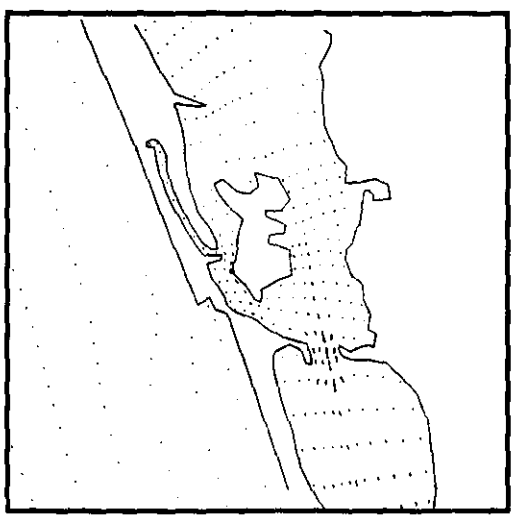
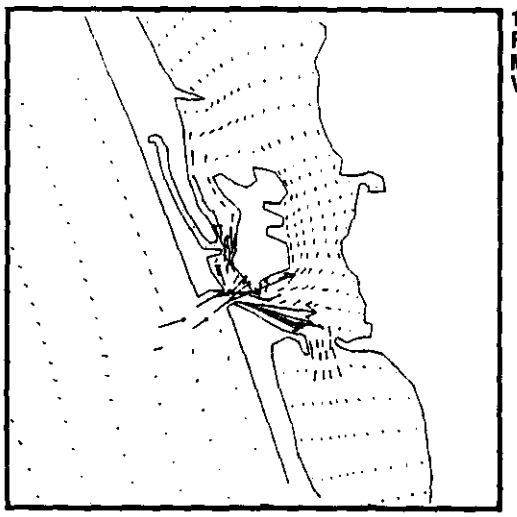


Figure 16. Vertically integrated currents at (a) flood tide and (b) ebb tide with present conditions.



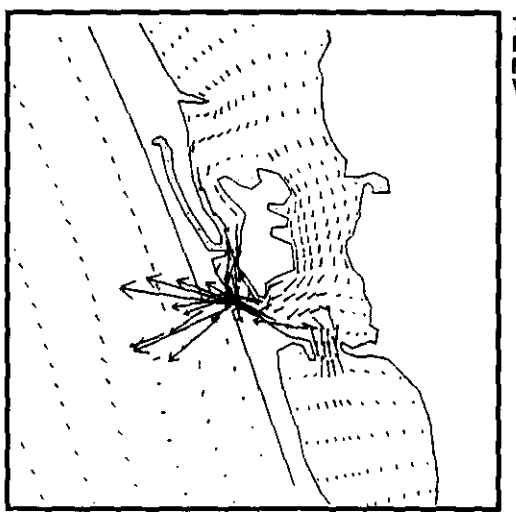


Figure 17. Vertically integrated currents at (a) flood tide and (b) ebb tide with the Midnight Pass opened.

the water quality of Sarasota Bay. It is found that water quality in Anna Maria Sound is generally lower than that in all pass segments (Lowrey, 1992), despite the significant tidal currents there.

Potential Influence of Opening Midnight Pass on Circulation and Water Quality in Little Sarasota Bay

Influence on Circulation

If Midnight Pass were opened, the circulation patterns in the Little Sarasota Bay would be significantly altered. Tides would be propagated into Little Sarasota Bay through Midnight Pass, in addition to tides from Roberts Bay and Blackburn Bay. Tidal fluxes and currents in the vicinity of Midnight Pass would be significantly enhanced. As an example, simulated tidal fluxes (vertically integrated currents) in the area are shown for the present condition *(Figure 16)* and the opened condition *(Figure 17)*.

Influence on Water Quality

As suggested by the tidal-flushing calculations shown above, the opening of the Midnight Pass might lead to enhanced flushing in the middle section of Little Sarasota Bay. The enhanced flushing means that the water quality behind Midnight Pass would be significantly improved, although water quality in the northern section of Little Sarasota Bay, near Phillippi Creek, might actually be degraded due to the reduced flushing rate there. However, these suggestions are based on somewhat qualitative calculations. For more quantitative estimation on the impact of Midnight Pass opening, a comprehensive water-quality modeling effort, integrating loading and circulation, would need to be undertaken.

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Tidal Inlet Dynamics

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Executive Summary

he tidal inlets entering Sarasota Bay are on one hand a dominant and extremely important part of the Bay, largely shaping its basic physical and biological characteristics, and on the other a source of major conflicts over competing uses and negative secondary impacts.

The significance of the Bay's passes and their management was identified early in the process by the Management Conference, and one of the seven program goals specifically addresses the need to better coordinate beach, inlet and channel activities. Others of the goals, such as improved transparency, habitat restoration, managed access and living resources, are inextricably tied to the tidal inlets. In these cases, also, the passes are frequently both a source of the problem the goal addresses and one option for improvement.

The State of the Bay Report 1990 emphasized the role of the inlets, and the Program's Technical Workplan included a project to develop regional beach- and inlet-management strategies. Unfortunately, in a climate of constrained resources funding priority had to be given to the more basic characterization projects, and little further progress has been made toward a better understanding of the specific inlets to the Bay.

This section is an attempt to address at least the principal issues. Because no new field work nor other site-specific analyses have been performed, the information is necessarily drawn from standard texts and is general in nature. The intent is to provide a basic understanding of the physical processes associated with inlets, both as a background to their influences in other framework projects and to better evaluate possible management actions.

The five passes exchanging water into Sarasota Bay (Passage Key Inlet, Longboat Pass, New Pass, Big Sarasota Pass and Venice Inlet) include examples from the entire range of morphology and maintenance levels. One is structurally fixed by jetties and rarely dredged, two are continually dredged

and two are rarely dredged. Water depths in the five passes range from nine to 10 feet to 27 feet; widths vary from approximately 100 to more than 1,500 feet. All the passes are connected by the Intracoastal Waterway (ICW), which extends through the Bay and exerts a strong influence on the hydraulic characteristics of this interrelated system. A sixth opening has historically existed between Siesta and Casey Keys, but the most recent such channel, Midnight Pass, was closed in 1983 and remains closed.

Inlets are systems in dynamic equilibrium. Two sources of energy, tides and waves (with their associated effects), form a locally unique balance that determines the specific characteristics of each inlet. As tides, waves and sand transport vary seasonally, or as a result of longer-term influences, the inlet's characteristics will change as well.

One effect of this balance is that sand often accumulates in two shoal areas, typically one opposite the inlet on the Gulf side and one on the Bay side. These deltas can be vast sediment reservoirs that alter nearshore wave patterns, determine currents and influence the adjacent beaches. For example, it is estimated that the ebb-tidal delta at Big Sarasota Pass contains over 13 million cubic yards of sand. In contrast, the much smaller energies at Midnight Pass supported an ebb shoal with only 500,000-600,000 cubic yards of sand, although the combined flood shoals from the recent channel and the former ones in the same area (the Jim Neville Reserve) include almost 1.3 million yards.

An inlet's tidal prism represents the volume of water flowing in or out of it in response to tidal fluctuations. This volume is obviously a very important characteristic, since it can be related to salinity inputs, circulation in the Bay, flushing and inlet stability. Tidal prisms have been calculated for a few of the Bay's inlets at different times and by different authors; values range from less than 10 to more than 30 million cubic meters. These methods can provide useful estimates for a single inlet. However, each of the five inlets contributes water to the Bay system, and each has a practical influence over only a portion of the Bay's surface area.

The tidal movement through an inlet is constrained by the geometry of the channels and the Bay, in simple analogy to water flowing through a pipe. Friction and other effects may cause sand to build up in the inlet, further changing the flow characteristics and affecting the inlet's stability. Very little data is available about the stability of Sarasota Bay's inlets, although most recent dredging has been performed for navigation safety and ease rather than to address perceived stability problems.

No definitive study has been made of what negative effects result from this practice, or if positive benefits to the Bay area and its user groups balance the negatives. It is unclear what range of management options might be considered for the existing passes.

Tidal-Inlet Dynamics

Introduction

Probably the classic definition of a coastal inlet is a short, narrow waterway connecting a bay, lagoon or similar body of water with the ocean; a *tidal inlet* is one in which a tide ebbs and flows. *Pass* is a regional term with no practical difference in meaning, and it will be used here interchangeably with inlet.

These are deceptively simple definitions toward an understanding of the processes associated with inlets. Even in this most basic (and rare) form, an inlet would be subject to complexities from the water-height and velocity variations associated with the tides, including monthly, seasonal and epochal extremes, local wind effects, upland runoff and inflow and tropical and extra-tropical storm surges.

The tidal passes into Sarasota Bay are further affected by the fact that they extend through, or are adjacent to, littoral-drift barrier islands. Since most of the Gulf coast of Florida is generally thought of as a micro-tidal, wave- (or storm-) dominated regime, it is arguably the perturbations in wave energy and resulting littoral sand transport that exert an influence of greater importance than the tides. These two sources of energy, the tides and waves (with their associated effects), form a locally unique balance that determines the specific geometric and functional characteristics of each inlet. This balance is often referred to as a dynamic equilibrium, to emphasize the point that as tides, waves and sand transport vary in their cyclic patterns, or as a result of longer-term influences, the inlet's characteristics will change as well. The idea of dynamic equilibrium will be further developed in later sections.

Coastal inlets are an important part of the Bay's natural functioning, acting as conduits from the Gulf for saline, oxygen-rich marine waters, providing ingress and egress for the biological community, allowing excess nutrients and fresh water to flush and promoting circulation and mixing. Inlets also serve commercial and recreational navigation needs, and can reduce the impacts of upland flooding associated with storms.

Five passes currently exchange water into the Bay: Passage Key Inlet (Anna Maria Sound), Longboat Pass, New Pass, Big Sarasota Pass and Venice Inlet. A sixth opening has historically existed between Siesta and Casey Keys, but the most recent such channel, Midnight Pass, was closed in 1983 and remains closed. Detailed descriptions of each of these inlets are beyond the scope of this chapter. Sources for this information include Hine *et al.* (1986) and the several state-mandated inlet-management plans being prepared by local sponsors. However, the following brief comments will serve to illustrate that the Sarasota Bay inlets include examples from the entire range of morphology and maintenance levels typically found on the Florida coast.

Passage Key inlet, adjacent to Anna Maria Island and within the Tampa Bay entrance system as well, is an example (perhaps with some others to a lesser degree) of a more tidally dominated inlet. Two inlets, New Pass and Longboat Pass, are still regularly dredged as federally maintained channels. No indication exists that either Big Pass or Midnight Pass was ever maintenance-dredged; others have some history of infrequent and irregular, minor maintenance actions. Only one pass, Venice Inlet, has a true functioning jetty system.

Several of the inlet openings are known to be the result of storm breaching, although their general locations and the historically persistent presence of some other passes have been suggested as being linked to underlying geologic conditions. Water depths in the open passes range from nine to 10 feet to 27 feet; widths vary from approximately 100 feet to more than 1,500 feet. All the passes are connected by the Intracoastal Waterway (ICW), which extends through the Bay and exerts a strong influence on the hydraulic characteristics of this interrelated system.

Schematic Inlet Morphology

While no two inlets are identical, they frequently share common general geometric

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and hydraulic features related to their similar energetics. These features usually include the types and locations of sub-channels, current patterns, areas of sediment accumulation and the alignments of adjacent shorelines. A number of engineering and geologic classification schemes are based on groupings by variations in such features.

As noted in the introduction, typical definitions describe an inlet in terms of a single waterway or channel. However, inlets on sandy coasts under tidal influence essentially will always have a more complex system of multiple channels, due principally to the non-symmetrical distribution of tidal water velocities versus tidal heights. Maximum and minimum velocities typically do not coincide with the water-level extremes, nor are the patterns in such phase variations the same under ebb and flood conditions.

On a flood tide, the Gulf waters rise in relation to the Bay, initially entering the inlet through one or two persistent marginal or "swash" channels running along the adjacent shorelines. As the water increases in depth, it flows through the pass into the Bay more evenly and uniformly, covering a large bottom area before maximum velocities are reached.

The opposite occurs during ebb tides or falling water levels in the Bay. By the time water velocities peak, the water level may have dropped to a point where increasingly it flows out only through a network of more well-defined Bay-bottom courses terminating at the actual pass in a single, deeper main channel (conveniently termed the main ebb channel, or sometimes the "gorge" channel). In many cases, the exact pattern of flow channelization may not be apparent without some research and field data; in others the evidence may be more obvious, such as the bifurcated interior channel around Bird Keys at Midnight Pass or the major confluence in the ICW channels at Longboat Pass. And lastly, in some situations one or both sides of the pass interior may have more scour-resistive sediments or shoreline structures that act coincidently to shape the flow patterns and channel configurations.

These tides entering the Bay (flood) or exiting the Bay (ebb) may produce water velocities sufficient to transport sand. The source of the sand is a combination of littoral drift material carried into the general area by waves and the sediment scoured locally from the channel bottoms and sides themselves. Because the water velocities vary considerably in strength (and direction) over a single tidal cycle and over longer periods, the sand entrained in the flows may be deposited, re-suspended and re-deposited in a continuous process, forming complex bedforms.

Usually, however, two somewhat similar areas of net sediment deposition will form, one opposite the inlet on the Gulf side and one on the Bay side. The Gulf-side deposit is related to ebbing currents and is variously termed the *ebb-tidal delta,* the *ebb shoals* or the *ebb fan.* The Bayside accumulation is more related to the action of flood-direction tidal currents and is, therefore, appropriately named *flood-tidal delta, flood shoal,* etc.

The size and geometry of these shoal areas are generally descriptive of the age and dynamic equilibrium of the particular inlet system, and also relate to its stability. As an example, geologically "younger" inlets may not have reached an equilibrium condition, and still may be accumulating sand in their shoals. Such passes will tend to have measurably smaller shoals with simpler geometries than older, more mature inlets exposed to otherwise similar wave and tide forces. Further, although it is somewhat a subjective matter of degree, passes where wave energy dominates over tides will have ebb and flood shoals with roughly equal volumes, but the Gulf-side deposits will tend to be more narrow, with complex, multi-lobed patterns. The contrasting local example is Venice Inlet, where the jetties have artificially reduced the wave impacts and accentuated the tidal-current effects. The result is almost no flood shoal and a thin, widely spread ebb shoal with little bathymetric relief.

An observer who judges the extent of the ebb and flood shoals only by the emergent (exposed) and/or inter-tidal sand bars and flats may grossly underestimate their size and importance to the system. They are actually vast reservoirs of accumulated sediment that alter nearshore wave patterns, determine the detailed current structure and influence the adjacent beaches. It is frequently of interest to know the actual volume of sand stored in shoal systems; sources such as Hine *et.al.* (1986) provide calculations or estimates for the inlets in this area.

As an example, they estimate that the ebb-tidal delta at Big Sarasota Pass contains more than 13 million cubic yards of sand. In contrast, the much smaller energies at Midnight Pass supported an ebb shoal with only 500,000-600,000 cubic yards of sand. Flood deltas generally tend to be slightly smaller than their ebb-side counterparts even in wave-dominated regimes, as shown by an estimate of seven million cubic yards for Big Sarasota Pass. Midnight Pass did not follow this general trend; the flood-shoal system from the recent pass and the former ones in the same area combined includes the entire

Bird Keys (the Jim Neville Marine Reserve) with a volume estimate of 1.3 million yards (calculated prior to the placement of ICW spoil).

Since these sediment accumulations are held in place by the balance of forces present at an inlet, and may even continue to grow with time – at least until some maximum equilibrium volume is reached and by-passing begins – the material deposited in the deltas may be thought of as "trapped." Whether this sand is viewed as lost from the littoral drift system or merely "banked" temporarily as a reservoir depends on the observer's reference timeframe and tolerance for manipulating the natural system, such as by dredging. In any case, the sand storage is one of the major influences inlets have on adjacent beaches; a subsequent section will expand on this and other negative shoreline effects.

Generalized Inlet Hydraulics and Analysis Methods

It should be apparent from just the above very brief discussion that – whether one wishes to view the problem as following the paths of individual water particles through the system or as the time history of water levels and velocities at specific points – the hydraulic characterization of real inlets can be exceedingly complex. The traditional approach to the analysis has been to make a large number of simplifying assumptions about the geometry and the tides, then compare those approximated properties to empirical relationships developed by observing and measuring many existing inlets. This approach still is satisfactory in most cases, especially if only approximate results are needed and time and funds are constrained. Numerical modeling offers the opportunity for more accurate analyses with fewer approximations, but the detailed field data necessary to support the increased capability may not always be available.

A brief discussion of some of the more significant approximations used to create an "idealized" situation for analysis may be useful to define terms and aid in a basic understanding of inlet hydrodynamics.

Tidal Prism

One of the fundamental properties of interest is called the *tidal prism,* and represents the volume of water (usually in cubic feet or cubic meters) flowing into or out of an inlet in response to tidal fluctuations and other local forces. This volume is obviously a very important characteristic, since it can be related to salinity inputs, circulation in the Bay, flushing and inlet stability.

The calculation or estimation of a tidal prism usually assumes that the only force driving the water is the difference in elevation between the tide on either side of the inlet and that the Bay level rises uniformly (i.e., the water surface has no slope). The tide is frequently assumed to be sinusoidal. The velocity imparted to the water is proportional to the amplitude of the tide, and in the simplest formulations is represented by the average over an entire ebb or flood phase. More detailed methods may use a maximum velocity, or mean maximum, with various coefficients. (Note that some form of averaged velocity is usually sufficient to look at the volumetric transport of the water, but the instantaneous bottom velocities and their perturbations are of greater influence in the entrainment and movement of any sediment.)

The tidal movement is constrained by its passage through the geometry of the inlet in simple analogy to water flowing through a pipe. Similarly, the volumetric flow rate through any such conduit is a function of the velocity of the water and the area of the opening through which it flows. A difficulty in analyzing real inlets is that the shape and cross-sectional area of the entrance channels frequently vary significantly over their lengths. Continuity considerations require the water velocity to vary with each change in cross-section. The channels' bottoms and sides also impart friction to the flow, which further affects the velocity; since the surface area of the channel wetted by the flow changes as the water level rises or falls, the frictional effects are non-linear.

Critical Section

At some point over the length of a variable channel, however, the cross-sectional area is a minimum. This area is termed the *critical section,* the *critical area* or the *"throat" section.* It is tempting to assume that the critical section occurs where the top-width of the pass narrows to a minimum, but in erodible sandy material the channel depth may also increase in proportion, so that the cross-sectional area is unchanged. Determining the true critical section requires careful examination of the flow path, and successive calculation and comparison of cross-sectional areas.

Once this minimum-flow cross-section is identified, it is often assumed to be the point controlling the entire flow, again in general analogy to a constriction in a pipe. For an approximate analysis, in fact, the whole inlet can be replaced by an equivalent, geometrically regular channel that has this critical cross-section. We have mentioned the effect

of friction on the flow and that those frictional losses vary over the real channel; the solution is to assume that our substitute constant-section channel has a fictitious length, the *effective length*, such that the total friction losses in the hypothetical flow would equal those over the length of the actual variable-section channel. The result of these (and other) approximations is an idealized hydraulic analogy that allows us to more easily view related concepts.

From the above discussion, it is apparent that the tidal prism could be determined by identifying the critical section in a pass, measuring the water velocities at that point over half of a tidal period and calculating the volume flowing through the area. This approach is certainly valid, but requires considerable field effort to make multiple velocity measurements concurrently at several depths and cross-flow points, and over one or more tidal cycles.

A more commonly used estimate can be made by measuring the peak water-level rise in the Bay for a given tide (or using tabulated tide-station values) and applying the assumption that the level rises uniformly over the entire Bay. It can be seen that the volume of water entering the Bay must equal the increase in height multiplied by its water surface area. All that must be known or measured is the surface area.

Another method of estimating prism volumes returns to the idea of some critical section controlling the flow. Observations by several investigators at a number of inlets have resulted in regression relationships directly between the critical throat area and the associated prism. This eliminates the need to determine velocity or Bay surface area; the critical cross-section can be established by conventional bathymetric survey and the approximate prism calculated from the equations or graphs.

As examples of the range of results using approximate techniques, Bruun (1978) estimated tidal prisms for several area inlets (all in millions of cubic meters) as 20 at Longboat Pass, 0.6 at New Pass, 30 at Big Sarasota Pass and seven at Midnight Pass. The actual data used in Bruun's analyses were probably from surveys in the late 1960s or early 1970s, which, in the case of New Pass, would not reflect the presently maintained channel cross-section. CPE (1992) has suggested updated (but unverified) estimates for New Pass and Big Sarasota Pass to be on the order of 11 and 22 million cubic meters, respectively. In work for Sarasota County, CPE also estimated the 1955 prism at Midnight Pass to be approximately three million cubic meters using rough bathymetric charts from the time.

These methods can provide useful estimates for a single inlet. However, one problem with using them in Sarasota Bay is that five inlets contribute water to the system. Each has a practical influence over only a portion of the Bay's surface area, and the 50-mile length of the Bay, together with the tide-phase differences, invalidate the assumption of uniformly rising water levels. In this case it would seem useful to generalize the idea of a tidal prism at a single inlet to that of a combined prism (volume) entering the entire Bay. Each inlet contributes to the overall Bay prism, or "captures" part of the total volume, in proportion to its cross-sectional area and local tide amplitude. This model is intuitively more appealing and satisfying than the traditional single, isolated pass analyses. It is also sufficiently complex that even solutions on the most basic level would require fairly sophisticated, costly numerical methods.

Shoal Volume Relationships

The introduction presented the idea of an equilibrium of forces at an inlet. Various expressions of this can also be found in other empirical and regression relationships that use the basic hydraulic parameters.

For example, the volume of sand stored in an ebb-tidal delta can be approximately predicted by knowing only the tidal prism. Since the volume of sand in the shoal is related to the wave energy and the prism is a function of the tidal energy, such a relationship at a specific site, when compared to the general regression fit for many sites, may suggest the nature or trends in the equilibrium at the individual pass. As will be discussed, this may be used as one approach to evaluating inlet stability.

Lastly, a few caveats should be offered about these hydraulic parameters and analyses. Measurements or estimates of values such as the critical area or shoal volume represent only one point in time. Even though a hypothetical equilibrium geometry may exist, the actual conditions are continually changing around that idealized configuration. In measurements at one inlet by Byrne, De Alteris and Bullock (1974) the cross-section varied by more than 10 percent in periods as short as a week (seven percent in three days). Even greater fluctuations typically occur in the shoals during seasonal reversals in transport, or storms that may have preceded a survey period.

Inlet Stability

Stability is a difficult term to define because it is often used loosely and embodies

a certain basic subjectivity. One might reasonably ask: "stable," but for what purposes – navigation, water exchange? – and within what time frames – weeks, years, forever? In several cases, the researchers who performed the original measurements and developed the major theories of stability faced similar questions: at what point should an inlet be considered unstable or even "closed?" Also, if the geometric and hydraulic parameters suggested a pass was unstable, how could it be determined (especially from one measurement) if the trend were unstable and tending toward closure, or unstable but improving toward stability? This becomes more than a semantic debate when management options and site-specific actions are being considered.

A comprehensive view of inlet stability probably should at least separate the problem into two distinct facets: first, the tendency of an opening through a sandy coast to migrate, or move along the shore. This has been referred to as *positional, lateral* or *geographic stability.* The second facet is the tendency of an inlet's cross-section to vary significantly in area (constrict or expand), generally called *cross-sectional, hydraulic* or *geometric stability.* The two tendencies are often related, as will be discussed, but that relationship is not well-defined, and is certainly not always causative.

In its simplest form, either type of instability might be viewed as sediment depositing in or adjacent to an inlet so as to change its geometry and flow characteristics. What is important in this view is that the deposition is, at first anyway, the result or manifestation of some other change in the balance of forces at the pass. If the deposition continues for a significant period, or is in the form of a large, sudden change, it may certainly begin to contribute to a further imbalance and deterioration may progress. The following are some simple hypothetical examples of instability and, in the first one, of a causative relationship between lateral and hydraulic stability.

It is often the case that the axis of an inlet is not perpendicular to the shoreline, but orients generally in the direction of the predominant littoral drift. An increase in the sand-transport volume in the area may successively "push" the channel entrance laterally along the shoreline. Assuming the bay-side opening remains in the original position, the lateral movement of the other end must result in a net increase in the channel length (it "stretches"). Since the channel bed offers frictional resistance to the tidal flows, an increased bed length increases that friction and decreases velocity. If the original inlet were hydraulically stable, but barely so, the reduction in flow energy might be sufficient to allow additional sand to accumulate throughout the channel and decrease the cross-sectional area below that required for stability. If this iterative process continued without other influences, over time the pass might tend toward closure.

This is only one basic model of a force imbalance leading to instability. Another, for example, involves the growth of a flood shoal and bay sedimentation. Tidal currents carry sediment into a bay, where it is deposited and accumulates over time. This accumulation in that bay is less likely to be further transported, or "bypassed" analogous to the ebb-delta, because the unit bay energies are lower. It is possible, therefore, that the flood system could grow to occupy an appreciable volume of the bay (previously available to store water), decrease the potential tidal prism together with its flow energy) and result in the pass channel shoaling to closure.

A third example is one suggested by many observers as the principal reason for the trend in Midnight Pass even before it was finally filled. An earlier paragraph introduced the idea of the critical channel section acting as a control on the flow. This presumes that no other flow constriction or greater energy loss occurs "upstream" of the gorge channel. The construction of the relatively deep ICW channel through Little Sarasota Bay behind Midnight Pass provided an alternative flow path for at least a portion of the ebb-tidal prism that would otherwise have had to exit through the pass. Tidal energy that would have scoured the pass's critical section was lost or dissipated without reaching the opening. This process most certainly worked in combination with the continuing entrapment of sediment in the flood direction and the actual reduction in the potential prism as above in our second example. In the last several years the pass was open, its lateral migration probably further contributed to the hydraulic instability through the process described in the first example. This is less obvious, however, since the pass had a history of such movement (more than 1,700 feet) even when its cross-section was apparently stable.

In that last example we begin to see that a number of factors often work in combination, so the simple models do not always fully explain stability trends. For instance, although many passes orient with the littoral drift, a number of notable exceptions exist, including Redfish Pass at Captiva Island in southwest Florida. In other cases, even when drift pressure tries to move a channel, the tidal energy is often sufficient to successively

re-breach the prograding spit, and no change in stability occurs. Examples also can be found of inlets that do migrate laterally, sometimes even "wildly" in cycles, but continue to remain open.

On the other hand, many investigators – e.g., Bruun (1978), van de Kreeke (1990) and others – have frequently made statements to the effect that since entrained sediment will eventually be deposited somewhere within the channel-delta system, the theoretical ultimate limiting fate will always be closure, and no perfectly stable inlet can exist on a littoral drift coast. This is a plausible and interesting rhetorical construction, but what is often left out of such statements when they are quoted is the rate of presumed closure and/or the definition used for "stable."

In one well-known system for classifying inlet stability, Bruun and Gerritsen (1960) grouped numerous existing channels by the ratio of their tidal prisms to the total adjacent littoral drift volumes (an energy ratio-based theory). The scheme suggests five conditions of increasing stability (e.g., a larger ratio indicates relatively more tidal energy than wave-induced sediment transport). A difficulty with universal application of this system is that it was originally intended primarily to address navigation concerns about ebb-shoal bar formation. In other words, when the authors were originally deciding which study inlets had "good stability," they meant that there was little offshore bar formation to impede navigation; an unstable inlet was one that did not have a "permanent" channel. It might continue to exchange water over much of a normal tidal cycle by overflow across a bar system, or it might even seasonally recover a more pronounced channel. Interestingly, of the Sarasota Bay passes only Longboat Pass would rate a "good stability" based on this system, and it is routinely dredged; all the others are "poor."

O'Brien (1966) and Escoffier (1977) both developed stability theories based on the idea of equilibrium channel velocities. These approaches focus on the detail of scour and deposition at the level of individual sand grains. In addition, empirical correlations were developed, as mentioned earlier, and are frequently used.

An analysis has been performed for a 1955 condition at Midnight Pass and for the proposed design of the re-opening. The channel cross-section in 1955 was estimated to be approximately three times the critical area necessary for stability, using a combination of the above theories. The proposed design did not progress beyond a very preliminary schematic, but the cross-section was intended to match the 1955 condition with a small factor of safety to account for initial post-dredging slope adjustments. No general source is known that tabulates stability values for all of the other passes, or reviews the history of variations in stability at a single pass over time.

Management Options

It is unclear what range of options might be considered for the existing passes, since no overall assessment of impacts from the present practices has been made. With "no action" (or, more accurately, no change) New Pass and Longboat Pass will continue to be dredged on a four- to six-year cycle, with clean sand deposited on the adjacent beaches. No definitive study has been made of what negative effects result from this practice, nor if balancing positive benefits exist for the Bay area and its users. The present maintenance dredging is largely directed at navigation ease and safety, with secondary effects on lateral channel stability. No obvious evidence exists of hydraulic instability nor of the need for structural solutions to other conditions at the open inlets. Obviously, a different situation exists with the former Midnight Pass channel.

Further Data Needs

As noted, local sponsors have independently contracted for Inlet Management plans for several of the area passes. It is not suggested that these efforts be duplicated by the Sarasota Bay National Estuary Program office; however, the program could make major contributions in two areas: review and regional coordination of the individual study results, and measurement of background turbidity inputs at the passes.

The first recommended area reflects the point that most hydraulic analyses focus on the prism at individual inlets without consideration of multiple openings to the Bay. Any individual pass-management plan should be reviewed for consistent assumptions about Sarasota Bay's surface areas, tides, littoral transport and similar parameters, and the results should be extracted for use in developing a Bay-wide view of volumetric exchanges, residency time and Gulf shoreline impacts.

The second area of further work simply recognizes the need to establish baseline information about re-suspension and transport of particulates through the passes into the Bay on normal and storm tides. Without such basic data, management options to reduce impacts from pass-maintenance dredging address meaningless goals.

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Inlets and Shorelines

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Stability of Mutiple Inlets

In considering the stability of multiple inlets, it is essential to note that in the general case, the inlets compete for the available tidal prism of the common bay. If the inlets are located sufficiently far from one another, they are somewhat decoupled from each other; if for some reason the size of one inlet changes, there is not such a tendency for the other inlet to compensate.

The fact that Midnight Pass has been closed since 1983 surely has resulted in some increase in the cross-sectional area of Big Sarasota Pass and possibly Venice Inlet. The significance of this discussion on an attempt to reopen Midnight Pass is that Big Sarasota Pass, through its present increased size, is more competitive, and consequently Midnight Pass is less competitive in remaining open.

Interaction of Inlets with Shorelines

Inlets have a substantial potential to interact with the adjacent shorelines, thereby affecting their stability. Present understanding of this interaction is at a qualitative level such that it is possible to interpret and explain observed phenomenon. However, predictive capability is not considered reliable in the absence of a reasonably long history at a specific inlet. This may be due in part to the unfortunate lack of well-documented field projects, but is also undoubtedly a result of the extremely complex systems and processes associated with inlet evolution.

For example, the shorelines adjacent to an inlet may remain relatively stable for a number of years, followed by a period of rapid inlet migration and associated erosion and deposition on the downdrift and updrift shorelines, respectively, with no *apparent* change responsible for the migration. It does appear that a relatively strong, significant feedback mechanism may be associated with inlet stability such that if a change starts to occur, it will induce forces that will reinforce the change tendency, further complicating prediction.

For undeveloped shorelines, the impacts of inlet migration and associated shoreline perturbations on the adjacent beaches would be inconsequential; however, with today's general dense shoreline development, it is essential that human-induced modifications at inlets be accompanied by an established program to ensure that the associated adverse effects be minimal and correctable. The paragraphs below describe the mechanisms by which inlets can interact with the shoreline and the associated magnitudes, and also discuss the available engineering measures to accomplish the dual goals of a functioning inlet system and acceptable adverse impacts to the adjacent shorelines.

The system comprising an inlet and the adjacent beaches is sometimes referred to as a "sand-sharing system." This is a useful concept, since in the absence of physical sand removal or addition, the amount of sediment in this system remains more or less the same. The distribution of sediment among the various components (inlet shoals and beaches) can be affected, however.

Two types of adverse interaction occur. In the first, the inlet removes sand from the beach components of the sand-sharing system. This effect could occur due to sand storage in the ebb- and flood-tidal shoals, and is most likely to be greatest for newly opened inlets, since these sand bodies will increase in volume until they reach an approximate equilibrium condition. Dean and Walton (1975) have developed and applied methodology to calculate volumes in the ebb-tidal shoals and have carried out such calculations for a number of Florida inlets. Walton and Adams (1976) applied this methodology to many more inlets, correlating the volumes with the respective tidal prisms of the inlets and establishing the relationship shown in *Figure 1.* The three lines represent various levels of wave energy, the significance of which can be interpreted in the framework of two relevant and competing "forces" affecting the equilibrium volumes of the ebb-tidal shoals. The ebb-tidal currents tend to displace sand offshore, and the waves tend to transport the sand

back into the beach system. Thus in relatively high-wave-energy areas the volumes of sand in the ebb-tidal shoals will be less. A difference also exists in the *shape* of the ebb-tidal shoals versus wave-energy level. In areas of more energetic waves, the shoal contours tend to be smoother than in low-energy areas.

The general Sarasota area is one of low wave energy, resulting in relatively large volumes in the ebb-tidal shoals for the existing tidal prisms. To summarize, deposition in the flood- and/or ebb-tidal shoals represents material removed from the beach components of the sand-sharing system; the effect of such removal must be manifested as a comparable volumetric erosion of the beach component. Although our ability to predict where and when the compensating erosion will occur is very limited, the same volumetric erosion must occur.

The second type of interaction is one that keeps the same volumes in the shoal and beach components, but redistributes the volumes within their respective components. This can occur, for example, due to inlet migration, and can result in a different type of adverse effect due to the jeopardy migration can cause to dwellings.

In recognition of the effect modified inlets can cause on the adjacent shorelines, Florida enacted legislation in 1986 with the goal of minimizing related impacts. This legislation states:

> The Legislature hereby recognizes the need for maintaining navigation inlets to promote commercial and recreational uses of our coastal waters and their resources. The Legislature further recognizes that inlets alter the natural drift of beach-quality sand resources, which often results in these sand resources being deposited around shallow outer-bar areas instead of providing natural nourish ment to the downdrift beaches.
>
> (1) All construction and maintenance dredgings of beach-quality sand should be placed on the downdrift beaches; or, if placed elsewhere, an equivalent quality and quantity from an alternate location should be placed on the downdrift beaches at a location acceptable to the department.
>
> (2) On an average annual basis, a quantity of sand should be placed on the downdrift beaches equal to the natural net annual longshore sediment transport. This sand shall be placed at no cost to the state. The placement location and quantities based on natural net annual transport shall be established by the [Florida Dept. of Natural Resources], and the sand quality must be acceptable to the department.

Possible Engineering Solutions

The principal engineering goals at inlets in Florida and elsewhere have been navigation and water exchange. For somewhat different reasons, these goals are best served by a fixed, deep inlet. The traditional approach to establishing a relatively deep inlet of fixed alignment has been through the construction of jetties and the dredging of those portions of the inlet channel as they become too shoaled to satisfy their design functions. At several inlets, programs have been implemented to transfer sand around the inlet from the updrift to the downdrift side, thereby reinstating, to a degree, the sand-transport system prior to the inlet modification.

The last entrance cut in Florida was Port Canaveral Entrance, with construction initiated in 1951. With the growing recognition of the potential adverse effects of inlets on the adjacent beaches, as reflected by the aforementioned legislation, and the state's efforts toward requiring responsible inlet management, it is worthwhile to discuss the requirements that would likely attend a permit for opening a new inlet such as Midnight Pass.

Undoubtedly at least three major elements would be required:

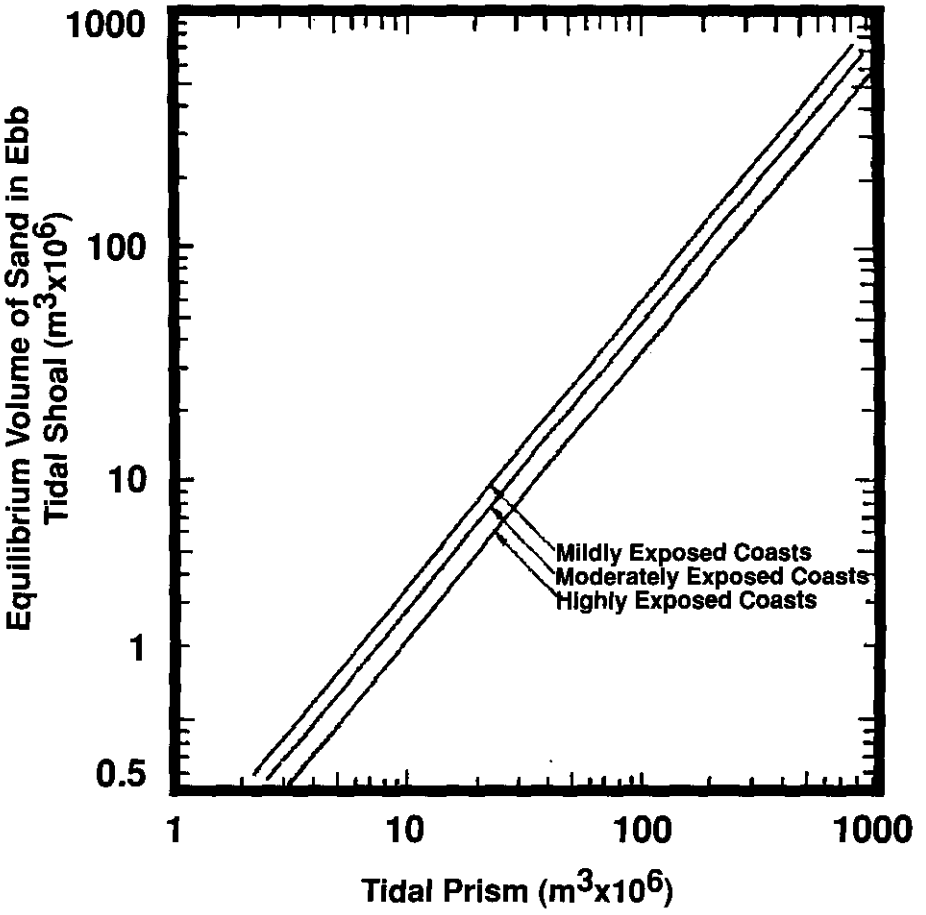

Figure 1. Relationship between equilibrium volume of sand stored in ebb-tidal shoal and tidal prism (adapted from Walton and Adams, 1976).

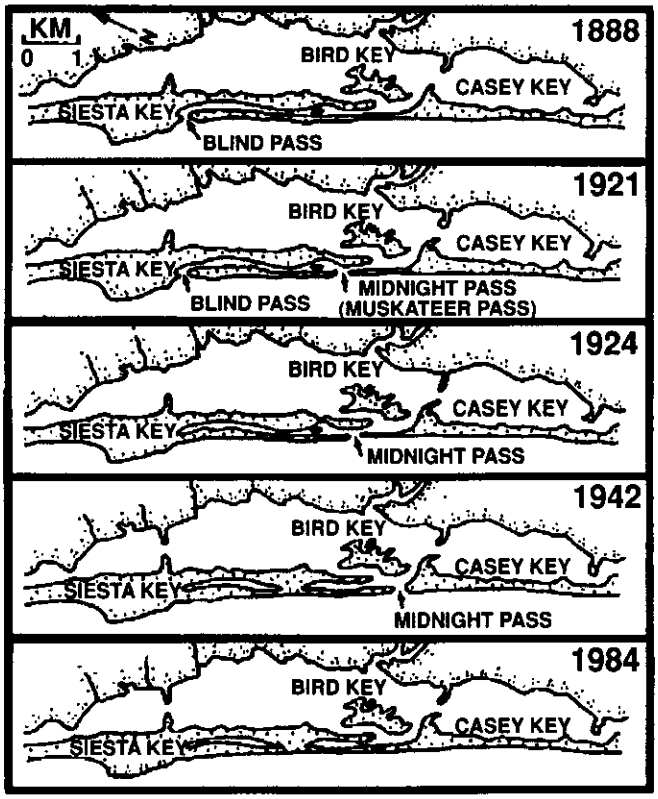

Figure 2. Historical inlet positions in the vicinity of Midnight Pass. (Davis *et al.*, 1987)

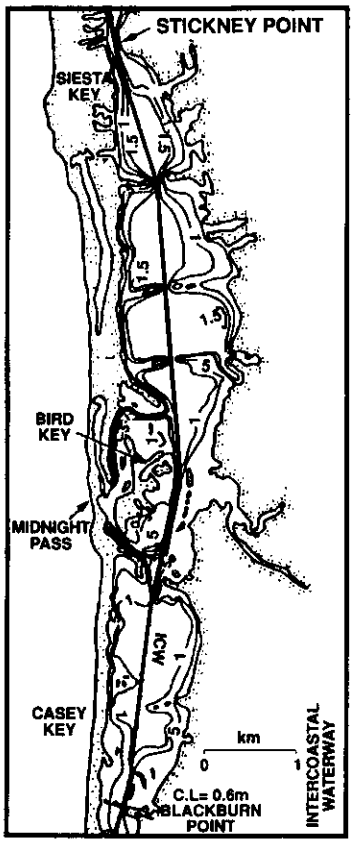

Figure 3. Bathymetry of Little Sarasota Bay. (Davis *et al.*, 1987)

(1) A monitoring program to document the effects after construction, and preferably before construction, to provide a gauge to compare effects and to provide a protocol for initiating corrective action;

(2) A faithful attempt to predict the potential sand-management requirements, so any adverse effects could be held to an acceptable level;

(3) Provision of acceptable assurance that adequate financial resources will be available to carry out effective sand management (in accordance with the quoted legislation).

In particular, in the case of a new inlet, it could be necessary to stockpile (or preplace) adequate sand to form the equilibrium ebb-tidal shoal and to provide in some detail the plan to transfer or otherwise relocate sand based on the findings of the monitoring plan. Additionally, it would be desirable to preaddress possible disagreements and to attempt to reduce potential litigation over possible effects following construction and different interpretations thereof.

Midnight Pass

The history of Midnight Pass and Little Sarasota Bay dates back some 100 years. The Pass was a natural opening, free to migrate and to vary in cross-sectional area. Davis *et. al.* (1987) have documented the locations and various names assigned to present Midnight Pass and other inlets in the adjacent area *(Figure 2).*

In 1888, no opening was near the more recent locations of the Pass; apparently the existing opening had migrated to the north, limited by the Point of Rocks outcrop. The 1888 location of Bird Key (today the Jim Neville Marine Preserve), which is interpreted as a flood-tidal delta, indicates a previous pass location near that in recent times. Davis *et al.* (1987) also documented the general bathymetry of Little Sarasota Bay and emphasized the "compartmented" character of the Bay (*Figure 3*). In addition to the constrictions at Stickney Point and near Phillippi Creek, at least three cross-channel shallow "sills" had been formed by oyster bars. They report that the tidal prism of Midnight Pass in 1955 was approximately 2.7×10^8 ft^3, which by 1982 had decreased to between 1.4×10^6 and 5.4×10^6 ft^3. The study of Davis *et al.* appears somewhat uncertain as to the effect of human intervention on the Pass's demise. They state, "Data on circulation and morphology indicate that tidal exchange between Little Sarasota Bay and the Gulf of Mexico had not at any time been dominated by Midnight Pass or its precursors."

They also state, "There is considerably more evidence to indicate that the dredging of the Intracoastal Waterway is the primary reason for the deterioration of Midnight Pass. The enlarging of the channels provided for a major pathway for tidal circulation in directions already receiving pressures based on previously recorded currents and long-term morphology. As a result much of the tidal prism was diverted from the inlet to both ends of the Bay." *(Editor's Note: Data collected by Sarasota Bay National Estuary Program [Sheng and Peene 1992] do not support these conclusions.)*

Chiu (1979) conducted a study based primarily on aerial photographs dating back to 1948. Prior to the 1940s, the pass was of a considerable cross-sectional area, allowing navigation during periods of moderate wave action. From 1948-57 the pass moved 1,000 feet to the south, accompanied by a southward migration of the south end of Siesta Key of about 1,450 feet. From 1957-71, the north end of Casey Key changed little, while the south end of Casey Key receded about 520 feet. The period 1971-79 saw a continuous northward migration of the Pass.

Sheng and Peene (1992) have carried out numerical model simulations of the Sarasota/Little Sarasota Bay system with and without the Intracoastal Waterway (ICW) channel. They note that their results are not definitive regarding the effect of the ICW channel on stability of the Pass, stating that in part this is due to their model combining two segments, the flows within which apparently are

related to the effect of the ICW on tidal prism through the Pass. They do conclude, "The reduced tidal prism through the Midnight Pass presumably accelerated the instability and closure of the Midnight Pass in 1983." It appears that in their simulations, Sheng and Peene may not have had available the exact bathymetry that existed prior to dredging activities (which commenced in the 1920s) to connect Sarasota Bay with Little Sarasota Bay (Sheng, 1992).

By 1983, when Midnight Pass was closed by artificial means, the pass had diminished in size, and its northward migration was threatening dwellings. Following closure of Midnight Pass, a "Blue-Ribbon Committee" was formed at the request of the Sarasota County Commission to develop recommendations relative to appropriate future actions at Midnight Pass. The committee recommended that the Pass be opened and left natural (i.e., unjettied), and that the opening be considered as a trial. If closure occurred, the county could then consider in light of this experience whether it was better to maintain the Pass open or to leave it closed.

It is interesting to attempt to determine why the Pass exhibited a tendency toward closure; however, it is not possible to answer this question definitively. One possibility is that the Pass had simply lived out its natural life, and closure was the natural consequence, as happens for unstabilized inlets. More likely, closure was abetted by human actions that made the adjacent inlets more competitive and Midnight Pass less competitive. In particular, the dredging of the Intracoastal Waterway has made Big Sarasota Pass more effective in satisfying the tidal prism of Little Sarasota Bay. According to Davis *et al.*, the initial dredging of the present ICW commenced in the 1920s; the later, more extensive dredging to the present authorized depths occurred in 1963-64.

Prior to this deepening, a degree of "partitioning" existed between Little Sarasota Bay and Sarasota Bay and was especially effective in maintaining the Pass open during low water and ebb flows, which tend to transport sand back to the Gulf. In fact, under these conditions it is possible that Big Sarasota Pass contributed *positively* to the stability of Midnight Pass via the following mechanism. During high tide and inflows into the Bay, substantial quantities of water entered the Bay system through both Big Sarasota Pass and Midnight Pass; however, the inflows through the former were greater. During ebb flows accompanied by the lower water levels in the bays, the hydraulic connectivity between the bays was reduced, resulting in substantial outflows through Midnight Pass. It is quite possible that the ebb flows through the Pass were substantially greater than the flood flows. (It is well-known that inlets dominated by ebb flows tend to be deeper and less prone to accumulation of flood-tidal shoal sediments and closure than inlets dominated by flood flows.)

The dominant changes that contributed to the demise of Midnight Pass have included dredging of the Intracoastal Waterway and construction of Venice Inlet, both of which would tend to decrease the stability of a relatively small inlet in proximity to one or more larger inlets. The principal effects on Midnight Pass of dredging the Intracoastal Waterway were to increase the hydraulic connectivity, especially during ebb-flow conditions; this effect was particularly significant in the vicinities of Stickney Point and Phillippi Creek. It is believed that this effect is enough to have initiated a gradual process that enhanced the sizes of the adjacent inlets, thereby decreasing the viability of Midnight Pass.

Considerations of Opening Midnight Pass

The prevailing sentiment expressed in the report of the "Blue-Ribbon Committee" (1984) is that if Midnight Pass were opened, it should be opened without constructing jetties. Although jetties would definitely enhance the lateral stability and viability of the Pass, thereby reducing maintenance requirements, their potential impact on the adjacent shorelines, their permanence and their aesthetics are regarded as negative. Therefore, the following discussions are based on maintaining the pass open without the assistance of jetties.

The recent history of Midnight Pass suggests that the Pass will exhibit both closure and migrational tendencies, making it necessary to counter these through maintenance programs.

Very briefly, the opening of Midnight Pass would probably require making a financial commitment through establishment of a new responsible entity such as an inlet-management district with taxing authority, or the acceptance of this responsibility by an appropriate existing entity. Engineering studies would be required to: (1) develop recommendations for opening the Pass, with placement of the material removed to complement the natural processes; (2) estimate the types and frequency of maintenance and establish recommended procedures for such maintenance; (3) estimate the effects of Pass opening on hurricane-induced storm surges and on

adjacent inlets; (4) quantify the effects on the adjacent beaches, and establish recommendations to minimize adverse effects; and (5) develop a recommended monitoring plan with "thresholds" identified for type and timing of mitigative action.

Environmental studies could be required to establish the associated benefits of Pass opening; economic analysis could be necessary to establish the cost-effectiveness and to identify the beneficiaries of Pass opening. Finally, legal efforts would undoubtedly be required to anticipate and hopefully reduce future litigation.

Summary

The evolution of inlets and their tendencies to migrate and close are affected by a variety of factors including hydraulic efficiency, which can be decreased due to shoaling. Multiple inlets competing for the tidal prism of a common bay area can lead to one entrance enlarging and the second decreasing in size and eventually closing. In spite of recent advances, predictability of inlet behavior is poor, due in part to the complex processes and also to the lack of well-documented case studies over long periods of time.

Although an element of doubt remains, taken in aggregate the weight of the evidence is that the dredging of the ICW commencing in the 1920s was instrumental to the closing of Midnight Pass. *(Editor's Note: Data collected by the Sarasota Bay Program [Sheng and Peene 1992] do not support this conclusion.)* Model simulations using the 1920 bathymetry may be helpful in addressing this question.

If Midnight Pass were opened without the stabilizing effects of jetties, it would likely tend to close again, as it has in the recent past; substantial maintenance efforts would be required to maintain the Pass open and in a particular location. Opening of the Pass should be preceded by adequate engineering, environmental, economic and legal considerations to cope with the wide range of possible effects on adjacent beaches and to respond to the migration and closure tendencies of the inlet.

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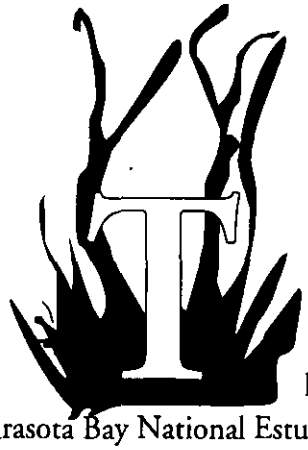
Wetlands

Tidal Wetlands

Freshwater Wetlands



Tidal Wetlands

by Ernest D. Estevez, Ph.D.
Mote Marine Laboratory

Executive Summary

The status and trends of tidal wetlands within the Sarasota Bay National Estuary Program (NEP) study area have been characterized. Sarasota Bay acquired its modern shape about 5,000 years ago, and wetlands have grown on islands and the mainland shore for about 3,500 years. Mangrove forests are the dominant tidal wetland type in Sarasota Bay. The majority (51percent) of tidal forests are dominated by either red or black mangroves. Grassy and herbaceous marshes are also present, but are not extensive because they are rapidly replaced by mangroves. Mangroves are near the northern limit of their range and are adversely affected by low temperatures. Tidal wetlands of both types are valuable because they produce foodstuff and provide habitat for economically important fishes and invertebrates. Wetlands also retard erosion, buffer uplands from storms and contribute to water quality.

Florida had 20,325,000 acres of wetlands in 1850, not counting open water. By 1956, the state's wetlands had been reduced by 25 percent; another fourth of the remaining wetlands were lost during the 1950s, 1960s and 1970s. By 1985, Florida had lost a total of 9,286,713 wetland acres, about 46 percent of its original area. The overall average rate of loss during that 135-year period was more than 100 square miles of wetland per year.

A number of wetland studies have been conducted in the vicinity of Sarasota Bay, but varying methods, geographic areas of study and other differences make comparing them difficult. Two estimates are available on the loss of tidal wetlands in Sarasota Bay. The measurement produced by this study (39 percent) is lower than a previous estimate (45 percent) that was made using different methods and a slightly different study area.

In 1950, the NEP study area contained about 4,104 acres of tidal wetland; the average wetland was relatively large (about 22 acres). The biggest wetlands in Manatee County were on the Bay side of Anna Maria,

around Perico Bayou and on Perico Island. The largest wetlands in Sarasota County were on Longboat Key south of Buttonwood Harbor. Most (82 percent) of the area's original tidal wetlands were in Manatee County.

By 1975, one-third of the area's tidal wetlands had been converted to upland or open water; by 1990, this wetland area had been reduced to 2,495 acres. The overall loss (1,609 acres) represents a rate of 40 acres per year. Fragmentation of remaining wetlands has also been extensive, resulting in a 240-percent increase in the number of small wetlands.

Status of wetlands was defined as their structural condition: area wetlands are in relatively good condition. No significant differences exist for segment-wide condition values. Large (greater than one-half acre) wetlands tend to be in better condition than small (less than one-half acre) wetlands. No significant difference was found in the condition of island wetlands compared to mainland wetlands.

About one-fourth of the area's wetlands displayed some form of natural damage, including freeze effects, lightning strikes, herbivory and natural erosion. Natural erosion most often occurs at the long ends of the Bay, where fetch is greatest. Three areas of the Bay were distinguished on the basis of natural impacts. Two (Longboat and Midnight Passes) had below-average impacts of natural origin. One (Buttonwood Harbor and the Bay side of Longboat Key in Sarasota County) had above-average levels of natural impact.

Human impacts include dredge and fill, mosquito-ditching, trimming and invasive-species encroachment.

Fifteen tidal wetland areas have extensive ditching, spoil piles, or both. Spoil piles support non-native plant species and will be difficult to remove. About one-third of the area's tidal wetlands have some amount of trimming, an estimate based on wetland counts rather than areas. Top-down pruning, or hedging, was the prevalent practice. Selective limb removal was used in less than five percent of surveyed wetlands that showed any kind of trimming. Many (36.8 percent) property owners trim only an end or perhaps a "window" in adjacent mangroves, thereby affecting less than 33 percent of the forested wetland's total length. Most (39.3 percent) trim two-thirds or more of the wetland's total length. Any trimming that occurs tends to reduce the trees' overall height by less than one-third, 38.7 percent of the time. Trimming reduces the trees' overall height by more than two-thirds in 21.7 percent of all cases.

The two dominant nuisance plant species in tidal wetlands are Brazilian pepper (*Schinus terebinthifolius*) and Australian pine (actually three species of *Casuarina*). Both species grow along the upland margins of tidal wetlands, encroaching on mangroves and displacing tidal-marsh and

saltern-plant communities. Brazilian pepper and Australian pine also proliferate on spoil islands and spoils from mosquito ditches.

Of tidal wetlands with invasive species, about one-third are affected by Brazilian pepper alone, one-third by Australian pine alone and one-third by both species together. Three-fourths of the tidal wetlands have less than a third of their shoreline in Brazilian pepper, and a few (less than seven percent) have peppers along two-thirds or more of their shoreline. Australian pine has a similar distribution, but extensive encroachment by this species is about twice as frequent as that by Brazilian pepper.

In summary, a significant, long-term decline has occured in the abundance and condition of tidal wetlands in the Sarasota Bay NEP study area. This decline is expected to continue, resulting in decreased levels of wetland values and beneficial uses.

A number of management tools exist to arrest and reverse the trend of wetland decline. Based on overall wetland loss and damage to remaining wetlands, it is advisable to establish Bay-wide wetland-management programs to reverse wetland decline. The Program should consider establishing an annual restoration or recovery goal of one percent of total past losses. In Sarasota Bay, that recovery rate – calculated on the basis of losses since 1950 – would be 16 acres per year, equivalent to one major project annually, as described in the Early Action Demonstration chapter.

Thirty-three management options are identified to help accomplish the strategic goals. The options are presented under the topical areas of preservation, restoration, creation, shoreline softening and transparency improvements, creative programs and projects, and improvements to existing programs. Areas of new research related to local wetland management are also identified. Sea-level rise will pose continuing problems and opportunities for local wetland management.

Status and Trends of Sarasota Bay's Tidal Wetlands

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Introduction

Island margins and the mainland shore around Sarasota Bay are affected by tides that have an average range of 6.7 decimeters, or 2.2 feet (NOAA, 1991). These shorelines, and the banks of major creeks entering the Bay, constitute the natural habitat of several plant species able to tolerate periodic inundation, salt exposure and other special problems of living at the water's edge. Contiguous areas vegetated by such plant species are tidal wetlands. The presence and productivity of the plants modify underlying ground, resulting in unique wetland soils (Hyde *et al.*, 1991). The tidal shores are thus the habitat for wetland plant species, and wetlands in turn provide habitat for many other plants and animals.

Sarasota Bay acquired its modern shape and geometry about 5,000 years ago, as offshore bars migrated upward to form barrier islands (Brame, 1976). The Bay was narrower because sea level was lower, and the barrier islands were frequently overwashed by hurricanes.

Wetlands developed in shallow waters around most margins of the Bay, and have tracked a slow rise in sea level ever since (Knowles, 1983). Two forms of wetland colonized the region: tidal marshes and mangrove forests *(Table 1)*. During colder times, tidal marshes were probably more abundant than today, because mangroves are cold-sensitive trees (Walter, 1977). Although the past century has been relatively warm, resulting in a predominance of mangrove forests along tidal shores, patches of damaged mangroves may still be seen after brief winter freezes. The northern limit of mangrove forests on Florida's west coast is only about 100 kilometers (62 miles) north of Sarasota Bay (Odum and McIvor, 1990).

Wetland Values and Benefits

Mangrove forests and tidal marshes are valuable because of their ecological roles and beneficial uses. Among other values, wetlands produce large amounts of organic matter that can be consumed in marine food chains, contribute to peat formation or be exported to other ecosystems. Wetlands provide energy and habitat for numerous marine and estuarine species of economic, scientific and aesthetic value. Wetlands retard natural erosion, and in quiet areas can enhance sedimentation. Wetlands buffer upland areas from waves and storm damage; conversely, they buffer the Bay from upland impacts by retaining flood waters and scrubbing runoff of nutrients, heavy metals and other contaminants (Estevez, 1982). And until recently, mangrove wood was a popular fuel for local barbecues.

The importance of tidal wetlands to fisheries cannot be over-emphasized. Wetlands provide shelter and food to developing invertebrates and finfish. Around the Gulf of Mexico, "as much as 95 percent of commercial fish landed and 85 percent of the sport fish catch [by weight] spend at least a portion of their lives in coastal wetland habitats." In Florida alone, "wetlands were linked to approximately 80 percent of the total weight of fish landed by recreational fishermen, and to nearly 92 percent of [the state's] commercial landings" (Gulf of Mexico Program, 1992).

The values and benefits of wetlands depend largely on the wetlands' structural and functional characteristics. Structural characteristics include area, edge, location, type and architecture. More wetland area, for example, means more production of valued species such as penaeid shrimp (Turner and Boesch, 1988), more commercial finfish species throughout the Gulf of Mexico (Deegan *et al.*, 1986) and more bird species (Oviatt *et al.*, 1977). More wetland shoreline edge means greater habitat for mangrove root-fauna such as sponges, oysters, barnacles, tunicates and other filter-feeding animals (Sasekumar, 1974).

Edge largely determines the "refuge" quality of tidal marshes for larval and juvenile invertebrates and fishes (Montague and Wiegart, 1990). Wetlands near highly saline inlet areas are inhabited by different species of invertebrates and fishes than wetlands in brackish or tidal fresh water

(Tabb and Manning, 1961). Birds that nest in mangrove forests do not generally nest in tidal marsh. Severely pruned mangrove wetlands differ in a variety of significant ways from mangroves with natural canopies (Beever, 1989).

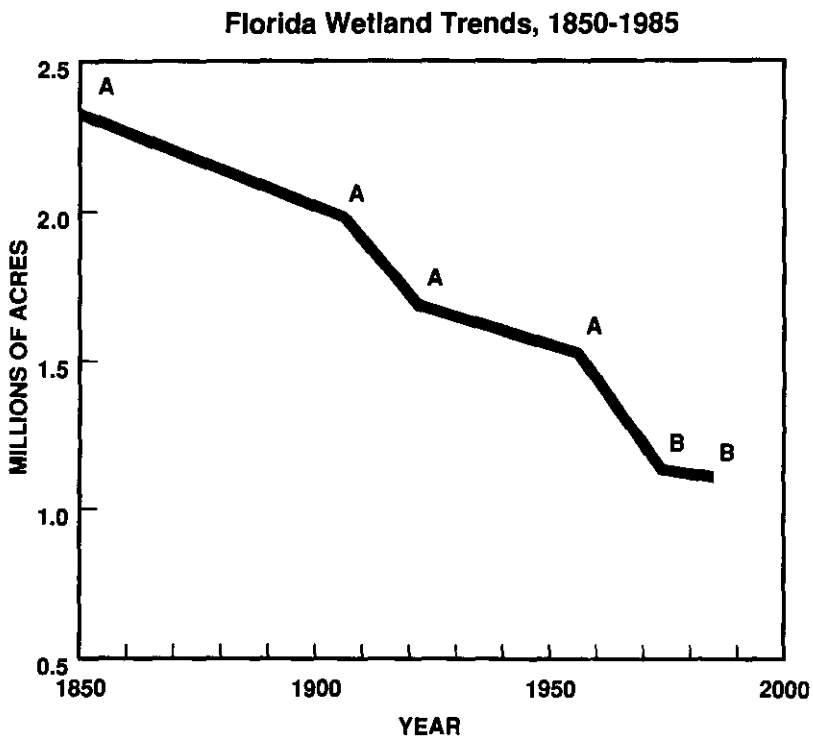
National, State and Local Trends

Approximately 221 million acres of wetlands existed in the lower 48 states at the time of European colonization (Dahl, 1990). By the mid-1980s, that wetland area had been reduced to about 103.3 million acres (Dahl and Johnson, 1991).

Florida had an estimated 20,325,000 acres of wetlands in 1850, not counting open water (Shaw and Fredine, 1956). By 1956, the state's wetlands had been reduced by 25 percent to 15,266,400 acres, with the greatest losses (more than 46,000 acres per year) occuring from 1906 to 1922 *(Figure 1).* Another fourth of the remaining wetlands were lost during the 1950s, 1960s and 1970s. The loss rate fell significantly between 1974 and 1985, but even then the total loss was 260,300 acres, or 23,664 acres per year (Frayer and Hefner, 1991). By 1985, Florida had lost a total of 9,286,713 wetland acres, about 46 percent of the original wetlands area. The overall average rate of loss during that 135 years was more than 100 square miles of wetland per year.

A number of wetland studies have been conducted in the vicinity of Sarasota Bay (Estevez *et al.,* 1990), but varying methods, geographic areas of study and other differences make comparisons difficult. Based on data provided by the Florida Dept. of Natural Resources for the tidal waters of Sarasota County, Duke and Kruczynski (1991) reported a 45-percent decline in mangroves, and an 83-percent decline in tidal marshes, between 1948 and 1987. The combined area of marshes and mangroves in 1948 (4,490 acres) decreased to 2,201 acres in 1987, an overall loss of 2,289 acres, or 51 percent. During the 39-year period analyzed by that study, the average rate of wetland loss in Sarasota County's tidal waters was 59 acres per year.

Figure 1. Florida wetland trends, 1850-1985. Source A: Shaw and Fredine (1956). Source B: Frayer and Hefner (1991).



Relationship to National Estuary Program Goals

The distribution, abundance and condition of tidal wetlands have direct and important bearing on two National Estuary Program (NEP) goals for Sarasota Bay:

•Eliminate further losses of seagrasses and shoreline habitats and restore lost habitats.

•Restore and sustain fish and other living resources.

The first goal states that existing tidal wetlands will be preserved and new ones created, and implies that damaged wetlands will be rehabilitated. The second goal states an ambition that living resources such as wetlands be restored and separately advocates that fish stocks be restored and sustained. Wetland management is critical to the successful management of Florida's marine and estuarine fishery species (Comp and Seaman, 1985).

Tidal wetlands have indirect but important bearing on three NEP goals:

•Improve water transparency to the maximum allowable by Gulf and local weather conditions.

•Reduce the quantity and improve the quality of stormwater runoff.

•Provide increased levels of managed access to the Bay and its resources.

The influence of wetlands on transparency of adjacent waters is not well-known, but available information indicates that wetlands decrease sediment resuspension (Dieter, 1990). Likewise, "wetlands have great potential to help solve stormwater-management problems [but] more information is needed to ascertain possible effects on wetlands and their fauna from addition of untreated stormwater" (Livingston, 1990). Wetlands are not a serious physical barrier to Bay access, but mangroves do limit visual access to the scenery of Sarasota Bay and estuaries elsewhere in the world (Hutchings and Recher, 1977), and therefore wetlands are relevant to the third listed NEP goal.

Study Objectives

As an NEP characterization study, the tidal-wetlands project undertook the description of resource status and trends by:

1. Describing historic tidal-wetland distribution and abundance within the NEP study area.
2. Using existing wetland-inventory results to depict changes in wetland loss through time.
3. Describing present-day (1990-91) tidal-wetland distribution and abundance within the NEP study area.
4. Cataloging tidal-wetland condition and causes of condition declines.
5. Incorporating tidal-wetland distribution, abundance and condition data into GIS map format.
6. Recommending wetland-management options for the *Framework for Action* and *Comprehensive Management Plan.*

A companion study was performed for the non-tidal (freshwater) wetlands of the project area.

Methods

A scoring system was developed for tidal wetlands in the Bay area, recognizing that the majority of wetlands are dominated by mangroves. The scoring system reflected approaches used in other wetland classification and evaluation programs, but emphasized structural characteristics.

Natural stresses such as erosion, insect and borer damage, lightning strikes and freeze damage were considered. Anthropogenous impacts included filling, hydrologic alterations, structures, trimming and pruning, and the presence of invasive or nuisance species. Erosion caused by human activity was also included. Positive attributes included management status, proximity to submerged aquatic vegetation and wildlife use.

All shorelines were reconnoitered; individual wetland units were identified by interpreting 1988 color aerial photographs printed at 1:24,000 scale, and by simultaneous observations made in the field. Data on natural condition, merits and demerits were recorded in the field for each wetland unit. Aerial overflights and automobile trips were used to supplement field data collected from boats, to provide a thorough census of area wetlands.

Data on individual attributes such as natural stresses and anthrogenous impacts were compiled manually and with a personal computer, and composite scores were calculated for each wetland unit, using the system described above. A score of 90 resulted if a wetland exhibited no natural or human-caused stresses, but also had no exceptional habitat, seagrass or management merits. Lower scores reflected accumulating negative impacts; higher scores reflected wetlands in exceptional *structural* condition. Merits offset demerits to produce intermediate scores.

Final maps were produced by annotating acetate overlays registered to stable composite prints of U.S. Geological Survey topographic quadrangles. The quadrangles were produced by Geonex Martel, Inc. for the Southwest Florida Water Management District, and include Florida land-use and cover data, with wetlands mapped to half acres (Florida Dept. of Transportation, 1985). Annotations included changes in and additions to wetland units and an overall

Table 1.

Native plants found in tidal wetlands of the Sarasota Bay NEP study area. Common names follow Reed (1988).

Tidal Marshes	
Acrostichum sp.	(leather fern)
Typha sp.	(cattail)
Distichlis spicata	(seashore saltgrass)
Spartina patens	(saltmeadow cordgrass)
Spartina alterniflora	(smooth or saltmarsh cordgrass)
Spartina bakeri	(sand cordgrass)
Scirpus sp.	(bulrush)
Cladium jamaicensis	(saw grass)
Juncus roemerianus	(black needle rush, needlegrass rush)
Batis maritima	(saltwort)
Salicornia sp.	(glasswort)
Suaeda linearis	(sea blite)
Sesuvium sp.	(sea purslane, seepweed)
Baccharis sp.	(saltbush, false willow)
Mangrove Forests	
Rhizophora mangle	(red mangrove)
Conocarpus erecta	(buttonwood, button mangrove)
Laguncularia racemosa	(white mangrove)
Avicennia germinans	(black mangrove)

wetland condition score. Overlay data including segment boundaries (Estevez and Palmer, 1990) were scanned into digital form and incorporated as ARC/INFO files by Geonex Martel, Inc.

Historic data from the 1970s National Wetlands Inventory were provided by the National Oceanic and Atmospheric Administration (NOAA) for the Sarasota Bay NEP study area. Similar data from a 1980s LANDSAT survey were provided by the Florida Game and Fresh Water Fish Commission. Soil Conservation Service imagery from the 1940s and 1950s was analyzed at Mote Marine Laboratory using a Bioscan Optimas computerized image-analysis program in conjunction with IBM PC Windows. An Ikegami short-range video camera attached to a high-resolution Sony monitor was used to acquire images. Image data were adjusted, analyzed and recorded in an Excel spreadsheet. Methods are described in detail in the Tidal Wetlands Technical Report.

Results: Tidal Wetland Trends

Based on Soil Conservation Service sources, the total area of Sarasota Bay's tidal wetlands amounted to approximately 4,104 acres in 1950 *(Table 2)*. This estimate corresponds favorably with the 4,490-acre estimate in 1948 reported by Duke and Kruczynski (1991) for the tidal waters of Sarasota County. A total of 171 separate wetland units constituted the total area. Bay segments vary greatly in terms of size and the wetlands each contains. On a segment-wide basis, the mean wetland area was about 22 acres (+/- 19.0 acres, standard error) and wetlands accounted for an average of about 17 percent of each segment's surface area.

The Bay area's original wetlands tended to be large and contiguous, with a shoreline-to-area ratio of about 196 feet per acre. In other words, original wetlands tended to be as deep as they were wide. Mangrove forests were the dominant wetland type.

The largest system of wetlands then and now was in Manatee County. A large, contiguous forested area grew on the Bay side of Anna Maria Island, and included a large island forest called School Key (now Key Royale). Wide, fringing forests grew along Perico Bayou and around Perico Island and Tidy Island. In Sarasota County, a large contiguous forest grew on the Bay side of Longboat Key. Overall, 82 percent of the Bay's natural fringing mangrove forests and other tidal wetlands occurred in Bay segments 1 through 8, which lie mostly in Manatee County.

The first National Wetlands Inventory was queried by NOAA to determine that the Sarasota Bay NEP study area had approximately 2,800 acres of tidal wetland in 1975. In the 25 years after 1950, about 1,300 acres of wetlands were converted to uplands or open water, representing a 32-percent loss in 25 years, or about 52 acres per year. The greatest loss of tidal wetlands during this period occurred along the Bay side of Anna Maria Island, north of State Road 64 (Manatee Avenue).

Duke and Kruczynski (1991) cite data provided by the Florida Dept. of Natural Resources for Sarasota County's tidal-wetland coverage in 1987 of 2,201 acres. About 600 acres were lost in 13 years, equal to 21 percent of the 1975 area, or a rate of 46 acres per year. By 1987, total wetland loss since 1950 amounted to 1,899 acres, equal to an overall loss of 46 percent and an overall rate of 49 acres per year.

It is estimated that the tidal-wetland cover of Sarasota Bay in 1990 was 2,495 acres. The loss since 1975 was 305 acres, representing an 11-percent decrease and a loss rate of 20 acres per year. The rate of loss after 1975 was therefore about one-third less than before 1975. The greatest loss of tidal wetlands after 1975 occurred along the Bay side of Longboat Key in Sarasota County, south of Buttonwood Harbor. About 1,609 acres, or 39 percent of the 1950 tidal-wetland cover, were lost in 40 years between 1950 and 1990, equivalent to an overall loss rate of 40 acres per year.

Tidal-wetland losses are presented by segment in *Table 3*. Segment boundaries differ slightly from segments used in other

Table 2.

Sources and attributes of major data sources used in this report.

Trend Year	Period	Agency	Source	Scale	Wetlands Truthing	Area, acres
1950	1947-1954	Soil Conservation Service	Aerial PI	1:20,000	>90 percent	4,104
1975	1972-1984	National Wetland Inventory	Aerial PI	1:24,000	10 percent	2,800
1987	1987-1988	State of Florida	LAND-SAT	NA	Aerial	3,240
1990	1990-1991	SWFWMD/ SBNEP	Aerial PI	1:24,000	>98 percent	2,495

PI—Photointerpreted
SWFWMD—Southwest Florida Water Management District
SBNEP—Sarasota Bay National Estuary Program
NA—Not applicable

Table 3.

Segment and Baywide comparison of tidal wetlands, 1950 and 1990.				
	Tidal Wetlands			
Segment No.	Area Description	Area, Acres 1950	Area, Acres 1990	Change in Area Percent
1	Anna Maria Sound	699	74	-89
2	Perico Island	994	804	-19
3	Palma Sola Bay	344	241	-30
4	Longboat Pass	0	8	NC
5	Sister Keys	492	149	-70
6	Long Bar Point	287	554	+9
7	Bishops Point	507	134	-53
8	New College	56	15	-73
9	New Pass	0	0	0
10	Bird Key	77	89	+16
11	Sarasota	0	4	NC
12	Big Pass	70	65	-7
13	Roberts Bay	238	151	-37
14	Little Sarasota	90	86	-4
15	Midnight Pass	83	56	-33
16	Blackburn Bay	167	65	-61
NEP Study Area Total		4,104	2,495	-39.2%

NC: Not Calculated

NEP projects, to simplify calculations. Throughout the Bay, wetland losses were greatest (625 acres or 89 percent) in segment 1, along the island shoreline of Anna Maria Sound. Major reasons for wetland losses in this segment were conversion to open water and residential uses. Other segments with above-average losses (> 39.2 percent) included segments 5, 7, 8 and 16, corresponding to the east and west shores of Sarasota Bay and all of Blackburn Bay, respectively.

Tidal-wetland losses in the Sarasota Bay area have been caused by the elimination of small and large marshes and forests, and also by fragmentation. In 1950 the area had 171 mappable wetlands; in 1990 we were able to map 411, an increase of 240 percent. Average wetland size decreased from 22 acres in 1950 to about 5.6 acres in 1990. Construction of roadways, bridges, channels, utility crossings, boat ramps, homes and scenic vistas has divided surviving wetlands into smaller, isolated units *(Figure 2)*.

Values and benefits of wetlands and other natural landscapes change as they are fragmented by development (Reid and Trexler, 1991). Wetland productivity, habitat value and buffering ability decrease, and susceptibility to weeds and pests increases, with fragmentation.

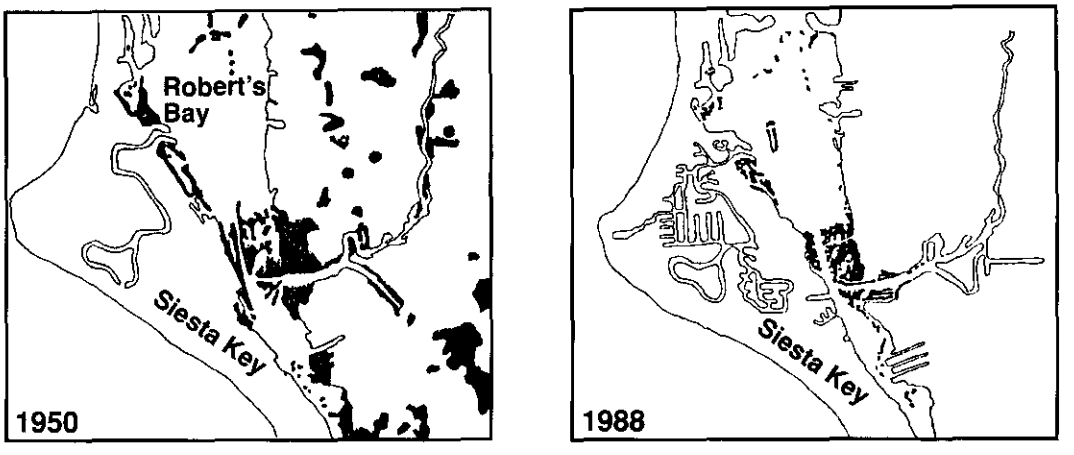


Figure 2. Loss and fragmentation of tidal and freshwater wetlands and wetland soils (dark areas), 1950-88, in Phillippi Creek and adjacent waters of Roberts Bay.

Results: Tidal Wetland Condition (Status)

Wetland Type

More than 90 percent of the tidal wetlands in Sarasota Bay are mangrove forests *(Figure 3)*. The majority (51 percent) of tidal forests are dominated by either red or black mangroves; about 40 percent are dominated by white mangroves or, more commonly, are highly mixed in terms of species. Forests are primarily of the fringing or overwash forms (Lugo, 1977), and range in aspect from tall forests to scrub or shrub (Cowardin *et al.*, 1979).

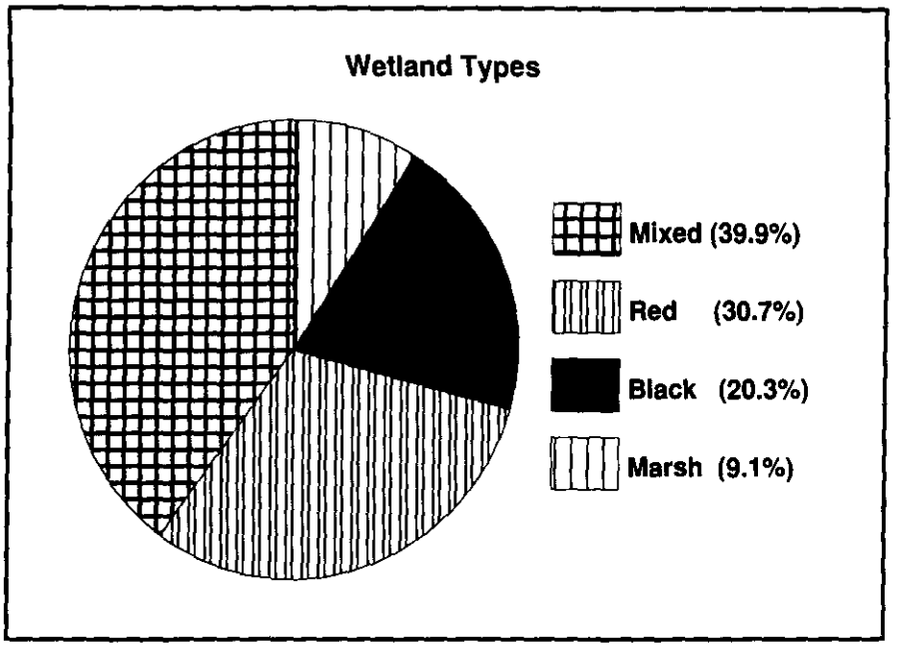


Figure 3. Relative composition of tidal wetlands in Sarasota Bay.

Tidal marsh is comparatively rare and of mixed species composition. Common marsh species include cattail, saltgrass, cordgrass, bulrush and black-needle rush. Common ground cover in and upland of salt marshes (and mangroves) includes saltwort, glasswort, sea blite and sea purslane. Marshes are best-developed in tidal creeks and are rare on the barrier islands.

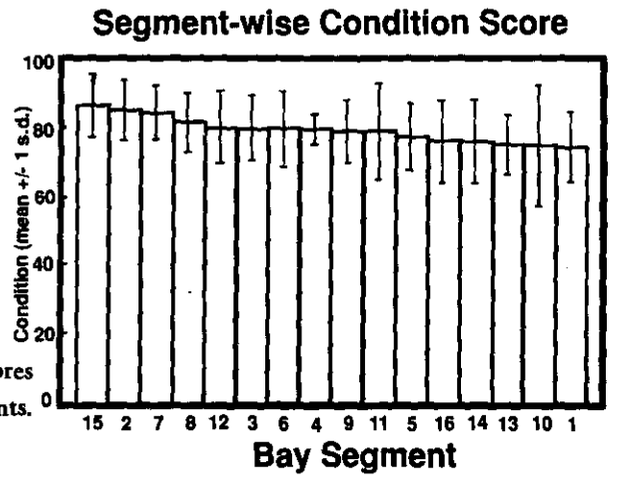


Figure 4. Mean condition scores for Sarasota Bay study segments. S.D., standard deviation.

Wetland Condition

For characterization purposes, wetland *trends* were evaluated in terms of area. The *status* of Sarasota Bay's tidal wetlands was defined as the condition of surviving wetlands. The basis for assessing wetland condition was structural rather than functional. (Functional condition includes measures of productivity, actual habitat value, contaminant load and other parameters beyond the scope of characterization.)

As described in the Methods section, structural condition was evaluated on the bases of natural and human-caused stresses, management status and other static features. Condition results are presented in terms of overall wetland condition and also specific merits and demerits. Condition data are useful as indicators of the type and extent of needed wetland restoration and rehabilitation. Condition data also highlight areas with high preservation potential.

Overall Condition

No significant differences were found in the overall condition of tidal wetlands between segments *(Figure 4)*. The segment with the lowest overall condition score (segment 1 – Anna Maria) was not significantly different from the segment with the highest score (segment 15 – Midnight Pass). Southern segments tended to have lower overall scores than northern segments, but this trend was also statistically insignificant.

Large wetlands tend to be in better condition than small ones *(Figure 5)*. Wetlands larger than one-half acre and mapped at a 1:24,000 scale had many scores greater than 80 and the most scores near 90, indicating that large wetlands had fewer structural demerits or had more compensating merits. For example, large wetlands tended to have fewer invasive species and less pruning than small wetlands; large systems also tended to be associated with nearby seagrass beds or were actively managed – two compensating merits.

On the other hand, wetlands smaller than one-half acre had normally distributed scores with a mean value 20 points less than that of large wetlands. Small wetlands also had more low to very-low scores (less than 60), indicating that demerits were more common and that small wetlands had fewer

compensating merits. Small wetlands had more invasive species and pruning damage, and many were far from the nearest seagrass beds. Islands tend to exhibit higher overall condition scores than nearby mainland wetlands of comparable size, but these differences are not statistically significant.

Wetlands showing one or a few forms of stress tended to have high scores, irrespective of stress severity; low scores were caused by multiple, severe stresses. The relative distribution of major types of stress is shown in *Figure 6.* (Data in *Figure 6* do not add to 100 percent because a given wetland may have more than one form of damage.) The co-occurrence of impacts is described in a subsequent section. About 14 percent of all wetlands in the Sarasota Bay study area were free of structural damage. This does not mean that these wetlands were without impact – contamination could be a problem in some of these wetlands, but data on contamination are unavailable.

About one-fourth of the area's wetlands displayed some form of natural damage, including freeze effects, lightning strikes, herbivore damage and natural erosion.

Freeze effects were most evident in tidal creeks, appearing as lowered canopy with dead branches emerging through the canopy. Freeze damage is affected by tidal stage; if a period of low temperature occurs during high tide, the canopy is insulated and damaged less.

Lightning strikes were seen on islands and larger fringing forests. Strikes appear as circular patches of dead trees, and damage to individual trees was sometimes evident. Lightning creates light-gaps in which new mangrove seedlings flourish.

Herbivory damage in canopies was evident in the form of skeletonized leaves, damaged propagules and prolific branching of aerial roots. Insects and crabs cause most of the damage to canopies. Prop roots of red mangroves growing in tidal creeks were damaged by wood-boring isopods; borer damage was more conspicuous along eroding shores.

Natural erosion occurs mostly at the long ends of the Bay, such as the mouth of Bowlees Creek, where the fetch is greatest. Erosion caused by boat wakes was also noted, but not counted as natural damage. (A good example of boat-caused erosion in mangroves was found along the Intracoastal Waterway near Phillippi Creek.)

Three areas of the Bay can be distinguished on the basis of natural impacts *(Figure 7).* Two (Longboat and Midnight Passes) had statistically low impacts of natural origin. One (Buttonwood Harbor and the Bay side of Longboat Key in Sarasota County) had statistically high levels of natural impact.

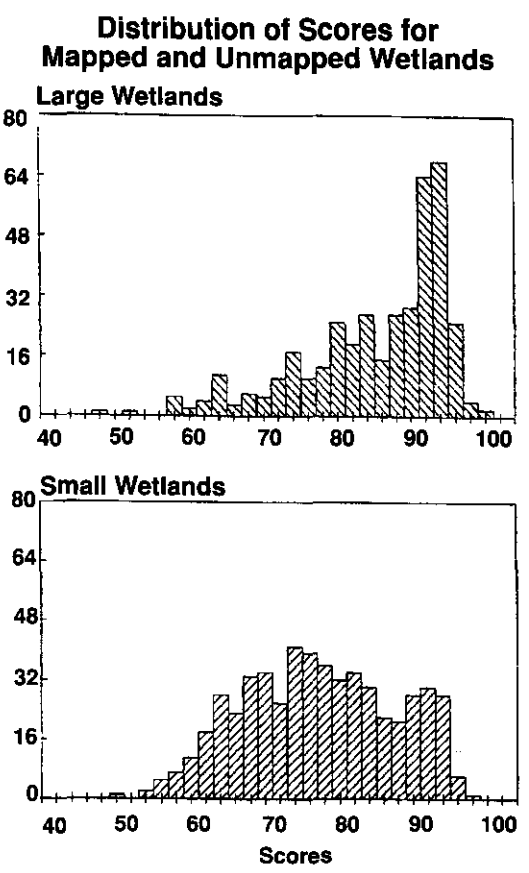


Figure 5. Distribution of condition scores for large (>0.5-acre) and small (<0.5-acre) tidal wetlands.

About one-third of the area's tidal wetlands show some amount of trimming, an estimate based on wetland counts rather than areas. Counts tend to overstate the importance of small wetlands, but are used to describe trimming levels because most trimming occurs in residential wetlands too small to map. Trimming takes two forms – topping or hedging, and selective limb removal. Details on trimming are given in a later section.

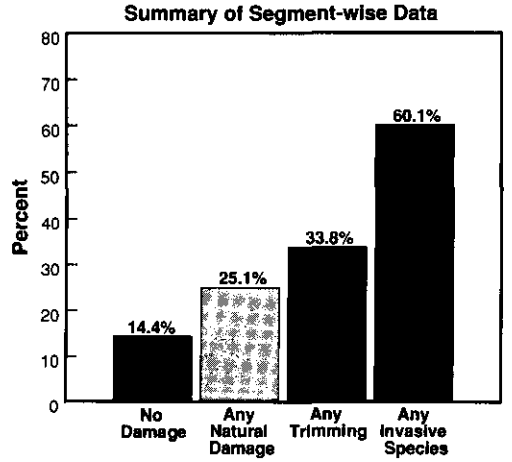
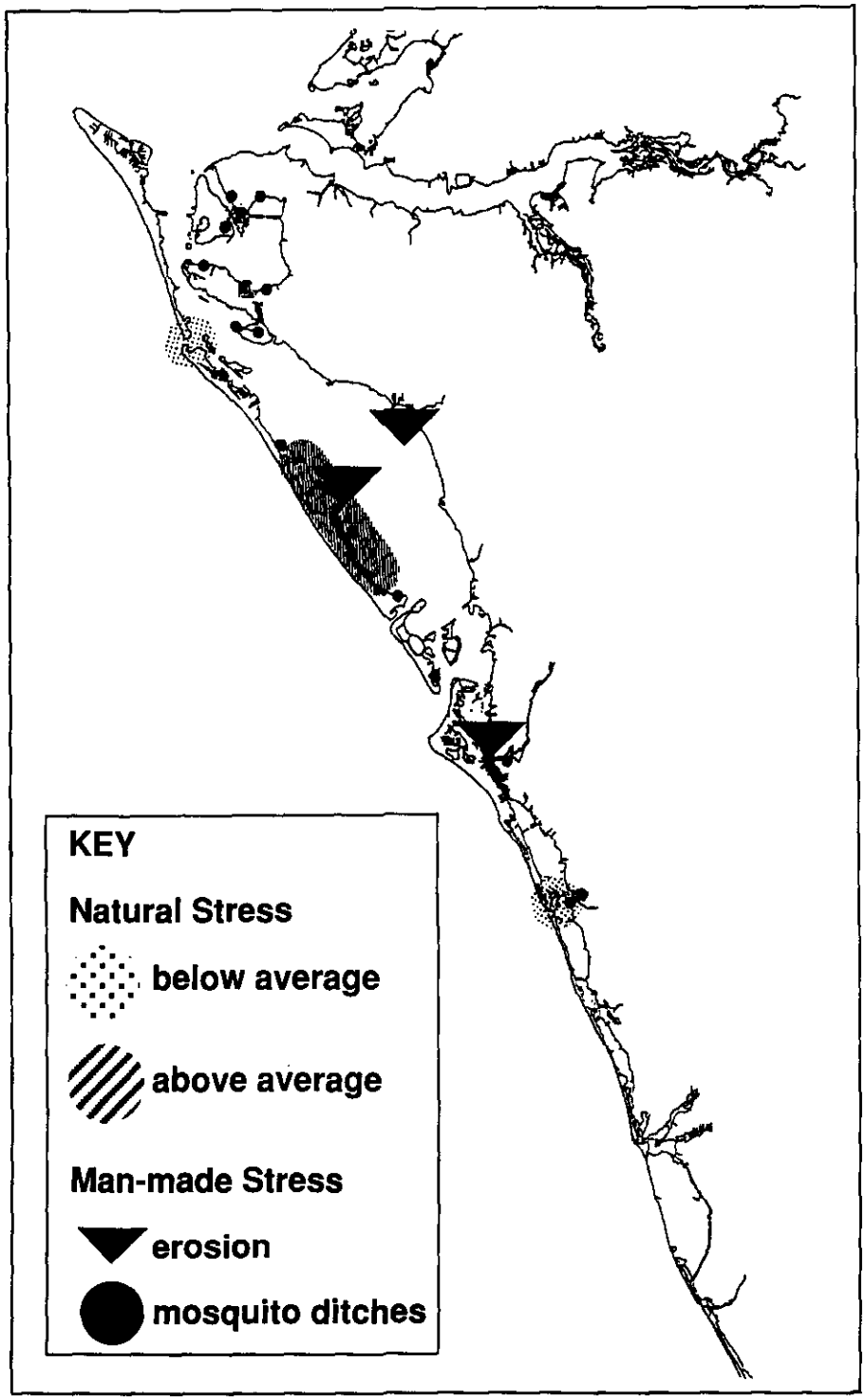


Figure 6. Incidence of natural damage, trimming and invasive species compared to tidal wetlands with no structural damage.

Almost two-thirds (60 percent by count) of the wetlands host some measure of invasive species; Brazilian pepper and Australian pine are the dominant invasive species. Details on the abundance of these species also follow. Encroachment of tidal wetlands by invasive species was more common than any other form of structural impact.

Figure 7. Geographic distribution of naturally occuring and man-made stresses in tidal wetlands.



Individual Impacts

Erosion mentioned above is of both natural and man-made origin. Erosion problems are not extensive or severe in tidal wetlands within the study area. Three areas do have pronounced erosion problems, however *(Figure 7)*.

The entrance to Bowlees Creek is exposed to a long fetch. Combined with boat wakes from traffic using the creek, wave energy there is sufficient to undercut banks and topple mangroves.

The Bay side of Longboat Key in Sarasota County is another eroding area. There a channel runs parallel and landward of the seaward fringe of a mangrove forest that was cleared and filled for development. The seaward fringe is all that remains of the forest. Wakes in the channel and waves from the Bay combine to winnow peat and sediments from the remaining mangrove strand, and this forested area is likely to disappear completely in the next few years.

The third eroding area occurs along the Intracoastal Waterway near the mouth of Phillippi Creek. The edges of the fringing mangrove system on both sides of the Intracoastal Waterway are being dissected by wave energy. Toppled trees create local blowouts along vegetated banks, resulting in a scalloped shoreline.

Dredging and filling has been a common practice in the study area, and was the primary cause for the 45-percent loss of tidal wetlands reported above. Filling of remaining wetlands is also pervasive, but evident mostly as small, localized encroachments of residential lots into the upland sides of wetlands.

A more conspicuous and permanent form of filling has been the placement of spoils in tidal wetlands. The majority of spoils were produced when tidal wetlands were ditched for mosquito-control. Fifteen tidal-wetland systems in the Bay area exhibit ditching or ditching and spoils associated with mosquito-control or drainage *(Figure 7)*. Spoils tend to be large piles of sand, shell or peat, separated by subtidal or intertidal ditches. Spoils support dense growths of Brazilian pepper and Australian pine; other spoil-pile vegetation includes Spanish bayonet, prickly pear, palms and other ornamental species.

Trimming of some kind was encountered in about 34 percent of all wetlands, by count. Top-down pruning, or hedging, was the prevalent practice; selective limb removal was used instead of or in addition to hedging in less than five percent of the affected wetlands. Although it may become more

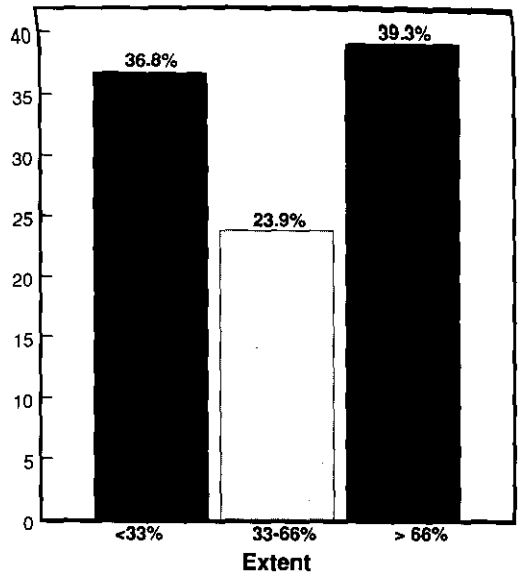
common in the future, selective limb removal is not presently in wide practice, and will not be discussed further.

Two measurements are needed to describe pruning in wetlands. "Extent" refers to the along-shore dimension; "severity" refers to the top-down dimension *(Figure 8)*. A mangrove area may be pruned along its entire length or along one part. Where pruned, the resulting hedge may be reduced only slightly from the height of nearby uncut trees, or it may be reduced greatly. Characteristics of pruned wetlands are given in *Figure 9*. Many (36.8 percent) property owners trim only an end or perhaps a window in adjacent mangroves, thereby affecting less than 33 percent of the forested wetland's total length. Most (39.3 percent) trim two-thirds or more of the wetland's total length.

One-third (33.8 percent) of the area's 927 wetlands were trimmed to some extent. If any trimming occurred, it reduced the trees' overall height by less than one-third, 38.7 percent of the time. In other words, the study area had 121 lightly trimmed wetlands (13.1percent of the total number). Trimming reduced the trees' overall height by more than two-thirds in 68 wetlands, or 21.7 percent of all cases of pruning (7.3percent of all wetlands). Sixty wetlands – representing 18.4 percent of wetlands with any level of trimming, or 6.5 percent of all wetlands counted in the study – had the greatest extent *and* severity of trimming.

Trimming and invasive species constitute the two most common structural impacts in tidal wetlands. Their co-occurrence is depicted in *Figure 10*. More wetlands are affected solely by invasive species than by trimming alone, and about one-third of the wetlands are affected by both.

The two dominant nuisance plant species in tidal wetlands are Brazilian pepper (*Schinus terebinthifolius*) and Australian pine (actually three species of *Casuarina*). Pepper resembles mangrove in aspect. It has a full, light-green canopy and produces large amounts of leaf litter and aerial branches.



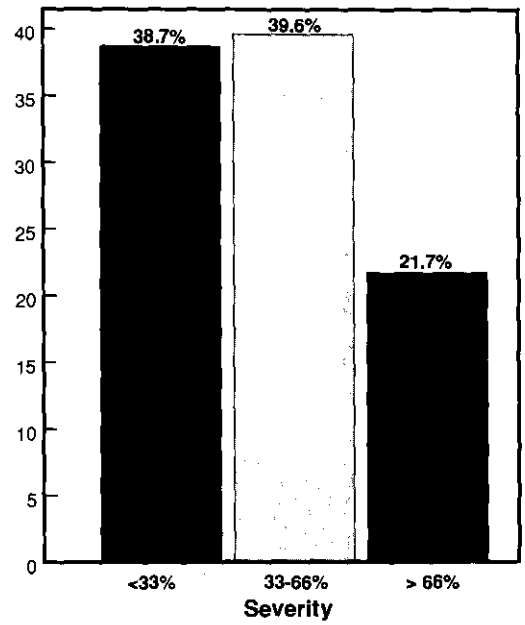


Figure 9. Lateral extent and vertical severity of mangrove trimming among 313 affected wetlands (of 927 total).

Australian pine resembles pine, but is not a true pine. It has a tall, erect form, massive trunks and shallow roots; it too produces large amounts of litter in the form of twigs resembling pine needles.

Both species grow along the upland margins of tidal wetlands. They encroach upon mangroves and displace tidal-marsh and saltern-plant communities. The two species

Figure 8. Illustration of lateral extent and vertical severity of mangrove trimming.

Figure 10. Frequency of trimming (only), invasive species (only) or both among affected wetlands.

Figure 11. Frequency of Brazilian pepper (only), Australian pine (only) or both among 557 wetlands with invasive species (60.1 percent of all wetlands).

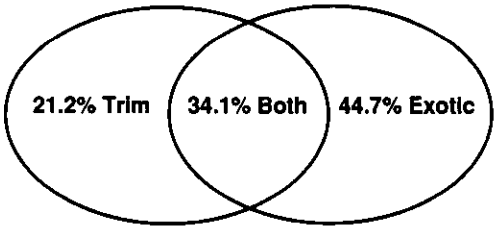


Figure 10.

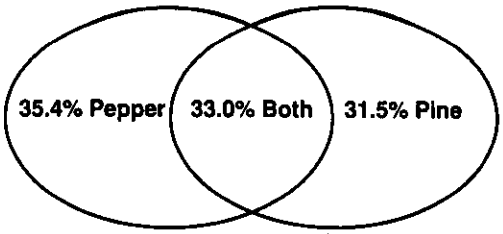


Figure 11.

also proliferate on spoil islands and spoils from mosquito ditches. Like mangroves, both are intolerant of cold (Morton, 1980).

About one-third of tidal wetlands with invasive species are affected by Brazilian pepper alone, one-third by Australian pine alone and one-third by both species together *(Figure 11)*. Smaller wetlands tend to have more invasive species than unditched large ones, but otherwise no definite patterns exist. Because invasive species tend to encroach upon the shoreline, it is possible to describe the extent of their distribution in the same way that the extent of trimming was described *(Figure 12)*. Three-fourths of the tidal wetlands have less than a third of their shoreline in Brazilian pepper, and few (less than seven percent) have peppers along two-thirds or more of their shoreline. Australian pine has a similar distribution, but extensive encroachment (greater than 66 percent) is about twice as frequent as that of Brazilian pepper.

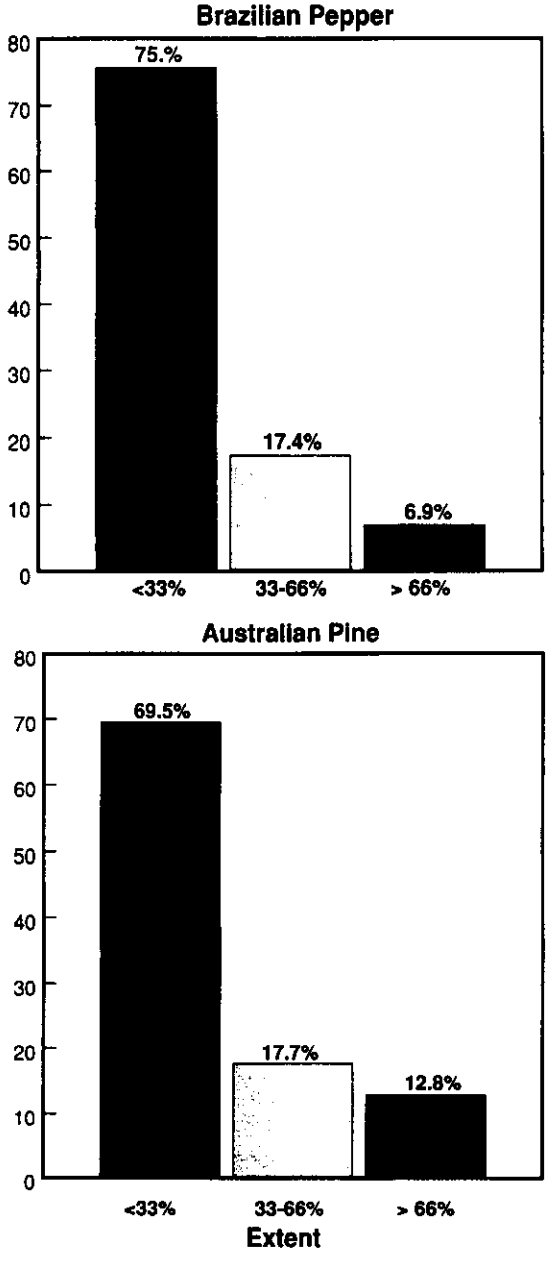


Figure 12. Lateral extent of invasive-species encroachment in tidal wetlands.

Discussion

The use of Soil Conservation Service (SCS) aerials to delineate early wetland cover leaves open the possibility of misstating actual wetland area. Soil data are accurate tidal-wetland indicators (Eicher, 1988), but in some settings may be imprecise. Soil types tend to be mapped inclusively, meaning that a tidal marsh or tidal-swamp soil may include unvegetated areas. In tidal settings, these barren areas are either incipient wetlands (e.g., salterns) or recently denuded wetlands (as happens after storms or freezes). The use of SCS imagery, therefore, has the potential to overstate actual wetland acreage. Close inspection of source imagery and experience with tidal wetlands in Florida suggests that this error is insignificant in Sarasota Bay.

Furthermore, any authentic overestimate may be considered to offset wetland conversions that occurred prior to the date of SCS soil-mapping. Finally, the estimate of 39-percent total loss of tidal wetlands since 1950, starting with SCS data, agrees with the estimates made by the Florida Dept. of Natural Resources and reported by Duke and Kruczynski (1991). Using photointerpretation of separate source images, they reported a 45-percent loss of mangroves and a 51-percent loss of all tidal wetlands since 1948 in the tidal waters of Sarasota County. The difference in total loss between the two estimates is due primarily to

the inclusion of some Manatee County wetlands in the present study.

Historic tidal-wetland losses in Sarasota Bay parallel losses in other estuarine systems around the Gulf of Mexico:

Texas river-delta marshes	70 percent
Galveston Bay marshes	16 percent
Louisiana marshes	51 percent
Tampa Bay marshes and mangrove forests	44 percent
Charlotte Harbor salt marshes	51 percent
Sarasota Bay marshes and mangroves forests	**39 percent**

(Adapted from Duke and Kruczynski,1991)

On average, 40 acres of tidal wetlands have been lost every year since 1950; the average loss rate since 1975 is lower, 20 acres per year. The rate of loss since adoption of the Warren S. Henderson Wetlands Protection Act in the mid-1980s is presumably lower than for previous periods, but all available data indicate that the overall trend in Sarasota Bay's wetland cover is one of continuing decline. At the 1975-90 rate, all remaining tidal wetlands would be lost by 2115 A.D.

According to the Conference Agreement, the intent of the National Estuary Program is to:

- *Eliminate further losses of seagrasses and shoreline*
- *Restore and sustain fish and other living resources.*

These goals signify that any continued rate of decline in the amount or condition of remaining wetlands needs to be arrested and reversed. As described above, several mechanisms of wetland decline are operating in Sarasota Bay other than their direct conversion to open water or upland. Fragmentation is a persistent problem, likely to continue as pressures to increase Bay access increase. For the same reason, mangrove trimming is likely to accelerate as a growing population seeks visual access to the Bay. Present regulations discourage top-down hedging of mangroves and favor the thinning of canopy by selective limb removal, but no data exist to verify that these new procedures would accomplish NEP goals.

It was observed during field studies that the shortest mangrove hedges seemed to adjoin older residences, especially those built at ground level. Although we do not have quantitative data to test the idea, it is tempting to hypothesize a relationship between hedge height and the base floor elevations of existing structures. If such a relationship exists, pruning severity may gradually relax if older, low buildings are replaced by new structures that meet flood-protection requirements.

Whether or not the preceding scenario is valid, the relative impacts of trimming and encroachment by invasive species should be subordinated to those of filling, as by the spoiling of fill from mosquito ditches or navigation channels. This conclusion follows from the ability of trimmed trees to grow out if trimming is avoided, and from the ability of natural recruitment and vegetative growth to repopulate areas where Brazilian pepper or Australian pine are removed. The two invasive species are extremely common in southwest Florida (Workman, 1978), requiring that their removal from tidal wetlands be considered as an active and ongoing management practice.

Wetland fill will be easier to avoid in the future than to repair. Techniques for removing fill from ditched wetlands do not presently exist, and the expense of doing so may outweigh the benefits. On the other hand, removal of spoil from islands created by construction and maintenance of the Intracoastal Waterway is possible, because tidal-wetland creation can succeed with proper design and construction (Lewis and Bunce, 1980; Fernald and Barnett, 1988).

Wetland-creation projects will be one key method of arresting the historic decline of total wetland acreage in the Bay. Left unanswered by the present characterization effort are some important process-related questions: "How and where should tidal wetlands be constructed to benefit transparency?" and "Will fisheries benefit more from the construction of a few large wetlands or many small ones?"

To prevent erosion and degradation of water quality in mangrove silviculture, Snedaker and Getter (1985) recommend a minimum depth of unfelled mangroves along the shoreline equal to the product of tidal amplitude times 15 – this amounts to 33 feet in Sarasota Bay. As described earlier, analysis of 1950 wetland data showed that original wetlands were approximately as wide as deep. Further study may show that wetland patches approximately 33 feet wide and deep could be used as minimum planting units to meet NEP goals for water quality, habitat or erosion.

Another key method for countering wetland decline will be rehabilitation. Wetlands presently rated in "poor" condition should not be viewed as candidates for development; too few wetlands are left for that interpretation and the fulfillment of

Sources and Effects of Tidal Wetland Degradation

Natural Causes of wetland degradation can include erosion, rising sea level, subsidence, lightning and storm damage, plant diseases and pests and extremes of temperature and salinity. Subsidence and salinity extremes are not problems facing local tidal wetlands; the other natural stresses do occur locally. They decrease wetland cover and can reduce wetland vigor, as in lower growth rates, reproductive output or litter production. Wetlands facing these stresses are consequently less useful to animals.

Man-Made Causes of wetland degradation outnumber natural causes and are more significant and permanent than natural causes.

Construction and maintenance of canals and channels permanently displace natural wetlands. Continued spoil disposal prolongs and extends shoreline-wetland losses. Spoils placed in wetlands also promote weedy species of trees. Channels can reverse local currents and change salinity and flushing in small bays. Wakes produced by boats using the channels cause or enhance erosion of surviving wetlands.

Dredging and filling along shorelines creates uplands and finger-fill canals for residential and commercial uses; these activities also cause permanent wetland loss. Construction promotes turbidity, and deep canals trap organic matter. Many canals in the area are filled with "muck" that animals cannot inhabit.

Continued on page 6.16

Continued from page 6.15.

Upland development generates and speeds the delivery of fertilizers, pesticides and other contaminants to surviving wetlands and Bay waters.

In subtropical Florida, ornamental plants grown along the coast have invaded natural wetland areas. These species encroach on the upland edges of mangroves and tidal marshes, crowding out salt meadows and overgrowing salt flats. Nuisance species grow on spoils placed in tidal wetlands from the creation of mosquito ditches. Invasive species also proliferate in wetlands where local fill (sand, building debris, rock, tree cuttings, etc.) has been dumped.

Mangroves obscure views of open water. Shoreline residents have traditionally topped mangroves in order to see over them. This process produces mangrove hedges that look good, but do not provide the habitat value or other beneficial roles, such as flowering and seed production, of natural trees. New laws promoting selective limb removal reduce some impacts of topping, but the ecological effects of selective limb removal have not been scientifically studied.

The inflow of fresh water and daily exchange of tidal waters are frequently altered by ditches, culverts, roadways, sediment traps and salinity barriers. These changes reduce wetland productivity and promote the accumulation of contaminants; they also make wetlands less accessible to marine organisms.

NEP goals. Wetlands are often in poor condition because of the combined effects of natural and man-made damage. New trimming practices and the control of invasive species will restore affected wetlands to markedly better condition. By the same token, wetlands in the best condition should be considered as candidates for preservation, but highly restrictive protection should depend on functional as well as structural analyses (Sather and Stuber, 1984).

As described later, freshwater wetlands have also undergone numerous changes as the watershed of Sarasota Bay has developed. Large losses of wetlands occurred in northern watersheds, and freshwater wetlands throughout the basin have been fragmented and stressed by ditching, dredging and filling, and invasive species. The overall pattern has been one of large losses of northern freshwater wetlands and large losses of island and southern tidal wetlands.

This pattern may reflect the history of settlement in the area. Manatee County was settled along the inland shores of the Manatee River, whereas Sarasota County was settled along coastal and Bay shores. Growth of these population centers radiated west in Manatee County and east in Sarasota County *(Figure 13)*, leaping to the barrier islands after World War II. Freshwater wetlands were converted to agricultural lands, whereas inland areas of Sarasota County were used as pasture. Consequently, the majority of remaining tidal wetlands are in Manatee County, while the majority of remaining freshwater wetlands are in Sarasota County.

In conclusion, a significant, long-term decline has occured in the abundance and condition of tidal wetlands in the Sarasota Bay NEP study area. This decline is expected to continue as the effects of individual actions accumulate, resulting in decreased levels of wetland values and beneficial uses (Estevez *et al.*, 1986).

A number of management tools exist to arrest and reverse the trend of wetland decline. Specific management options developed during the tidal-wetlands project follow.

Management Options

It follows from the purposes and methods of the National Estuary Program that the Comprehensive Conservation and Management Plan will contain elements that bring management to locally important natural resources. Therefore, it is useful to propose two "strategic" goals for tidal wetlands in order to organize management options that follow.

Strategic Goals

1. Establish Bay-wide or area-specific wetland-management programs.
2. Reverse wetland decline by one percent of total losses per year.

The first strategic goal establishes the intent that tidal wetlands be managed so as to bring to bear different kinds and amounts of regulation, enhancement and restoration, education, etc., than presently exist. Input by the Citizen's Advisory Committee commends the establishment of Bay-wide *and* area-specific wetland-management programs.

The second strategic goal signifies the desired outcome of the first: that the trend of wetland losses around Sarasota Bay be reversed. The suggested rate of recovery, one percent of total losses per year, is equal to that adopted by the Surface Water Improvement and Management Plan for Tampa Bay (SWFWMD, 1992). In Sarasota Bay, the recovery rate calculated for the period 1950-90 would be 16 acres per year.

Tactical Options

The management conference has several options from which to choose in order to achieve its strategic goals (for tidal wetlands) and overall goals (for Sarasota Bay).

1. Preserve existing wetlands.

- A. Implement wetland-acquisition programs in both counties.
- B. Use acquisition and comprehensive planning to protect low uplands, salt flats and wetland buffer areas.
- C. Plan for sea-level rise.
- D. Regulate boat wakes near eroding wetland areas.

2. Restore existing wetlands.

- A. Remove exotic species.
- B. Allow pruned mangroves (hedges) to grow into approved shapes and sizes.
- C. Remove old spoil piles.
- D. Open barriers to flow.
- E. Remove salinity barriers and other tidal checks.

3. Use wetland restoration (and creation) to add area and edge and reduce conflicts with visual access.

- A. Inventory public waterfronts for creation and mitigation potential.
- B. Promote *a priori* mitigation for shoreline projects, including docks and piers.
- C. Lower old spoil islands to intertidal elevations.

D. Link visual-access improvements to restoration projects.
E. Use salt marsh instead of mangroves in habitat-creation projects, but not mitigation.
F. Expand tidal creek wetlands.

4. **Use wetland creation and improvement projects to soften shorelines and decrease turbidity.**
   A. Remove seawalls where feasible.
   B. Replace or supplement seawalls with rip-rap.
   C. Create wetlands along historically barren shorelines.
   D. Create wetlands where monitoring and modeling data show turbidity sources and sinks.
   E. Establish wetlands along causeways and bridge approaches.

5. **Develop creative wetland programs and projects.**
   A. Adopt a post-hurricane habitat and shoreline contingency plan.
   B. Plan new spoil areas as wetland sites.
   C. Use tax incentives as rewards for proper trimming, exotic-species control and other improvements.
   D. Institute a program of conservation easements.
   E. Fill unwanted deep areas to intertidal elevations.
   F. Use volunteer programs to control exotic species.

6. **Adapt existing wetland programs and projects to local conditions, and provide for their continuation.**
   A. Consolidate and refine wetland permit tracking.
   B. Intensify permit review within a defined shore-side area.
   C. Focus wetland education on local needs and wetland sites.
   D. Employ a two-county wetlands "extension agent."
   E. Limit mangrove trimming to licensed specialists.
   F. Create a local status-and-trends program.
   G. Provide long-term funds for applicable research.

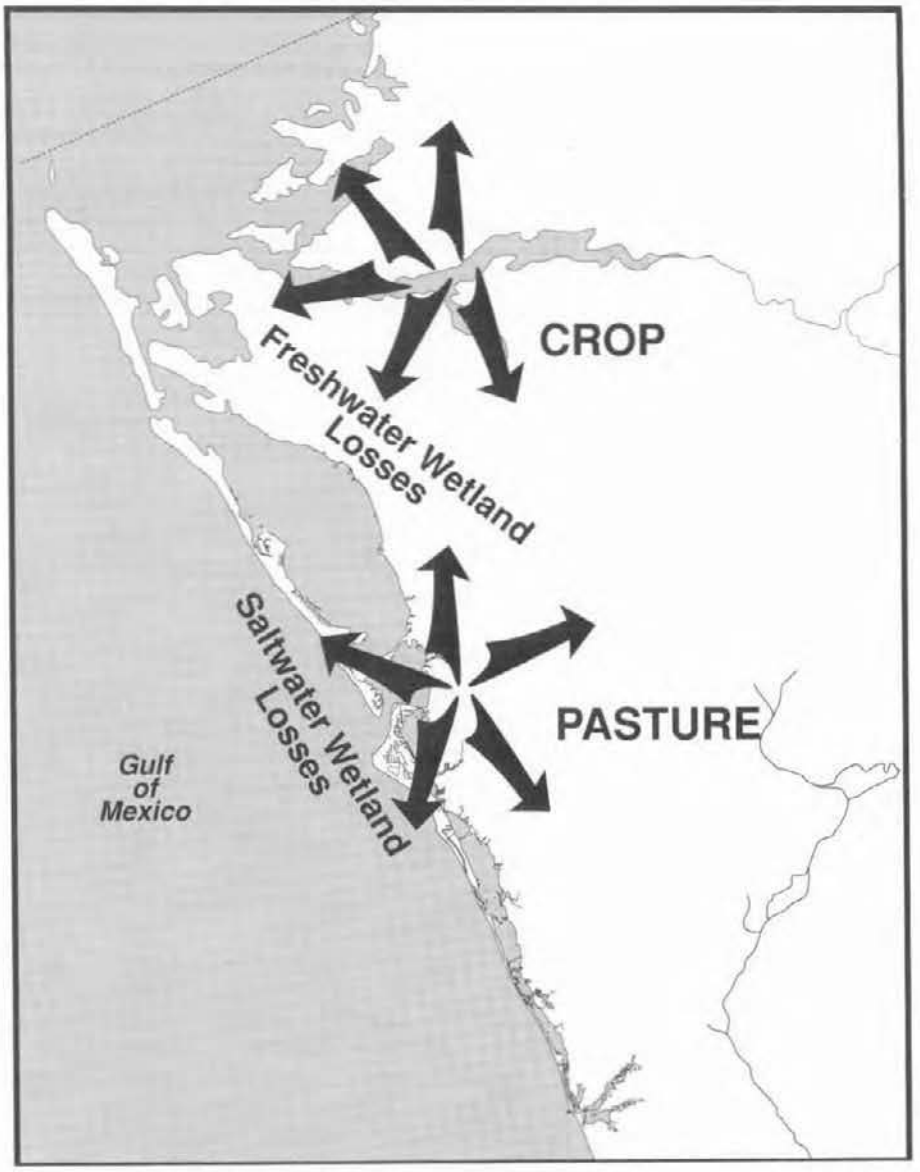


Figure 13. Settlement and agricultural expansion of Manatee and Sarasota counties. Manatee County was settled on the Manatee River, whereas Sarasota was settled along the coast.

Research Needs and Needed Research

New insight into the basic structure and function of Sarasota Bay is critical to its effective management. The research need of the Sarasota Bay area is for long-term funding, so locally important technical problems can be addressed with efficiency and economy. The management conference should adopt definite plans for funding applicable research. Examples of needed research in tidal wetlands follow:

— How do tidal wetlands affect the transparency of the Bay?
— Are a few large wetlands better than many small ones, in terms of reducing turbidity and increasing water clarity?
— Should wetlands created for fish and invertebrates be designed differently from wetlands created for birds, or for other wetland values?

— Where are the public waterfronts, and what publicly owned land is available for wetland creation or restoration?
— How does tidal marsh compare to mangrove in terms of NEP goals for water quality and habitat?
— What are the specific impacts of top-down trimming of mangroves, and what are the impacts of selective limb removal?
— What are the specific impacts of invasive species in wetlands, and what are the consequences of removing nuisance species?
— Where are there low uplands adjacent to tidal wetlands, and what can be done to preserve these sites in anticipation of sea-level rise?
— How can old spoils be removed from wetlands that were ditched for mosquito control, and what are the impacts of spoil removal?

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Freshwater Wetlands

by Reed Beaman
A.F. Clewell, Inc.

Executive Summary

Freshwater wetlands serve a number of functions important to water quality and biological diversity in Sarasota Bay:

- balancing the regional climate and hydrology
- purifying waste
- recharging groundwater supplies
- maintaining a hydrostatic head to reduce saltwater intrusion
- fixing carbon dioxide into carbohydrates and oxygen
- storing and exporting nutrients (nitrogen, phosphorus, etc.)
- breaking down organic matter and storing it in the form of peat
- supplying the source of fresh water for brackish water ecosystems
- serving as a habitat for wildlife.

Status and trends of freshwater wetlands for the Sarasota Bay National Estuary Program have been characterized. The area of study encompasses about 147,000 acres, and includes all freshwater wetlands with a hydrological connection to Sarasota Bay.

Historically, most wetland destruction has resulted from agricultural development. That may still be true for Florida as a whole, but in the Sarasota Bay area the recent trend has been to convert agricultural lands, including former wetlands, into residential and concomitant commercial development.

The Swamp Land Act of 1850 gave Florida the right to determine disposition of all swamp and overflow land within its borders. Early developers were bound by legal stipulations to drain and make land usable as a condition of sale.

Freshwater-wetland losses have been much greater than losses of tidal wetlands. Florida has nearly 10 times more freshwater wetlands than tidal wetlands. About 11 percent of all wetlands in the lower 48 states were in Florida in the mid-1970s. A 12-percent loss of palustrine wetlands occurred in Florida from 1954-74; freshwater wetlands accounted for 74 percent of the total wetland loss in the state during this period. In the Sarasota Bay area, non-

forested freshwater wetlands declined by 1,900 acres, or 35 percent, in the period 1975-91, equivalent to a loss of 119 acres per year.

Eleven mapping units for freshwater wetlands were recognized. Six are forest-covered, four are not forested and one includes wetlands dominated by exotic species. Wetland types included bay swamp, hydric hammock, willow heads, bottomland hardwood swamp, wet flatwoods, mixed wet flatwoods and hardwood forest, marshes, wet prairies, emergent aquatic vegetation, intermittent ponds and exotic-species communities.

A total of 1,388 wetlands were mapped within the study area; forested wetlands accounted for 23.1 percent of them. Marshland alone accounted for 39.3 percent of wetlands, and wet prairie vegetation was the second-most-frequent type encountered (26.6 percent). Invasive exotic species have become dominant in 1.6 percent of wetlands.

Three sub-basin systems were recognized within the study area: Blackburn Bay, Little Sarasota Bay and Sarasota Bay. In addition, the area has a number of minor coastal drainage systems.

Blackburn Bay had a significantly better wetland condition than either Little Sarasota Bay or Sarasota Bay. It has a greater number of marshes and wet prairies than either of the other sub-basins, most remaining more or less intact, although almost all are intersected by a network of ditches.

The Little Sarasota Bay sub-basin had a higher percentage of hydric hammock than the other sub-basins. Many are fragments of extensive stands of hydric hammock undulating with mesic hammock, especially in the western half (west of Interstate 75). The eastern half of the sub-basin was not unlike the Blackburn Bay sub-basin, consisting of extensive systems of marshes and wet prairies interspersed within flatwoods.

The Sarasota Bay sub-basin has suffered the greatest amount of wetland loss. Only 194 wetland units remain; of these, 60.4 percent are forested wetlands. A 46-percent loss of mappable wetlands has occurred within this sub-basin since 1950. An extensive but somewhat fragmented system of hydric hammock and hardwood swamp still exists along part of Palma Sola Creek, most of it surrounded by agricultural development.

Condition of wetlands was defined by the type and extent of tangible impacts such as filling, dredging, dumping, presence of structures and invasion of exotic species. Overall, 285 out of 1,388 wetlands (20.5 percent) had no measured damage.

This is not to say that all these wetlands were pristine. For instance, agricultural, golf-course or stormwater runoff can have a significant impact on the health of a wetland (e.g., pesticide, nutrient and heavy-metal loading), but such impacts may not be directly visible.

Dredging and filling are the most pervasive impacts. More than three-quarters of wetlands had either been dredged or filled to some degree. Both filling and dredging are the typical means by which wetlands are lost completely. The presence of structures in a wetland (13.5 percent) generally correlated with filling activity during building or road construction. Dumping was observed in 6.3 percent of all wetlands.

Exotic species, many brought to Florida years ago as attractive ornamentals, pose a threat to the natural vegetation of wetlands. Brazilian pepper *(Schinus terebinthifolius)*, Australian pine *(Casuarina spp.)* and punk trees *(Melaleuca quinquenervia)* were the most-prevalent exotics in the study area.

Twenty-two percent of wetlands contain exotic species. Among the sub-basins, Sarasota Bay has the greatest frequency of exotic-species occurrence; Brazilian pepper was found in more than 66 percent of the wetlands in this sub-basin. Exotic species are most common in areas with a number of long-established ornamental plant nurseries or on disturbed soils, such as around active and abandoned agriculture.

Four critical headwater systems in the Bay basin are South Creek, Phillippi Creek, Whitaker Bayou/Pierce Creek and Palma Sola Creek; each still has substantial acreages of non-urbanized land. As urban development continues at a rapid rate, these areas will require intensive management. They are also the areas with greatest potential for ecological restoration.

Two strategic goals are proposed for freshwater wetlands: develop Baywide, ecosystem-specific management programs, and reverse wetland loss. Specific management options are listed under areas of preservation, restoration, development of upland buffer zones and enforcement.

Freshwater Wetlands

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Introduction

Freshwater wetlands form the inland drainage system for the Sarasota Bay water catchment. Deep, dark, forested hammocks and open, sunny, wet prairies alike function to balance the regional climate and hydrology, purify water, recharge groundwater supplies, maintain a hydrostatic head to reduce saltwater intrusion, fix carbon dioxide into carbohydrates and oxygen, store and export nutrients (nitrogen, phosphorus, etc.), break organic matter down and store it in the form of peat, supply the source of freshwater for brackish water ecosystems, and serve as ideal breeding grounds for mosquitoes, snakes and other wildlife. The water quality of Sarasota Bay is influenced by the ability of freshwater wetlands to function.

The freshwater ecosystem of Sarasota Bay nestles between two major Florida river systems, the Braden River and the Myakka River. The divide between Sarasota Bay and these two systems forms the boundary for this study. The study area encompasses about 147,000 acres.

Agriculture has been a primary component of land use in the Sarasota Bay basin since Bill Whitaker established his homestead in the 1840s-50s. Plantation owners grew sugar cane as a principal crop (Grismer 1946). Later agricultural developments included cattle ranches, citrus, sod, vegetable and flower farms and ornamental plant nurseries.

The recent trend has been to convert agricultural lands into residential and concomitant commercial development. Nagle (1984) asserts that pressure to use land for greatest economic return is what drives the urbanization process. In Florida, this is fueled by the understandable desire of pensioners and others to retire to a warm climate. While some of the qualities that encouraged Bill Whitaker to choose his bayou continue to attract people from the north, others are lost:

> "Bill Whitaker, then just 21 years old, came here in search of a 'dream spot' where he could settle down and make his home. He found exactly what he was looking for – a homesite on a bluff from which beautiful Sarasota Bay could be seen in all its splendor. Fertile land he also found, and forests filled with game and waters teeming with fish...
>
> "A short way up the bayou, on the east bank, they found a pool of fresh water, fed by crystal water pouring out of rocks in a steady stream. The ground around the spring was hard-packed. Indians undoubtedly had gotten their water here for countless years." (Grismer, 1946, p. 29)

Interlacing hammocks, flatwoods and wet prairies form a picturesque backdrop for any community. In well-considered residential estates, a measure of the natural marsh is maintained. In others, the flatwoods make fairways, hammocks make housing and wet prairies make water hazards and stormwater retention ponds. And Whitaker Bayou makes a good sewer.

The condition of Florida's remaining wetlands and the west-coastal rivers they connect to is affected by agricultural and stormwater runoff, waste effluent from septic and larger treatment systems, heavy industry and mining, and impounding of waterways for flood control (Estevez *et al.* 1991).

The geological origin of coastal freshwater wetlands is thought to be similar to that of tidal wetlands, forming when sea level rose during the last glacial period and flooded low lying coastal depressions (Mitsch and Gosselink, 1986). Coastal wetlands similar to those in the study area occur along the southern coastal Atlantic states, and along the northern coast of the Gulf of Mexico, as well as most of Florida (Hofstetter, 1983).

National, State and Local Trends

Estimates of original (pre-European settlement) wetland coverage in the contiguous continental United States range from 127 million acres suggested by Shaw and Fredine (1956) to 221 million acres by Dahl

(1990). Wetland-coverage estimates are not just dependent on scientifically determined delineation, but are colored by politics as well. The Swamp Land Act of 1850 gave the state of Florida the right to determine the disposition of all swamp and overflow land within its borders (Grismer 1946, Shaw and Fredine 1956). Large tracts of these lands were sold to speculators. In addition, Mott (1983) testified that early developers were bound by legal stipulations to drain and make land usuable as a condition of sale. About 20,325,000 acres were granted to Florida.

Grismer (1946) and Shaw and Fredine (1956) indicate that the Swamp Land Acts were abused. One form of abuse was to grab more than just wet land. Overstating the acreage of wetlands gave a state greater jurisdiction over its lands and put more money in the state coffers.

Grismer (1946) points out that land speculation in what are now Sarasota and Manatee counties began in 1881 when the state of Florida sold four million acres to Hamilton Disston under the Swamp Land Act of 1850. The percentage of this land that was wet is unknown.

In Florida, estimates of wetland coverage vary as much as the national estimates. Mott (1983) stated there were nearly 10 million acres of undisturbed wetlands in Florida in 1845. The 20,325,000-acre estimate for 1850 of Shaw and Fredine (1956) was based on land grants of the Swamp Land Act of 1850, and perhaps included some uplands.

Estevez (loc. cit.) calculated the rates of national and state Sarasota Bay tidal wetland losses over various time periods. Freshwater wetland losses have been much greater than for tidal wetlands. Hefner (1986) reported that Florida has nearly 10 times more freshwater wetlands than tidal wetlands. Frazer *et al.* (1983) found that 11 percent of all wetlands in the lower 48 were in Florida in the mid-1970s. Between 1954 and 1974 Florida had a 12-percent loss of palustrine wetlands; Hefner (1986) stated that this represented more than one million acres of palustrine wetlands destroyed, and it accounted for 74 percent of the total wetland loss in the state during this period.

One cause of wetland loss is artificial. Technical ability to determine wetland acreage was greatly refined with the advent of aerial photography. Early wetland acreage values are probably overstated. What was called swamp 100 years ago would now be mapped as a mosaic of wetlands and uplands. This is not to say that wetland loss has not occurred. Wetland loss is real.

Study Objectives

This project was designed to characterize freshwater wetlands of the Sarasota Bay drainage basin for the National Estuary Program. It was carried out in association with a study on tidal wetlands (Estevez, loc. cit.). The following objectives were designed to help meet NEP goals:

1. Describing current (1990-91) and historic freshwater distribution and abundance within the NEP study area.
2. Characterizing freshwater-wetland condition and the natural and human impacts that affect wetland condition.
3. Incorporating freshwater-wetland distribution, abundance and condition data into a geographical information system.
4. Recommending wetland-management options for the Framework for Action and Comprehensive Conservation and Management Plan.

Relationship to NEP Goals

Characterization of freshwater-wetland resources has import to four Sarasota Bay Program goals:

- Restoring and sustaining fish and other living resources.
- Improving water transparency to the maximum allowable by Gulf and local weather conditions.
- Reducing the quantity and improving the quality of stormwater runoff to Sarasota Bay.
- Establishing an integrated management system for the Bay.

The characterization of freshwater wetlands and their condition is reported with these goals in mind. General and specific means for achieving these goals are suggested.

Methods

Individual freshwater-wetland units were identified using 1991 land-use quadrangle sheets produced by Geonex Martel, Inc. for the Southwest Florida Water Management District (wetlands down to 0.5 acres were mapped), other existing wetland mapping projects (Soil Conservation Service, Sarasota County Planning Dept.) and field observations. Each wetland polygon within the study area was given an identification number.

Wetland units were visited and characterized in the field and/or photographed from the air using light aircraft at low altitudes. Each wetland was classified using a modified FLUCCS (Florida Land Use, Cover and Forms Classification System) designation (see Florida Dept. of Transportation 1985).

Vegetation Classification and Mapping Units

Eleven mapping units for freshwater wetlands were recognized. Six are forest-covered, four are not and one includes wetlands dominated by exotic species (not part of FLUCCS). Wetlands were classified in the field based on overall species composition. Sometimes fairly broad FLUCCS categories occur as a single specific type in the Sarasota Bay Basin. These specifics are discussed under the mapping unit descriptions below:

611 – **Bay swamp.** Bay swamp often occurs at the headwaters of a riverine system. It occupies the base of seepy slopes, where the soil is constantly saturated. A thick layer of peat may build up over sandy soils. The canopy is dominated by *Magnolia virginiana* (sweet bay), *Persea palustris* (swamp bay), *Gordonia lasianthus* (loblolly bay). Other overstory species, such as *Acer rubrum* (red maple) and *Pinus elliotii* (slash pine), appear in lesser numbers. The understory of this forest type consists of *Myrica cerifera* (wax myrtle), *Lyonia lucida* (fetterbush), *Ilex cassine* (dahoon holly) and a number of ferns. Ferns found frequently in bay swamps include *Osmunda cinnamomea* (cinnamon fern), *O. regalis* (royal fern) and *Blechnum serrulatum.* Bay swamps were the least-encountered forested ecotype in the study area.

615 – **Hydric hammock.** Hydric hammock is the midslope component of the forested wetland continuum. This ecotonal vegetation type often grades into mesic hammock on the upland side and other wetland types including hardwood swamps and bay swamps in wetter sloughs and seepages. Vince *et al.* (1989) note that some hammocks occur on poorly drained soils or on soils with high water tables with occasional flooding, and are frequently protected from fire by nearby bodies of water. Two dominant species, *Quercus laurifolia* (laurel oak) and *Sabal palmetto* (sabal palm), along with lesser numbers of *Liquidambar styraciflua* (sweetgum), Quercus nigra (water oak), *Magnolia grandiflora* (southern magnolia) and *Carya glabra* (pignut hickory), comprise the overstory of hydric hammocks in the Bay area.

Hydric hammock is often difficult to recognize as a mapping unit, especially when its distribution is patchy and associated with slightly undulating land, where hydric hammock mixes with mesic hammock, flatwoods and swamp. Hydric hammock is defined not as much by the vegetation that occurs within as by what does not. In surrounding mesic hammocks, both Quer*cus laurifolia* and *Sabal palmetto* are still there, but occurence of *Quercus virginiana* (live oak) along with *Serenoa repens* (saw palmetto) marks the area as mesic. Much of what is mapped in this project as mixed wet flatwoods and hardwood forest (630) contains patches of hydric hammock less than half an acre in size.

616 – **Willow head.** *Salix caroliniana* (Carolina willow) is frequently the first woody colonizer of disturbed wetlands. It is often seen along the edge of forested wetlands in disturbed, open, sunny situations. A willow head, however, is not just an ecotonal ecotype on the forest fringe. This type is often chronologically transitional. Willows have light feathery fruits that disperse in the wind. The trees grow fast once germinated, but in time, slower-growing overstory trees shade the willows out.

617 – **Bottomland hardwood swamp.** This is among the wettest of the forested ecotypes found in the Sarasota Bay drainage system. A diverse assemblage of wetland tree species often occurs in this mapping unit. This type was often encountered in the study area in early stages of regeneration, usually on abandoned agricultural land. *Acer rubrum, Fraxinus caroliniana* (pop ash), *Nyssa biflora* (swamp black gum) and *Quercus nigra* (water oak) are common constituents of the bottomland hardwood forest in the Bay basin.

620 – **Wet flatwoods.** This is among the least encountered of the wetland ecotypes, but was probably much more common before drainage ditches were put in place. Wet flatwoods forest is often mixed with hydric hammock. In situations where intermixing resulted in small patches and intergradations, the polygon was placed in the following category.

630 – **Mixed wet flatwoods and hardwood forest.** As the name implies, this mapping unit was used when a matrix of hydric hammock and wet flatwoods occurred in areas too small to be mapped.

641 – **Marshes.** Freshwater marshes and wet prairies were the most common ecotype encountered in this study. Marshes are submerged part or all of the year. Vegetation in a marsh is nearly always herbaceous. Commonly encountered plants include *Pontederia cordata* (pickerelweed), *Typha* spp. (cattails), *Panicum hemitomum* (maidencane), *Juncus effusus* (needlerush) and *Spartina bakeri* (cordgrass). Marshes occurring within the study area are frequently small (less than one acre) and circular in shape.

Whether a wetland unit was mapped as a marsh or in one of the two following categories depended in part on specific hydrological conditions at the time of the aerial photography and/or site visit.

643 – **Wet prairies and upper marsh transitions.** A wet prairie or upper marsh transition zone was frequently encountered and mapped surrounding a marsh. In cases like these, this ecotype is actually forming an ecotone between the marsh and surrounding uplands. Other times wet prairies can form extensive systems, as along the channel that makes up South Creek. Sometimes water moves slowly and intermittently through areas mapped as wet prairies and marshes (641 and 643). These are sometimes called sloughs (Clewell, 1991); the Everglades is one such "slough." Part of the South Creek draingage is of slough origin, but has been modified by ditching.

644 – **Emergent aquatic vegetation.** This category includes both floating aquatic vegetation and rooted aquatic vegetation. Usually, these are shallow ponds with varying combinations of *Lemnaceae* (duckweed), *Pontederia cordata* (pickerelweed), *Nymphaea* (water lily), *Nuphar* (spatterdock) and *Eichornia* (water hyacinth).

657 – **Intermittent ponds.** These ponds are usually found within pasture or other agricultural lands. As the name suggests, they are submerged only part of the time. These are most likely former marshes or wet prairies.

699 – **Exotic-species wetland community.** Presence of exotic species was recorded as a wetland impact. Exotic species are also capable of forming ecological communities. Woody exotics can alone or in concert form a closed canopy. These are *Schinus terebinthifolius* (Brazilian pepper), *Casuarina equisetifolia, C. cunninghamiana,* and *C. glauca* (Australian pines) and *Melaleuca quinquenervia* (punk tree or cajeput). To the extent that one or more of these can dominate a landscape, we added the exotic-species community to the FLUCCS mapping units for this study.

Often, what is absent is as significant as what is present. Sarasota Bay is part of a gap in the distribution of *Taxodium* (bald and pond cypress) in Florida. Although very common throughout most of Florida, cypress was not encountered in any of the natural wetlands in the study area, nor is it a part of the Myakka River ecosystem south of the State Park. There is a general paucity of vascular plant diversity there as well (Milligan 1990).

Wetland Condition

A scoring system was developed for quantifying wetland condition relating to human impact and other environmental stresses. Condition of wetlands was calculated by summing up the effects of filling, dredging (including ditching), presence of structures, garbage dumping and invasive exotic-plant species such as Brazilian pepper, Australian pine and punk trees. Each impact was scored as a percentage of a wetland unit that it affected, and all were given equal weight. Scores were normalized on a scale of 0 to 100, with a score of 100 representing no visible impacts.

Final wetland maps of the study area were produced as described by Estevez (loc. cit.). Historic data from the 1970s National Wetland Inventory were provided by the National Oceanic and Atmospheric Administration, for the Sarasota Bay NEP study area. Similar data from a 1980s LANDSAT survey were provided by the Florida Game and Fresh Water Fish Commission.

Results

Wetland Trends

The first National Wetland Inventory as queried by the National Oceanic and Atmospheric Administration showed that the Sarasota Bay Program study area had 8,400 acres of freshwater wetlands in 1975. It was determined that 3,000 acres were forested and 5,400 acres were not. The LANDSAT data provided by the Florida Game and Fresh Water Fish Commission suggest that there were 3,500 acres of non-forested wetlands in 1987. These figures indicate a loss of 1,900 acres of non-forested freshwater wetlands, or 35 percent, over 12 years. This is equivalent to a loss of 158 acres per year from 1975 to 1987.

Based on results of this Sarasota Bay Program characterization, in 1991 there were 7,040 acres of freshwater wetlands. This estimate, which includes both forested and non-forested wetlands, is 1,360 acres less than the 1975 estimate. In other words, there has been a 16-percent loss of all freshwater wetland acreage since 1975. This is equivalent to a loss of 85 acres per year.

In 1991, there were 3,564 acres of non-forested wetlands within the study area. This is a 64-acre increase from the 1987 data. It is doubtful that non-forested wetland acreage actually increased during the period 1987-91. This increase is more likely an artifact of different remote sensing techniques. The 1987 data are based on raster images from LANDSAT. The 1975 and 1991 figures are based on photo-interpretation of aerial photos, and are thus more comparable. The

LANDSAT data presented here reflect the difficulty of comparing data from differing sources, rather than a meaningful sense of wetland trends.

Wetland Characterization

Distribution of ecotypes for the entire study area by number of wetland units is illustrated in *Figure 1.* A summary with FLUCCS codes and percent frequency of occurrence is shown in *Table 1.* Marshland alone accounted for 39.3 percent of wetland units, and wet prairie vegetation was the second-most-frequent type (26.6 percent) encountered. Forested wetlands all together accounted for only 23.1 percent. Invasive exotic species have become dominant in 1.6 percent of wetland units.

Three sub-basin systems were recognized within the study area – Blackburn Bay, Little Sarasota Bay and Sarasota Bay. There are also a number of minor coastal drainage systems. In terms of the way the overall study area was divided, a sub-basin may be made up of one or more creek systems.

Blackburn Bay

Forested wetlands account for only 7.6 percent of wetland units within the Blackburn Bay system. Before 19th-century settlement, this system was probably dominated by flatwoods and wet flatwoods interspersed with about the same number of marshes and wet prairies as there are today. Most of the flatwoods are now converted to agriculture, pasture or residential development. A small number of large ranches, some selling parcels off for residential and commercial developments, sod farms and a state park are the current components of this sub-basin. A very extensive channel (and ditching) system connects almost all the 587 wetlands in this sub-basin with South Creek and then Blackburn Bay. It is bordered by, but not connected to, Cowpen Slough along most of its eastern edge. This sub-basin has a greater number of marshes and wet praries than either of the other sub-basins. Most of these unforested wetlands remain more or less intact, although almost all are intersected by a network of ditches.

Little Sarasota Bay

The Little Sarasota Bay sub-basin includes North Creek, Catfish Creek, Matheny Creek and Phillippi Creek systems. This is the largest of the sub-basins, and Phillippi Creek is the largest creek system basin-wide. Currently, 25 percent of the 597 wetland units in this sub-basin are forested. Many of these are fragments of extensive stands of hydric hammock undulating with mesic hammock, especially in the western half (west of Interstate 75). The eastern half of the sub-basin was not unlike the Blackburn Bay sub-basin, consisting of extensive systems of marshes and wet prairies interspersed within flatwoods.

Sarasota Bay

Sarasota Bay sub-basin is comprised of five creek systems: Hudson Bayou, Whitaker Bayou, Bowlees Creek, Cedar Hammock and Palma Sola Creek. The drainage for Palma Sola Bay is also lumped into this sub-basin. This sub-basin has suffered the greatest amount of wetland loss: only 194 wetland units remain. Of these, 60.4 percent are forested wetlands. Since 1950, a 46-percent loss of mappable wetlands has occurred within this sub-basin; comparative figures for the other sub-basins are not presently available. Residential development has claimed much of the land in this sub-basin. An extensive but somewhat fragmented system of hydric hammock and hardwood swamp still exists along part of Palma Sola Creek, most of it surrounded by agricultural development. In fact, the agricultural developments surrounding Palma Sola Bay and around Oneco are about the only extensive agriculture lands left in the study area; the urbanization of the Sarasota Bay Basin is almost complete. The Tallevast area within this sub-basin is also less developed, or more accurately, it has become partially abandoned agricultural

Distribution of freshwater wetland ecotypes in Sarasota Bay drainage basin

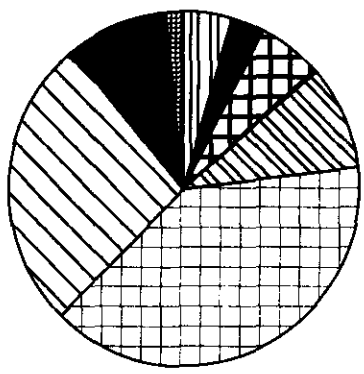

Figure 1.

Plant community	Percent occurrence	FLUCCS code
Exotic community	1.6	699
Intermittent pond	0.1	657
Emergent aquatic	9.4	644
Wet prairie	26.6	643
Marsh	39.3	641
Hardwood/conifer mix	9.3	630
Wet flatwoods	0.3	620
Hardwood swamp	5.8	617
Willow head	3.2	616
Hydric hammock	4.3	615
Bay swamp	0.2	611

Plant community, FLUCCS codes, and frequency of occurrence in Sarasota bay drainage basin

Table 1.

development. The Pierce Creek system, just outside the study area but formerly part of the headwaters of Whitaker Bayou, is now mostly abandoned agriculture, tending toward industrial development. In the other two sub-basins, agricultural remnants also exist around Fruitville, Bee Ridge and in the headwaters of South Creek.

The coastal drainage systems extend the entire north-south length of the Bay. Only 10 freshwater wetland units were recorded from the coastal drainage systems. These are small, usually isolated fragments of various wetland types.

Wetland Condition

Structural condition of individual wetlands was evaluated overall, for specific impacts and for combinations of impacts. The difference between Blackburn Bay and Sarasota Bay sub-basins is marginally significant on the basis of mean overall condition score. Scores are presented in *Figure 2.* These figures do not include completely destroyed wetlands.

Overall, 285 out of 1,388 wetlands have a condition score of 100, i.e., no impact. Distribution of condition scores is graphed in *Figure 3.* Letter grades were equated with the wetland-condition scores for simplicity in representing scores on a map. The scores, ranging from 74 to 100, were divided in a linear manner into five equal grades. A grade of A meant that a wetland has been affected by only one or two impacts, and only to a limited extent. Anything less than an A indicated that either several types of impact affected a wetland or the extent of one or more impacts was profound. Wetlands with scores of C, D or E would have limited functional value.

The same data are represented in *Figure 4,* but a breakdown by sub-basin gives a visual perspective of the overall number and condition of wetlands in each sub-basin. Blackburn Bay and Little Sarasota Bay sub-basins have about the same number of wetlands, but those in Blackburn Bay are in slightly better condition. Both the lower number and relatively poorer condition of wetlands in the Sarasota Bay sub-basin are apparent.

Basin-wide, 20.5 percent of wetlands had no measured damage. This is not to say that all these wetlands were pristine. For instance, agricultural, golf-course or stormwater runoff can have a significant impact on the health of a wetland, but such impacts may not be directly visible. Changes in hydrology, in either direction, affect wetlands, but not in a way quantifiable within the parameters of this study. Hydrological changes are both a significant and common impact on wetlands. Extensive urbanization has made this an issue of greater importance.

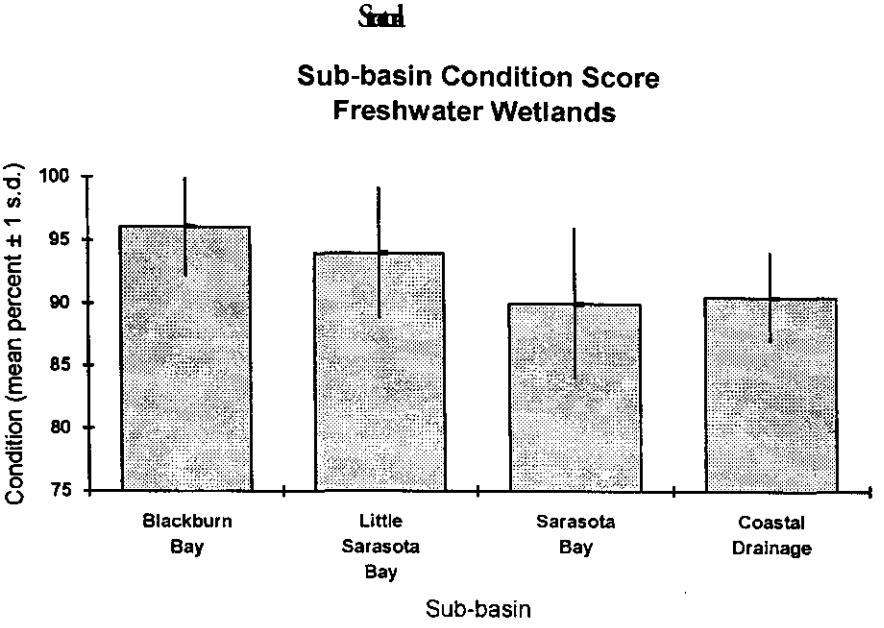

Figure 2.

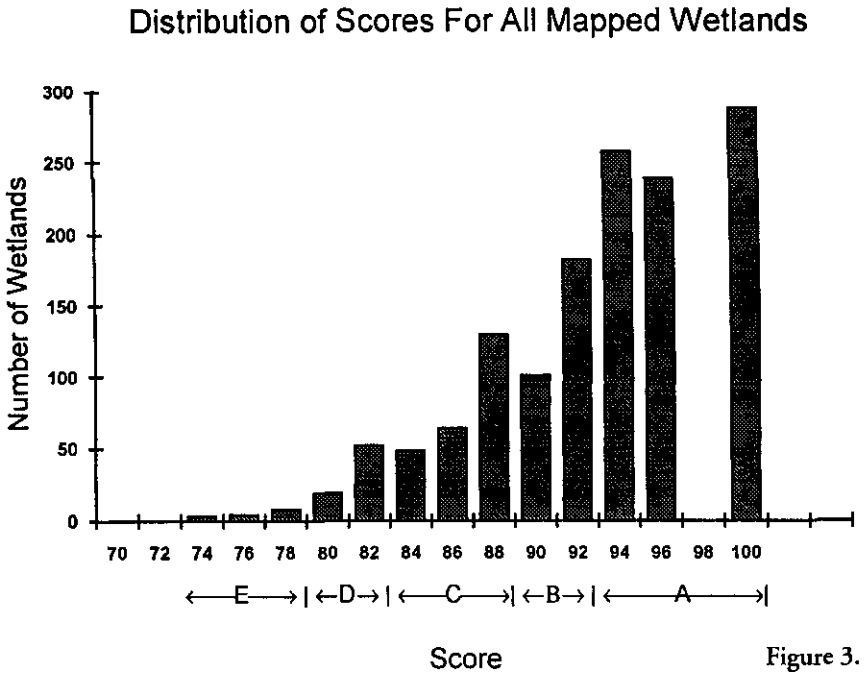

Figure 3.

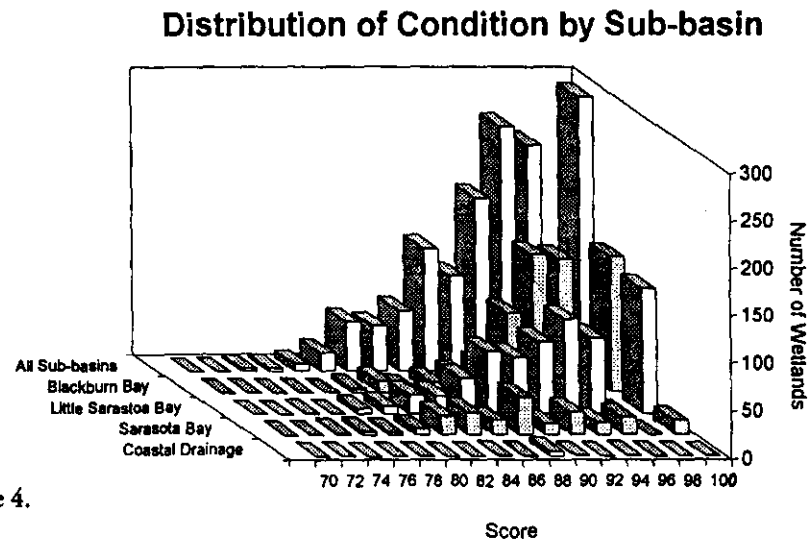

Figure 4.

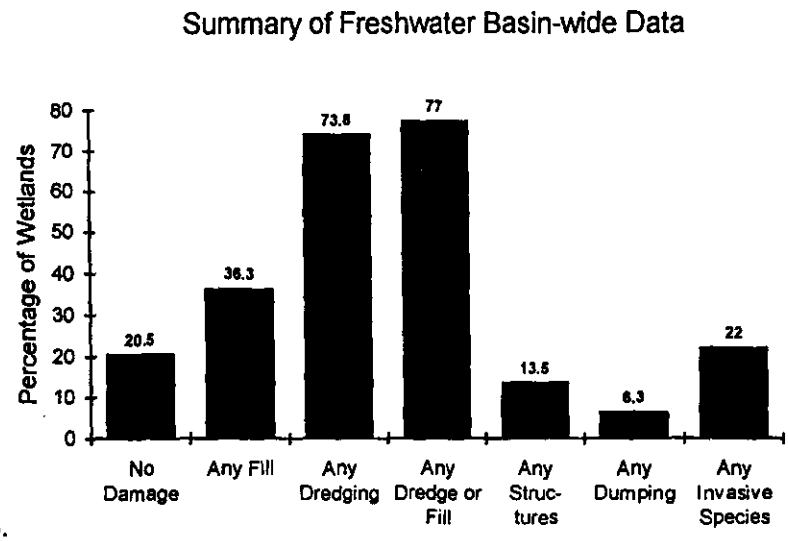

Figure 5.

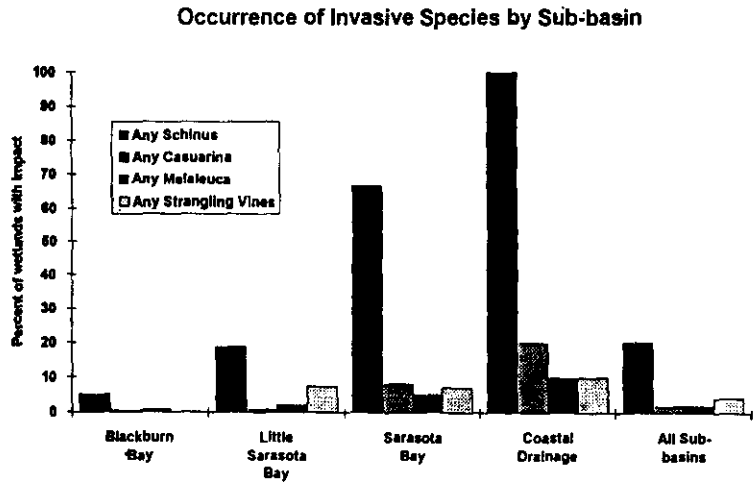

Figure 6.

Impacts

The occurence of observed impacts on wetlands is illustrated in *Figure 5*. Dredging and filling are the most pervasive of the impacts; more than 75 percent of wetlands had either been dredged or filled to some degree. Both filling and dredging are the typical means by which wetlands are lost completely. Wetlands can be filled to build on or dredged out, converting them to open water or stormwater retention ponds. "Lost wetlands" are not included in this graphical representation, nor are they ever to be restored or enhanced. The 73.8-percent value for dredging includes the construction of drainage ditches, a ubiquitous practice within the region for more than 100 years.

The presence of structures in a wetland (13.5 percent) generally correlated with filling activity during building or road construction. Mitigation for a small number of these intrusions was sometimes, but not usually, apparent.

Dumping was observed in 6.3 percent of all wetlands. Garbage can be fairly easily removed from wetlands, if not toxic. It is generally brought in by truck by people who do not wish to pay the tipping fee at the local dump. Dumping of organic lawn trash was not included.

Exotic-Plant Invasion

Exotic species, many brought into Florida as attractive ornamentals many decades ago, pose a threat to the natural vegetation of wetlands. Transportation of these exotics away from their native habitats isolates them from their natural enemies. The balance is tipped, and the exotic species are able to outcompete populations of native plants that must contend with naturally evolved control mechanisms. It is only then that introduced ornamentals become pests.

Exotic species can spread rapidly and aggressively; coastal areas tend to be most affected, but inland problems occcur as well. Twenty-two percent of wetlands have exotic species present. *Figure 6* shows the proportion of wetlands invaded by exotic species by sub-basin and pest type.

Among the sub-basins, Sarasota Bay has the greatest frequency of exotic species occurrence. Brazilian pepper was found in more than 66 percent of the wetlands in this sub-basin. Brazilian pepper and Australian pine are the most prevalent exotics throughout the study area. Exotic species are most common in areas such as Oneco that have a number of long-established ornamental plant nurseries, or on disturbed soils, such as around active and abandoned agriculture. In these places exotic species often become dominant features of the vegetation.

Discussion

A basin can be organized into two functional zones, a headwater and a channelway (Sullivan 1986). Different kinds and numbers of wetlands occur in headwaters vs. those found in channel ways. It is in the headwater sections of the sub-basins that buffering for flood events can occur. This is fortunate, since it is in the headwaters of the Sarasota Bay basin that wetland terrain remains. Most of the marshes and wet prairies are in the headwaters. The channelways of the sub-basins are already made urban, but a substantial area of the basin's headwaters remains as agriculture or ranches. Although both ranching and agricultural practices continue, they are vestigial.

In the period 1975-91, 16 percent of freshwater wetlands were lost, a smaller loss than for tidal wetlands within Sarasota Bay.

The Henderson Wetlands Protection Act has presumably worked to protect wetlands in a structural sense since the mid-1980s. As powerful as the Henderson Act is, it was not designed to protect all the functions of freshwater wetlands. As this study progressed, it was possible to observe construction of various urban and sub-urban developments. The wetlands themselves were generally spared encroachment; wetland buffer areas were not. Without wetland buffers, wetland function suffers. Runoff from lawns, golf courses and parking lots goes directly into wetlands. The wetland becomes analogous to a dirty, stopped-up drain.

It is the goal of the National Estuary Program not just to halt the loss of habitat, but to reverse the process and restore living resources of estuary systems. Proper function of freshwater wetlands is essential to maintaining the quality of the estuary. While it is unlikely that urban lands will be returned to nature any time soon, many functions of remaining wetlands can be restored or rehabilitated simply by restoring the original hydrology.

Wetland draining began with early land speculators in the 1880s. This indeed opened up a lot of land for development. But wetland draining does not necessarily take away the depression in which the wetland grew. It does change the hydrology.

Hydrological restoration would achieve several benefits. It would increase the hydrostatic head above the groundwater, thereby reducing saltwater intrusion, a potential peril along Florida coasts. Buffering capacity of wetlands and surrounding uplands to ameliorate flood waters would be increased. Dechannelizing major ditches would increase distance and area over which flood waters would flow so sediment and nutrient loading into the Bay would be decreased.

Four critical headwater systems in the Bay basin include South Creek, Phillippi Creek, Whitaker Bayou/Pierce Creek and Palma Sola Creek. Each still has substantial acreages of non-urbanized land. As urban development continues at a rapid rate, these areas will require intensive management. They are also the areas with greatest potential for ecological restoration. Many abandoned agricultural fields within these systems already have regenerating stands of swamp forest, but little species diversity.

Management Options

Strategic goals for freshwater wetlands are similar but not identical to those for tidal wetlands.

Strategic Goals

I. Develop Baywide or ecosystem-specific management programs.

II. Reverse wetland and wetland buffer-zone decline by one percent of total losses per year.

The wording in both goals recognizes the need to protect not just wetlands, but the whole watershed. Management of uplands that surround wetlands is critical to basic wetland function.

Tactical Options

1. Preserve existing wetlands

A. Acquire additional wetlands and buffer areas as public lands

B. Offer incentives for private maintainence of wetlands and buffer zones

2. Identify wetland violations

A. Develop image database linked to GIS system to highlight areas and specific wetlands showing evidence of dredge and fill violations

B. Compile a database on development projects in violation of state and local permitting

C. Prohibit the conversion of wetland into mere stormwater retention ponds

D. Limit dumping

3. Manage agricultural lands with upland buffers around wetlands

A. Discourage use of wetlands for grazing

B. Encourage using buffers between crops and wetlands

C. Offer incentives to abandon agricultural lands near wetlands

4. Restore and enhance hydrological conditions

A. Develop non-structural flood-prevention systems

B. Enhance surface-sheet flow on public and private lands

5. Restore, create and enhance wetlands

A. Develop public mitigation parks and encourage mitigation for urban wetlands in these parks

B. Offer incentives for restoration on private lands and for mitigation banking

C. Remove exotic species; concentrate on old nursery sites and their nearby wetlands

D. Encourage creation of wetland as opposed to stormwater retention

E. Encourge minimal slopes for wetland creation and stormwater retention projects.

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Sea-Level Rise

Implications of a Sea-level Rise on the Sarasota Bay Region

by Peter Clark
Tampa Bay Regional Planning Council

Executive Summary

During the last ice age (18,000 years ago) temperatures averaged five degrees C. colder than today, and sea level was 100 meters lower (Donn, Farrand and Ewing, 1962; in Titus, 1987). The Florida Gulf coast was located 130-160 km west of what is now the mouth of Tampa Bay (Fletcher, 1991), and the climate in Florida at the time was described as similar to the present climate in North Carolina (Fletcher, 1991).

Changes in sea level are caused by changes in climate, and therefore temperature. The changes that occurred during the last ice age were predominantly so slow that plant and animal life were able to adapt to changes in sea level. However, atmospheric loading of greenhouse gases is expected to increase global temperatures and accelerate rising sea levels to rates greater than those in normal climatic cycles.

The greenhouse effect is created by gases in the atmosphere that absorb heat (infrared radiation). Maintenance of global temperatures is achieved through a balance of sunlight that is received by the earth, reflected from the earth and absorbed by gases within the atmosphere (*Figure 1*). Gases in the atmosphere that absorb infrared radiation, thereby effectively preventing its escape to space, are termed "greenhouse gasses." The climate of the planet may be changing because of the increase of carbon dioxide, methane, nitrous oxide, chlorofluorocarbons and other greenhouse gases. These gases are produced primarily by the burning of fossil fuels and deforestation (*Figure 2*).

Carbon dioxide (CO_2), considered the most significant greenhouse gas, accounts for about half the documented warming and projected future warming. Atmospheric levels of carbon dioxide remained relatively constant for a long period of time before the industrial age; then, beginning about 1850, concentrations of carbon dioxide started to rise, primarily attributed to the burning of coal, oil and natural gas.

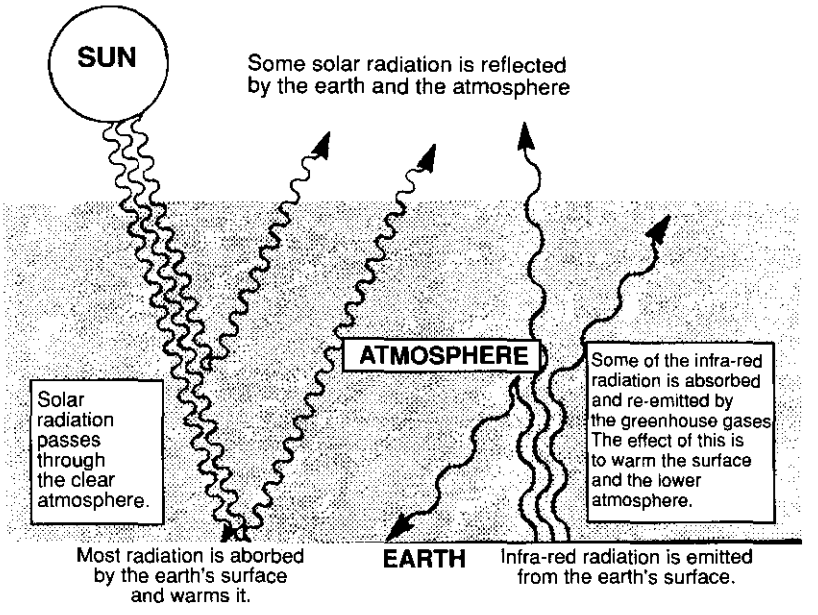

Figure 1. A simplified illustration of the greenhouse effect (IPCC, 1990).

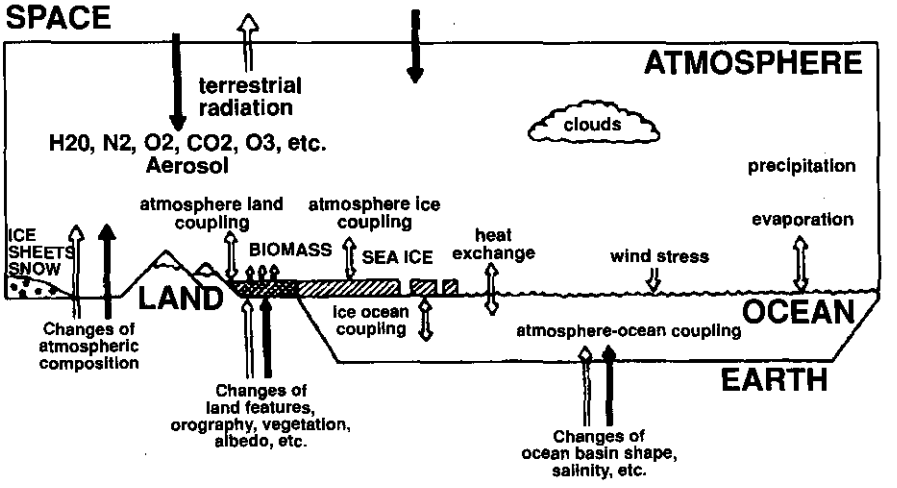

Figure 2. Illustration of climate components and interactions (Houghton, 1984, in IPCC, 1990).

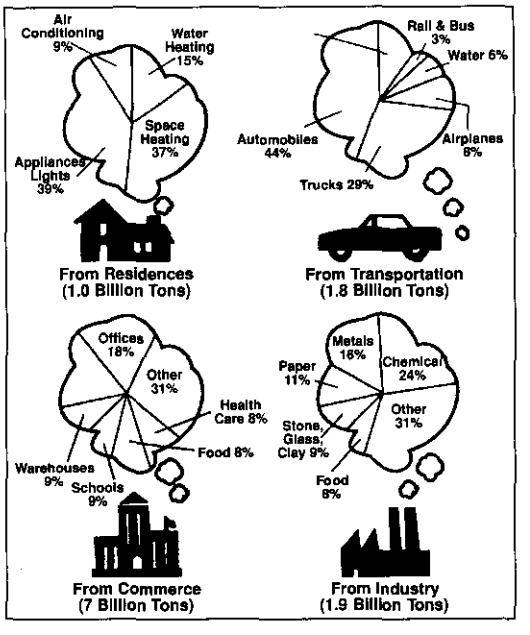

Figure 3. Annual CO_2 emissions in the United States (NAS, 1990).

Today the burning of fossil fuels releases about 16 million tons of CO_2 per day into the environment (Natural Resources Defense Council, 1989). The annual emissions and sources are depicted for the United States in *Figure 3*. Additionally, the conversion of carbon from the clearing and burning of forests adds 2.7-8.2 million tons of carbon per day (NRDC, 1989).

In addition to carbon dioxide, about 20 other greenhouse gases can moderate global temperatures. Methane is produced by bacterial decomposition in flooded fields, waterlogged soils, rice paddies, digestive tracts of animals (cattle, sheep and termites) and landfills. Other sources include release from coal seams, forest clearing and burning, venting from oil production and leakage from natural-gas pipelines. The increased use of nitrogen fertilizers to improve agricultural production is believed to cause increases in nitrous oxide, another greenhouse gas.

Chlorofluorocarbons (CFCs) are produced primarily through industrial activities (e.g., superconductor manufacturing and de-greasing solvents). CFCs are used as the working fluid in refrigerators and air conditioners, employed in the fabrication of insulation and styrofoam and released from aerosol cans. CFCs contribute substantially to global warming, since they can remain in the atmosphere for 100 years before breaking down (NRDC, 1991). Additionally, CFCs are known to destroy the protective stratospheric ozone layer, increasing our vulnerability to ultraviolet radiation.

A comprehensive consolidation of historical global-temperature records was accomplished by Jones and Wigley (1990), who systematically corrected data from land-based and marine observations to eliminate potential sources of bias (instrumentation, methodology, urban heat islands). The authors reported "conclusively that the world's climate, although highly variable over periods of decades or less, has become generally warmer during the past century. The rising temperature trend was briefly interrupted by a cooling spell from about 1940-70, but since then it has returned to an upward slope and shows no signs of abating" (*Figure 4*). Of further note, the years 1987 and 1988 were the two warmest years on record.

If emissions of CO_2 and other greenhouse gases continue unabated, the earth will warm five to 10 times faster than during the retreat of the last ice age, resulting in an average global temperature increase of one degree C. by the year 2025 and three degrees C. before the end of the next century (IPCC, 1990). Global sea level is expected to ascend due to thermal expansion and the thawing of ice sheets and glaciers.

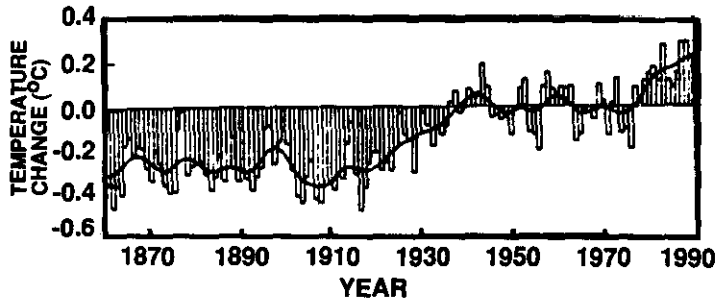

Figure 4.
Global mean temperatures, 1861-1989, relative the average for 1951-80 (Jones and Wigley, 1990).

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Implications of a Sea-Level Rise on the Sarasota Bay Region

Observations in Sarasota Bay

To calculate a potential sea-level rise in Sarasota Bay, Mote Marine Laboratory conducted a review of very recent literature on sea-level projection, and the most authoritative projection was selected. Then the projection was adapted for Sarasota Bay. This step involved the transfer of necessary data from nearby comparable sites for which the data are available. Next, tidal variation was added to the level stand projection and conditions in 2020 and 2065 were interpolated from conditions calculated for the year 2115. Finally, level stands were registered to an accepted vertical scale for mapping purposes. The SLR Technical Assessment contains a more detailed description of the projection calculations and methods. All tide levels were normalized to National Geodetic Vertical Datum (NGVD).

In the Sarasota Bay area the oldest water-level-gauging station is located in St. Petersburg. The tidal station is maintained by the National Oceanic and Atmospheric Administration (NOAA), National Ocean Service Sea and Lake Levels Branch, and has been in place since 1947 (U.S. Dept. of Commerce, 1988). The measurements are reported from a tide gauge that continuously measures sea-level heights relative to the land adjacent to the station location (U.S. Dept. of Commerce, 1988). Analysis of yearly averages is depicted in *Figure 8*. Ten-year averages are illustrated in *Table 1*.

In Sarasota Bay, the calculated position of mean higher high water (MHHW: mean of higher tidal events) in 2115 may reach 64 cm (2.1 ft) above present MHHW. By linear interpolation, mean higher high water in 2020 and 2065 may be 14.7 cm (0.5 ft) and 37.8 cm (1.2 ft) above present MHHW, respectively. These tide-level projections were overlaid on topographic contours for Sarasota Bay as quantified by the Southwest Florida Water Management District. The MHHW line for the years 1992, 2065 and 2115 is depicted on *Figures 5, 6* and *7* as generated by the Council's ARC/INFO geographical information system (GIS). The shoreline features are duplicated from United States Geological Survey quadrangles and are based on mean high water (1.5 feet above NGVD for Sarasota Bay). The tabulations of area covered by the MHHW line for each representative year are identified on *Table 2*.

Table 1.

Ten-year average water levels at St. Petersburg, FL. No. station, No. 8726520 (USDOC, 1988).	
Time Period	Average water level
1950-1959	4.25 feet
1960-1969	4.30 feet
1970-1979	4.41 feet
1980-1989	4.52 feet

Table 2.

New area covered by the MHHW line in 2065 and 2115	
MHHW in 2065 (1.3 feet to 3.0 feet NGVD)	6,180 acreas
MHHW in 2115 (1.3 feet to 4.2 feet NGVD)	6,810 acreas

Peter A. Clark

Mr. Clark is the principal environmental planner at the Tampa Bay Regional Planning Council, where his responsibilities include coordination of environmental research efforts, review of developments in the four-county region and directing the Council's Agency on Bay Management. Mr. Clark is actively involved with numerous public outreach activities to restore estuarine habitats and raise awareness and interest in protecting Tampa Bay. He has played a significant role in the designation of Tampa Bay into the National Estuary Program, installation of the Physical Oceanographic Real-time System (Tampa PORTS) in the bay and establishment of Florida's Surface Water Improvement and Management Program. Mr. Clark has worked for the Council for eight years.

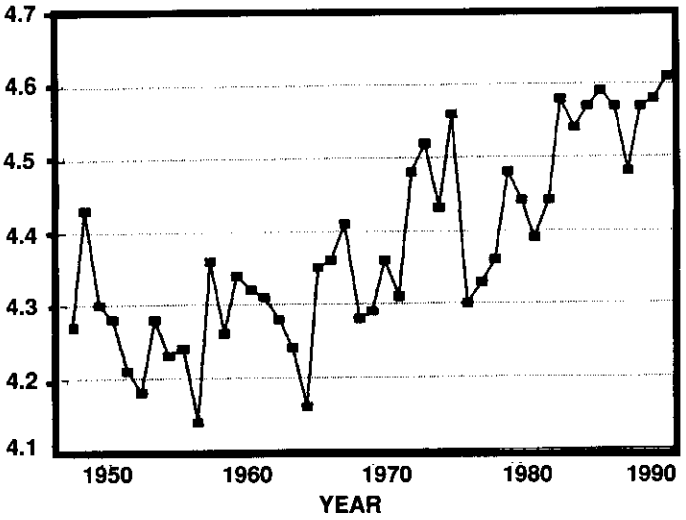


Figure 8. Yearly average water levels at St. Petersburg, FL (USDOE, 1988).

Figure 5.

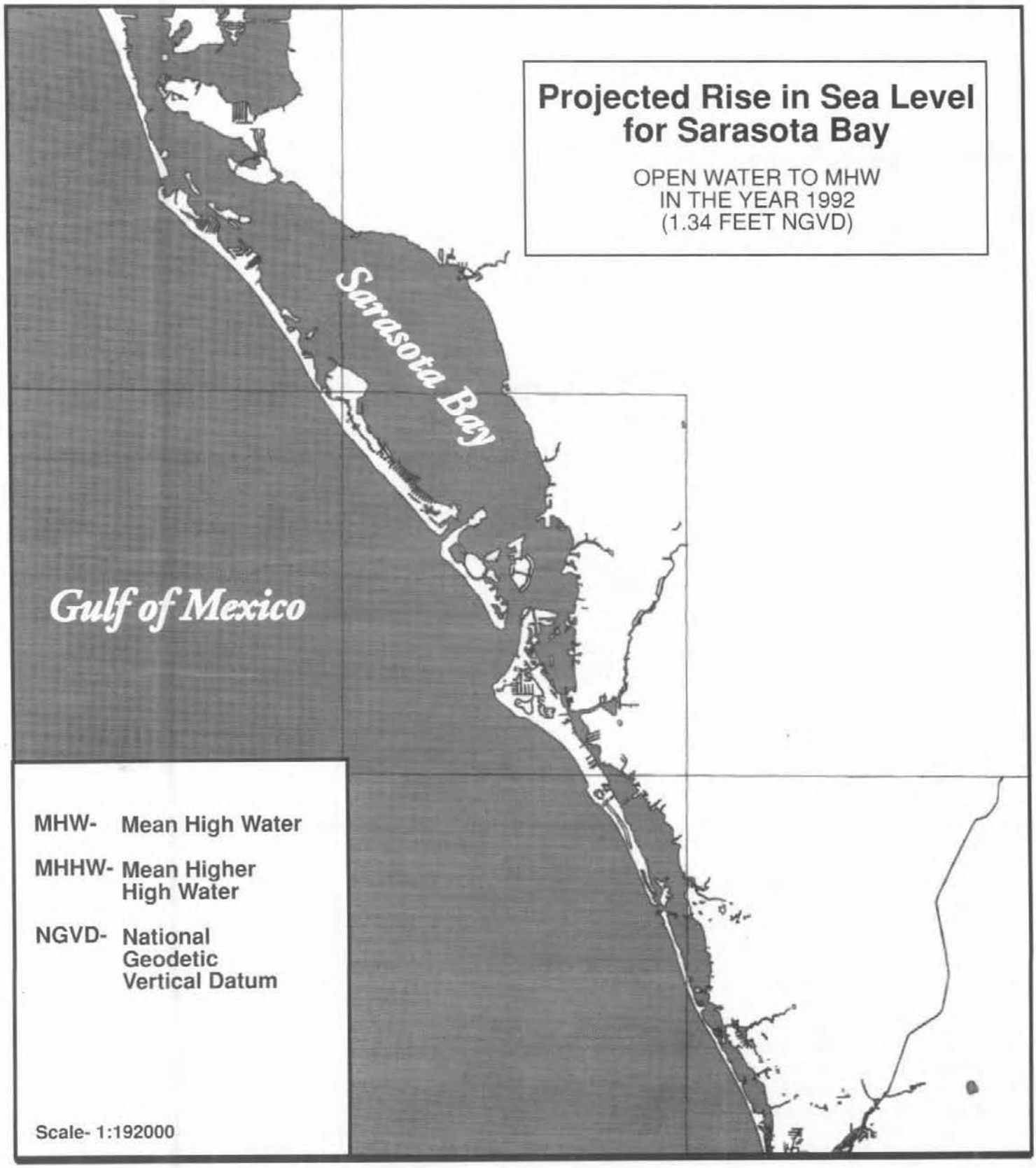

Projected Rise in Sea Level for Sarasota Bay
OPEN WATER TO MHW
IN THE YEAR 1992
(1.34 FEET NGVD)
Sarasota Bay
Gulf of Mexico
MHW- Mean High Water
MHHW- Mean Higher High Water
NGVD- National Geodetic Vertical Datum
Scale- 1:192000

Figure 6.


Projected Rise in Sea Level for Sarasota Bay
OPEN WATER TO MHHW
IN THE YEAR 2065
(2.85 FEET NGVD)
Sarasota Bay
Gulf of Mexico
MHW- Mean High Water
MHHW- Mean Higher High Water
NGVD- National Geodetic Vertical Datum
Island and peninsula features contain areas of higher elevation that would not become inundated as illustrated.
Scale- 1:192000

Figure 7.


Projected Rise in Sea Level for Sarasota Bay
OPEN WATER TO MHHW
IN THE YEAR 2115
(3.73 FEET NGVD)
Sarasota Bay
Gulf of Mexico
MHW- Mean High Water
MHHW- Mean Higher High Water
NGVD- National Geodetic Vertical Datum
Island and peninsula features contain areas of higher elevation that would not become inundated as illustrated.
Scale- 1:192000

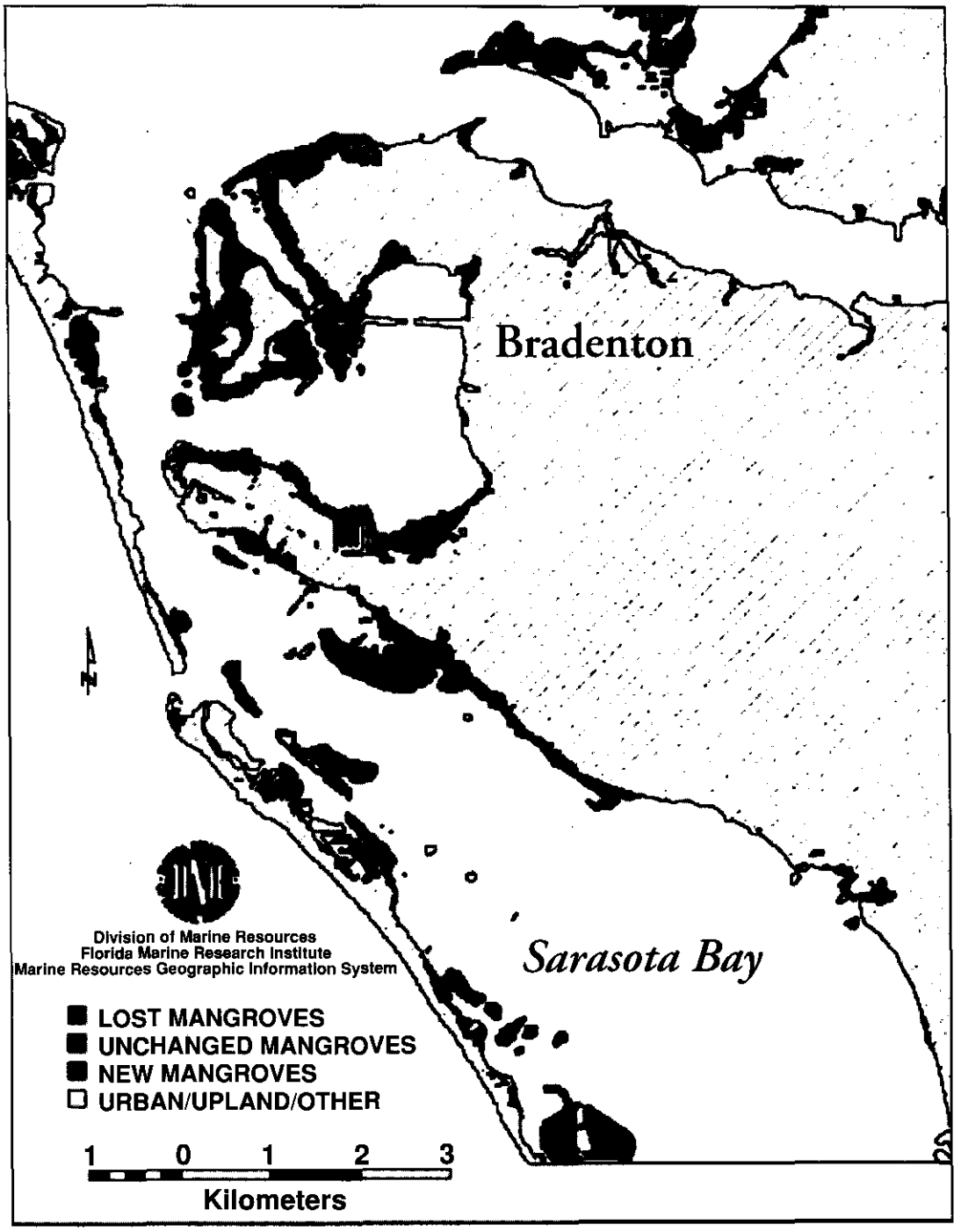


Figure 9. Wetland trends for mangroves in upper Sarasota Bay.

Clearly, 10-year average water levels monitored at St. Petersburg have been increasing over the 40-year time frame. The 40-year average change converted to metric calculated to 2.06 mm/year, correlating with the apparent secular sea-level rise calculation used in the rate assessment for Sarasota Bay (2.1 mm/yr).

To evaluate if the observed changes in water level have affected biological communities, an analysis of wetland trends for mangroves was accomplished for Upper Sarasota Bay by the Florida Dept. of Natural Resources, Bureau of Marine Research, for this project (McGarry, personal communication, 1992). The wetland trend analysis evaluated the southern third of the Anna Maria quadrangle and the entire Bradenton Beach quadrangle for the time period between 1948-52 and 1982. This area was chosen since it contains areas of relatively flat topography, undeveloped upland fringes and broad, extensive mangrove stands that would respond to minor changes in water level over time.

A depiction of this analysis is included in *Figure 9.* Mangroves would be able to respond

to changes in sea level over time by migrating into new lands receiving tidal inundation. Also, mangroves respond to rising sea level by accumulating peat *in situ*, thereby retaining their location. At the same time, wetlands can expand inland if low areas are available for recruitment. *Figure 9* indicates three areas where new mangrove growth occurred, in northern Perico Island, southern Perico Island and the south shore of Tidy Island.

The new mangroves on northern Perico Island surround agricultural fields and may represent growth into fallow lands, mosquito-ditching operations or geographical information system (GIS) translation error between upland and wetland vegetation. The southern Perico Island new growth may reflect new colonization of a mangrove fringe or a similar translation error, since the new growth contains a lost mangrove fringe indicator along the seaward edge.

The new mangroves on Tidy Island may reflect an actual migration, since the area has contained salt-barren and salt-prairie communities along the upland fringe, which would allow increased tidal inundation, gradual slopes and a seed source for mangrove colonization. The construction of mosquito ditches may have also led to increased tidal flushing, which would support mangrove colonization into previous salt barrens. To be noted, much of this area has since been developed into residential uses.

Although not specifically in Sarasota Bay, the effects of sea-level rise can be observed locally. Along the Gulf Coast from Cedar Key to Homosassa Springs, rising sea levels have been implicated in sabal palm mortalities. Recent observations by the Florida Dept. of Agriculture and Consumer Affairs indicate that thousands of palms are dying along the coast. Researchers have been able to rule out insect infestation or disease (FDACS, 1992; *St. Petersburg Times*, 1992). Additionally, the report identified palm-tree mortalities on Egmont Key at the mouth of Tampa Bay.

Early indications show that the dead or stressed trees have a higher salt content than healthy trees. This scenario can be linked to soil-water conditions. Although sea-level rise is implicated, aquifer withdrawals, saltwater intrusion and freshwater diversions can also lead to higher salt levels in surface soils (Barnard, personal communication, 1992).

The three examples cited of *in-situ* sea-level rise identify water-level changes, mangrove migration and coastal palm mortalities. The identified physical changes and biological responses describe measurable water-level increases during recent history. It continues to be necessary to monitor water levels and biological resources to determine if the observed changes are normal sea-level fluctuations or the beginning of a global response to atmospheric warming.

Implications for Sarasota Bay

Natural Systems

Salt-Marsh and Mangrove Communities

The contribution of marsh and mangrove communities to coastal and estuarine systems has been well-documented. As primary producers, wetland plants provide direct sources of nutrients, and as generators of detritus they support the food chain. Mangroves and salt marsh also provide critical habitat components for birds (pelican, ibis, spoonbills), fish (trout, redfish, mullet), shellfish (crabs, shrimp) and other wildlife. The roots and leaves of the plant help to settle sediments, reduce turbidity and attenuate wave energy. This action gives mangroves and salt marsh the ability to stabilize shoreline areas that could otherwise erode.

Analysis of geological formations in Florida indicate that marsh and mangrove communities have always been closely tied to sea-level conditions. During recent history, sea level has risen slowly, allowing sediment from rivers to maintain relatively stable mangrove communities. Sea level rose rapidly during the early Holocene period (>50 cm/100 years), when Florida experienced a rapid submergence (Parkinson and Meeder, 1991). Peat deposits indicated that sea level rose much higher than mangrove swamps could vertically accrete, and coastlines moved landward at a faster rate than mangroves could migrate (Parkinson and Meeder, 1991).

Specifically, Parkinson and Meeder (1991) report that if a rate of 20-78 cm/100 years sea-level rise occurs "rapid and widespread submergence of south Florida's coastal mangrove swamps (i.e., Everglades) will occur if these accelerated rates of sea-level rise are realized." In comparison, this study estimates a 58 cm/100 years increase for Sarasota Bay, well within the range projected by Parkinson and Meeder (1991).

A migrating shoreline driven by an accelerated sea-level rise would require available upland areas for landward migration. Shoreline areas that have been hardened or elevated around the Bay periphery prevent any migration, and would drown existing mangrove and marsh communities in-place. Undeveloped shorelines would be the best available areas for restoration activities, either by constructing planter shelves or by filling shorelines to appropriate elevations. All activities to prevent shoreline

alterations today will greatly enhance our ability to maintain and restore intertidal vegetation in response to sea-level rise.

Given the projected rates of sea-level rise and the extent of shoreline development, it is assumed that eventually mangrove communities will not be able to tolerate the anticipated sea-level rise by either natural sediment accretion or landward migration. To maintain natural benefits to the estuary system provided by mangrove communities, human intervention will be required. Mangrove areas can be supplemented with dredged material to maintain appropriate elevations for survival. Supplementation could be accomplished through hydraulic-dredge disposal of sediment onto existing stands, or tributaries can be enhanced to allow normal sedimentation to be carried and deposited onto mangrove forests. Older mangrove trees may become buried, but new recruitment should compensate for expected mortalities from burial.

Careful planning will be required to prevent unintentional impacts due to sediment supplementation. New areas can be created either by construction of upland planter shelves or by filling shoreline areas to allow mangrove recruitment. Any restoration activity will need to consider that future sea-level rise alterations can affect restoration activities. However, the construction of the Intracoastal Waterway created disposal islands that have become colonized by mangrove communities. Sister Keys received dredged material and continues to maintain a healthy fringe of mangroves.

Available literature is not as extensive for salt-marsh migration. Since mangroves are the predominant shoreline vegetation, salt marsh in many cases may replace mangrove communities as a dominant intertidal plant because of its rapid colonization. Currently, salt marsh is primarily used in estuarine wetland-restoration projects as a pioneer species, then mangroves are allowed to become established and replace the marsh plants.

Mangroves have the potential to be significantly impacted by the projected rise in sea level. Over time, sea-level rise will overwhelm existing communities and prevent natural landward migration. To maintain intertidal forest, substantial restoration/reconstruction activities will be necessary to provide minimal conditions for growth. Reconstruction projects will require the ability to consider future sea-level rise and allow gradual upland transitions to intertidal areas. Preventing shoreline hardening now will promote maintenance of intertidal habitat in the future.

Submerged Aquatic Vegetation

Management and restoration of seagrass can be accomplished in several ways to offset the potential adverse effects of a sea-level rise. Since seagrasses are intimately tied to water-quality conditions and light penetration, efforts to improve water quality can play a major role in seagrass protection/restoration. Eutrophication in the estuary can be reduced through the reduction of nutrient flows from wastewater effluent and stormwater runoff.

Recolonization of seagrasses into shoreline fringes can be greatly enhanced through the removal of hardened structures such as seawalls, rip rap or other structural adaptations. Replacement of shoreline fringes with gentle slopes will support the natural migration of intertidal wetlands landward, with the eventual replacement by seagrasses when water levels are conducive to persistent growth. Shoreline-restoration projects and environmental land purchases support proactive wetland planning for sea-level rise.

Seagrass restoration can include filling of subtidal borrow pits that have been previously excavated for fill material. Filling these dredge holes will increase the Bay bottom area available for seagrass colonization. This technique has been successfully used by the Florida Dept. of Natural Resources in Lassing Park (St. Petersburg, FL), where a subtidal hole (dredged for beach sand) was filled and sediments replanted with seagrass (Fonseca, 1990).

Freshwater Systems

Widespread development has severely restricted the function of tributaries to the Sarasota Bay estuary. With the advent of sea-level rise, the saltwater/freshwater wedge can be expected to be pushed upstream with the advance of higher tides. Movement of the wedge upstream will depend on quantities of freshwater flow discharged downstream as well as the topographic change of each stream. Movement of the wedge upstream may occur more quickly than sediment deposition necessary for plant communities to become established. Therefore, the plant communities necessary for fishery stages could be displaced.

In tributaries where a salinity barrier has been constructed, the tidal wedge will terminate at the barrier due to increasing depths; therefore, an elimination of the oligohaline (low-salinity) environment will occur. If projections are realized, sea-level rise will have major implications for fishery

resources due to the anticipated losses of juvenile habitats in streams and adult habitats in mangrove and seagrass communities.

Several management approaches can be utilized to mitigate a sea-level rise on tributary systems. Evaluation of freshwater discharges/tidal-wedge location and annual cycles will initiate an understanding of existing or predevelopment conditions. When sea-level rise occurs and a documented migration of the wedge is observed, upland excavation and marsh creation should be considered in the new location of the wedge to provide critical habitats.

Careful consideration needs to be given to tributary alterations and restoration activities that may increase saltwater intrusion by directing saltwater inland along the tributary paths. Saltwater intrusion from the expected rise in sea level could also contaminate potable groundwater supplies. Rising seas permit saline waters to penetrate upstream and inland; this impact is further exacerbated during periods of drought. In addition, the landward migration of saltwater could continue to add to the regional problem of saltwater intrusion into the Floridan Aquifer, a principal source of drinking water in west-central Florida.

The Southwest Florida Water Management District and the United States Geological Survey monitor groundwater conditions along the Gulf Coast. Saltwater intrusion is a concern, and will require continued monitoring by these agencies to balance withdraws with saltwater levels. Methods to mitigate saltwater intrusion, now and during exacerbated conditions brought on by sea-level rise, include the reduction of groundwater withdraws, reduction of impervious surfaces and irrigation with stormwater or wastewater effluent. Additionally, deep-well injection of treated stormwater or wastewater effluent can force brackish waters to retreat.

Septic tanks will be negatively affected by sea-level rise since the design of household-effluent disposal in septic tanks requires soil filtration before migration of waste to adjacent ground or surface water resources. A sea-level rise will bring groundwater levels closer to the septic-tank drain field, providing a conduit for poorly treated waste to enter and contaminate groundwater systems. Older areas containing septic tanks may not have been permitted or designed using today's standards. The problem of inadequately treated wastewater generated by older septic tanks will be further intensified.

Barrier Island Community - Longboat Key

The barrier island community of Longboat Key is characteristic of barrier islands along Florida's west coast. Many of the problems and processes witnessed there are similar to coastal areas throughout the country. This community can provide a guideline for measuring the rate of sea-level rise, its effects on natural and developed systems and the steps that can be taken to study and respond to the changes caused by a rise in sea level.

By the year 2115, a sea-level rise of 2.1 feet will mean that abandonment of existing development could be required, as large portions of the barrier island could be underwater during higher high tides.

A rise in sea level will increase the risk of damage and destruction to development and infrastructure on the barrier island. The low topography and proximity within the 100-year floodplain will result in even greater losses due to storm surges, increased flooding and erosion. By the year 2020, with a sea-level rise of 0.5 feet above present MHHW, many components of the barrier island's development and infrastructure will experience adverse impacts.

Increased property damage and destabilization of waterfront property will be increasingly widespread by the year 2020. By this time, the mean higher high water for this area could equal a 0.5-foot rise above present-day MHHW. Land uses along the Gulf of Mexico in both the Sarasota and Manatee county portions of Longboat Key include high-density residential or single-family residential. The Sarasota Bay side of Longboat Key also has a large number of single-family residential units, with scattered areas of high-density residential, especially within the Manatee County portion of the key (Reynolds, Smith and Hills, 1989). Waterfront property will naturally be the most susceptible to damage associated with a rise in sea level.

Storm events coupled with high tides will result in an accelerated rate of destruction of waterfront property. Loss of beach will accelerate erosion and increase the risk of property damage. Subsidence (from compaction of the earth, groundwater pumping or tectonic movement), can also exacerbate flooding and associated property damage. The area around Baytown, TX, on Galveston Bay has experienced frequent high-tide flooding due to subsidence (National Academy Press, 1987).

Although little land is left for new development on Longboat Key, all new development and redevelopment will need to

consider the future impacts caused by a rise in sea level. Town building codes have already been revised to conform with accepted shoreline building construction. Construction practices will need to be altered to lessen the dangers from flooding, erosion and storm surges. This could include elevating development through the use of pilings (so bottom floors are above floodwater levels), placement of all crucial equipment at higher stories, the ability to withstand high-velocity winds and increased setbacks from the shoreline. New development could be restricted in high-hazard areas.

Many existing structures will need improvements to withstand the increased risks. As sea levels rise and coastal areas are permanently inundated, structures will need to be placed farther back from the shore, or removed completely. Relocation, reconstruction and eventual acquisition or abandonment are all possibilities. However, given the large tax base of the town, it is unlikely that abandonment or acquisition will be embraced by residents or local governments. Additionally, residents might not be willing to leave without exploring all other options.

Infrastructure

By 2020, a 0.5-foot rise in sea level could negatively impact the infrastructure on Longboat Key. Ten residences use wells for potable water on the Manatee County portion of the island (*Figure 10*); it is likely that these wells will be affected by increasing saltwater intrusion, as some of them will fall within land projected to be up to the mean higher high water line in 2020 (*Figure 6*). (See the section on the City of Sarasota for management guidelines on potable water.)

The Town of Longboat Key has mandatory wastewater service, and no septic tanks are in use on the island. The sanitary sewer system is owned by the town, and serves only as a collection system. All wastewater is pumped to Manatee County and treated by the Manatee County Utilities System (Reynolds, Smith and Hills, 1989). The system is in good condition; however, rising sea levels will have an adverse effect on this system of collection, transport and treatment. Damage to structures and infrastructure (mains and treatment facility) by storms and flooding would hinder the operations of the system. Additionally, increasing population both on the key and in Manatee County would place increased pressures on the sanitary-sewer system by increasing demand. Thus, both damage and population could adversely effect the ability of the system to effectively treat sewage.

All drainage systems are maintained by the Town of Longboat Key, with drainage directed into either Sarasota Bay or interior retention areas (with one exception, which drains into the Gulf of Mexico). All new development must have stormwater-retention plans. Increased episodes of flooding from a sea-level rise will put stresses on this system, which might require extensive renovations to enable it to handle increased

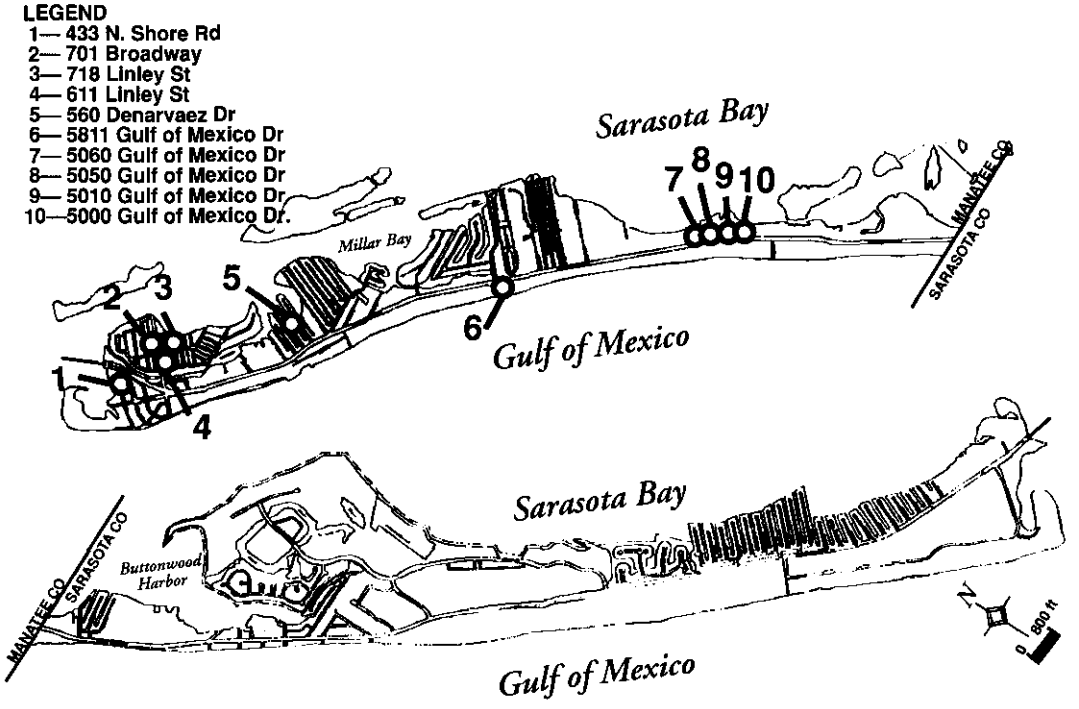


Figure 10. Existing water wells in the Town of Longboat Key, FL (RS&H, 1988).

drainage capabilities. The anticipated changes in weather patterns, coupled with increases in coastal flooding, will require a reworking of drainage capacity to prevent damage from unchecked stormwater runoff.

One study projecting the cost of overhauling the urban gravity drainage system in Charleston, SC, revealed that $2.4 million would be needed for a complete retrofit necessary to deal with an 11-inch rise in sea level (National Academy Press, 1987). While Longboat Key is much smaller than Charleston, the changes needed to accommodate a 15-inch rise in sea level by 2065 would be equally significant.

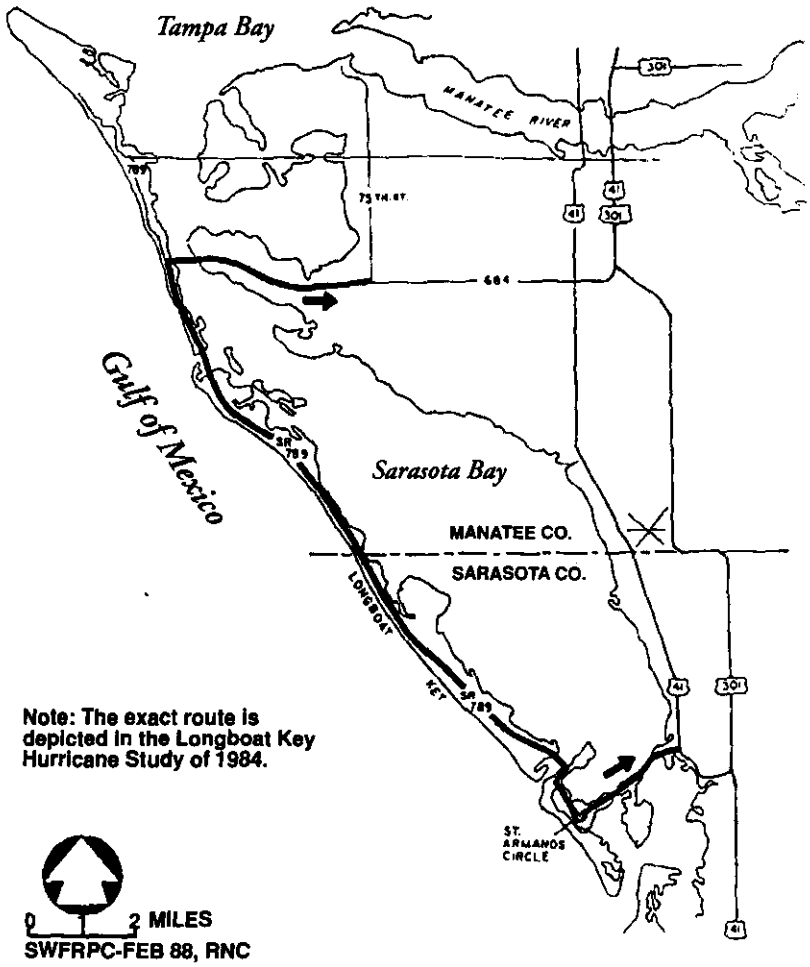
Problems resulting from flooding and/or destruction of electric power lines and transformer stations are obvious. Solutions might include moving, raising or rebuilding these services elsewhere, which would certainly involve tremendous costs and manpower. Other services that might be disrupted by rising water levels include telephone lines and television cables.

The potential for storm flooding and periodic tidal inundation of Longboat Key's transportation arterials, including causeways, would be a devastating impact caused by rising sea levels. Traffic problems would be commonplace as a result of street decay and flooding; many problems with emergency services (police, fire and paramedics) could cause life-threatening situations. One of the greatest dangers would be from the loss of key evacuation routes in the event of a severe storm.

A hurricane or tropical storm could have devastating results for the residents of Longboat Key. The flooding of roadways and causeways would cause residents to be trapped in extremely vulnerable and unstable areas. *Figure 11* illustrates existing evacuation routes. Higher population levels would hinder emergency-management operations, and elevated sea levels would decrease the time available for complete evacuation. Because land and beach areas will have already been eroded and property impacted because of higher water levels, severe storm and high tides would result in even greater degree of destruction and losses than would occur at present. Frequent analysis and redevelopment of appropriate maps and an updating of the evacuation plans and routes will help keep the island prepared for severe storms.

As illustrated above, infrastructure effects of sea-level rise will put economic, procedural and quality-of-life strains on the population of Longboat Key. Wise planning and a commitment to research and changes before negative impacts occur will provide the best defense for the island's residents and infrastructure.

Figure 11. Evacuation routes for the Town of Longboat Key (RS&H, 1988).



Beach and Shoreline Systems

Many residents choose to settle in areas such as Longboat Key because of their beaches and natural resources. The shoreline has always been an attractive amenity, offering great natural beauty, a close recreational resource and high property values. However, with rising sea levels, the beaches could be among the first features to be permanently lost.

Much of the Longboat Key shoreline has been stabilized by seawalls and groins, resulting in an artificial narrowing of the beach in several areas (*Figure 12*). These structures trap sand in the immediate vicinity, but locations down-current are deprived of sand and increased erosion occurs. Longboat Key has experienced some severe sand losses, partially due to the placement of erosion-control structures.

Plans are currently underway for a renourishment project along the Gulf coast of Longboat Key. The design calls for the renourishment of 49,980 linear feet of shoreline with approximately 2.86 million

cubic yards of beach grade material from offshore ebb-tidal shoals. It is anticipated that the project will begin by January 1993 (Nowicki, personal communication, 1992). Projected costs for the project total approximately $17 million, with a breakdown as follows:

Longboat Key Renourishment Project Costs (Erickson, Personal Communication, 1992).	
beach fill	$12,000,000
mobilization and demobilization	1,000,000
dune revegetation/ crossovers	775,000
pull structures/ hardbottom reef	400,000
miscellaneous contingencies	2,126,250
finance charges	300,000
construction supervision	150,000
	$16,751,250

Table 3.

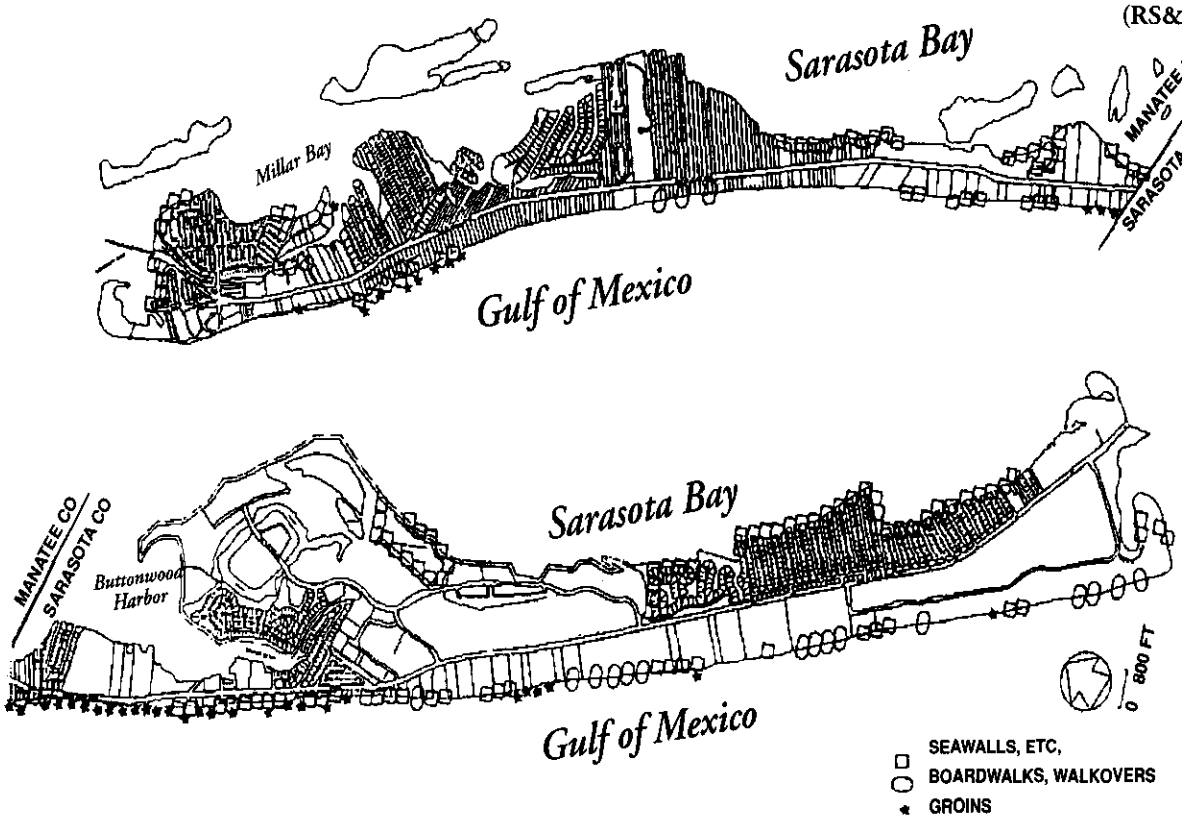
As sea level rises during the next century, it is likely that renourishment projects will again be required. Costs for these projects continue to increase. In the recent past, costs ran approximately $1 million for each mile of beach nourished; presently they are about $1.5 million for each mile (Nowicki, personal communication, 1992). Thus the costs for renourishment activities might be a prohibitive factor in the future with sea levels rising 0.5-1.2 feet between 2020 and 2115.

Management techniques for the beaches and coastal areas could take several forms. Shoreline structures such as seawalls, groins, rip rap and jetties are known to cause problems with increased erosion and altered deposition of sediment. Additionally, these methods offer only short-term solutions.

Regulations dealing with structural and nonstructural methods are in effect in several states. In North Carolina, the use of any type of stabilizing or hardened shoreline structure is prohibited (Edgerton, 1991). That state favors the use of beach nourishment and structural relocation. However, these methods carry their own difficulties. Beach nourishment is expensive, can be damaging to marine life and often requires continuous applications over time, especially in the event of a severe storm. Relocation is also very costly and depends on the availability of land. In the case of Longboat Key, with only 11 percent of its land area left vacant, relocating within the key would not be possible for many structures.

Setback regulations are another method of preserving shoreline areas. These laws restrict development in locations that can be expected to suffer from erosion. Florida's Beach and Shore Preservation Act allows the Florida Dept. of Natural Resources (FDNR) "to establish construction control lines that define the portion of the beach-dune system that is subject to severe fluctuations based on a 100-year storm surge, storm waves or other predictable weather conditions" (Edgerton, 1991).

Figure 12. Shoreline structures in the Town of Longboat Key (RS&H, 1988).



City Community - City of Sarasota

Development and Infrastructure

The City of Sarasota is a well-developed, established city containing many characteristic components of a Florida community. By the year 2020, a predicted 0.5-foot rise in sea level will begin impacting the infrastructure, drainage, transportation and development within in the city, especially those areas closest to Sarasota Bay. By 2115, a sea-level rise of 2.1 feet would result in widespread inundation of the coastline, and potentially damage a large number of residential units located in the coastal vicinity.

The city provides potable water to the entire population of Sarasota through a public water-supply system. Two sources provide the city's water supply: the Verna wellfield, located 17 miles east of the city, and a reverse-osmosis system at the St. Armands/city wellfield location (City of Sarasota, 1991). It can be expected that the Verna wellfield will not experience adverse impacts due to a rise in sea level because of its removed location. However, the St. Armands/City wellfield is located directly adjacent to Sarasota Bay, in the northwest portion of the city (*Figure 13*).

As sea levels rise through the next century, saltwater intrusion into the groundwater in this area is strongly anticipated. In fact, by 2115 some of the wells might actually become so contaminated by saltwater (given their proximity to the Bay, at less than 2,000 feet), that they are rendered useless. Previously documented saltwater intrusion on Long Island, NY, has shown that the interface between fresh and salt water can advance 3-60 meters per year, depending on local pumping conditions (Edgerton, 1991).

Solutions for dealing with saltwater intrusion, including building desalinization plants or relocating water intakes, are expensive and would require the commitment of more human and environmental resources. Additional steps include locating new pumping stations, placement of new sewage and hazardous-waste treatment facilities and acquisition of lands for future reservoirs. Governments and water districts would need to implement policies to ensure sufficient water supplies and allow for the development of new and alternative sources of water.

The City of Sarasota provides public sanitary-sewer service to more than 97 percent of the developed areas of the city (*Figure 13*); no private facilities are located within the city limits. Historically, wastewater received at the city treatment plant was treated, chlorinated and discharged into Whitaker Bayou. Beginning in 1989, a reuse program came on-line on a small scale. With the reuse system, treated effluent is held in a storage pond and used for irrigation. The treated wastewater is currently used for irrigating a ranch and golf course, and more golf courses and residences are planned for inclusion in the near future (Hazy, personal communication, 1992).

Historically, water quality in Sarasota Bay and Whitaker Bayou was adversely impacted by the disposal of treated effluent (City of Sarasota, 1991). The establishment of the reuse system has led to improvements in water quality in Whitaker Bayou, especially in the area south of the discharge point (Hazy, personal communication 1992). However, it does not appear that the City will ever be able to reclaim 100 percent of the treated wastewater and eliminate discharge into Whitaker Bayou at all times throughout the year. The intense rains during June 1992 filled the storage pond to capacity, and the City was again compelled to discharge into Whitaker Bayou (Hazy, personal communication, 1992).

Increased water levels from the predicted rise in sea level could adversely impact the infrastructure of the sewer system, by flooding lift stations and damaging pipelines. As the population continues to increase,

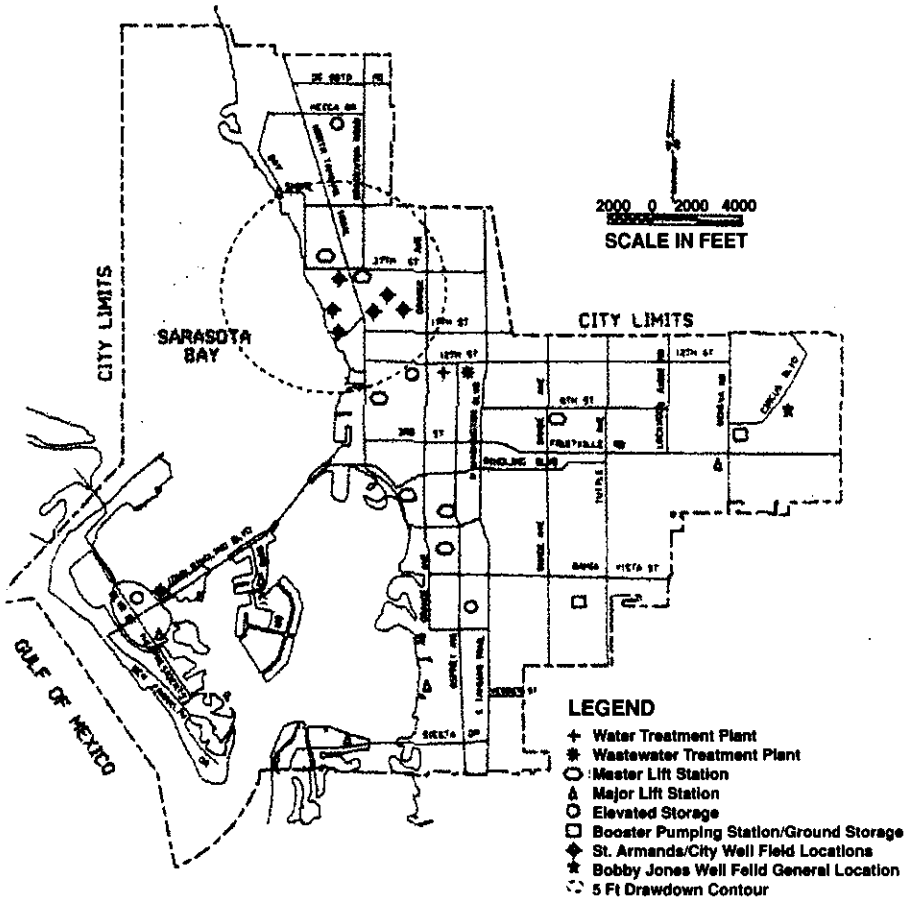


Figure 13. Potable water and sanitary-sewer facilities in the City of Sarasota (City of Sarasota, 1991).

increased levels of effluent could cause the pollution problem to worsen. However, the reclamation system should offset these problems somewhat.

Drainage in the City of Sarasota is handled by a system of natural and manmade conveyance and retention/ treatment facilities, including storm sewers, culverts and ditches. The system is divided into 12 drainage basins within the City limits. Stormwater runoff has been identified as a major contributing factor in the degradation of water quality in Sarasota Bay and surrounding waters (City of Sarasota, 1991). The city is investigating an improved system that would require more on-site detention and treatment for all new construction and possible consolidation with Sarasota County.

However, rising sea levels will increase the frequency of flooding in low-lying and coastal areas, and could require widespread changes in the drainage system, including relocation and addition of retention basins, movement of drainage outfalls and more capacity to deal with pollution of the surrounding waters.

Flood Control and Emergency Management

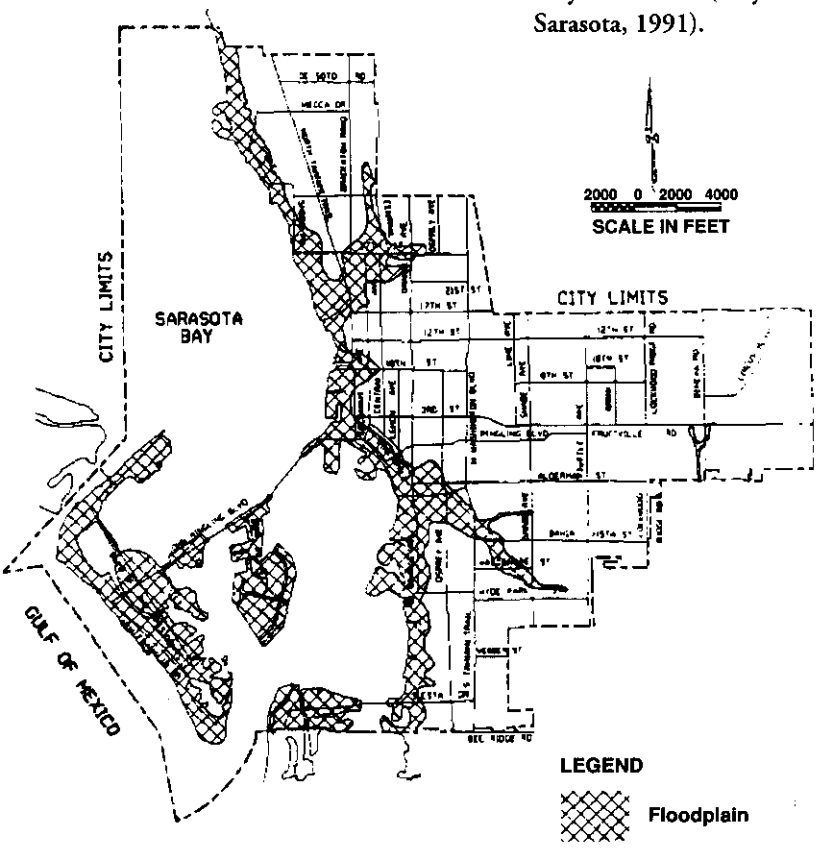
The entire coastline of the City bordering on Sarasota Bay, as well as the barrier islands, are part of the A and V zones of the flood-insurance rate maps of the Federal Emergency Management Agency (FEMA). The A zones are areas subject to 100-year flood hazard, and V zones are subject to 100-year flood hazard and associated wave action (City of Sarasota, 1991). These areas are heavily developed and include residential, commercial, recreational and community uses (*Figure 14*).

The City of Sarasota has approximately 40 miles of coastal shoreline within its corporate boundaries. Of these 40 miles, eight miles are in a natural state and 32 have been altered by some type of structure, such as seawalls and revetments (City of Sarasota, 1991) (*Figure 15*). While these hardened structures will offer some protection against the impacts of a rise in sea level, eventually they will not be effective in holding back the tide. Additionally, they will not offer complete protection in the event of a major storm. These structures are also known to cause adverse impacts such as artificial erosion and accretion to nearby beach areas. Removal and/or redevelopment of these structures further inland would be very costly, and again would not offer complete insurance against damage caused by rising water levels and flooding. The options, including retreat and redevelopment or increasing protective structures, both carry increased costs and problems.

In the event of a hurricane, Sarasota has many resources that will be at risk. In the future, increased sea levels will result in an even greater threat to lives and property within the City. Storms that at present require minimal evacuation will, in the future – with the predicted rise in sea level – result in greater numbers requiring evacuation.

Added to already stressed transportation resources and damage to roadways from sea-level rise, these storms could create a much greater degree of hardship than they would today. Some of the City's primary hurricane-evacuation routes are located in close proximity to Sarasota Bay, and therefore would most likely be flooded in the event of a major storm (*Figure 16*). At the present time, Sarasota County has a shortage of shelter space (City of Sarasota, 1991). It can be expected that in the future, increased population and the need for greater numbers to evacuate because of the rising sea level will result in an even larger demand for shelter space.

Figure 14. Floodplains in the City of Sarasota (City of Sarasota, 1991).



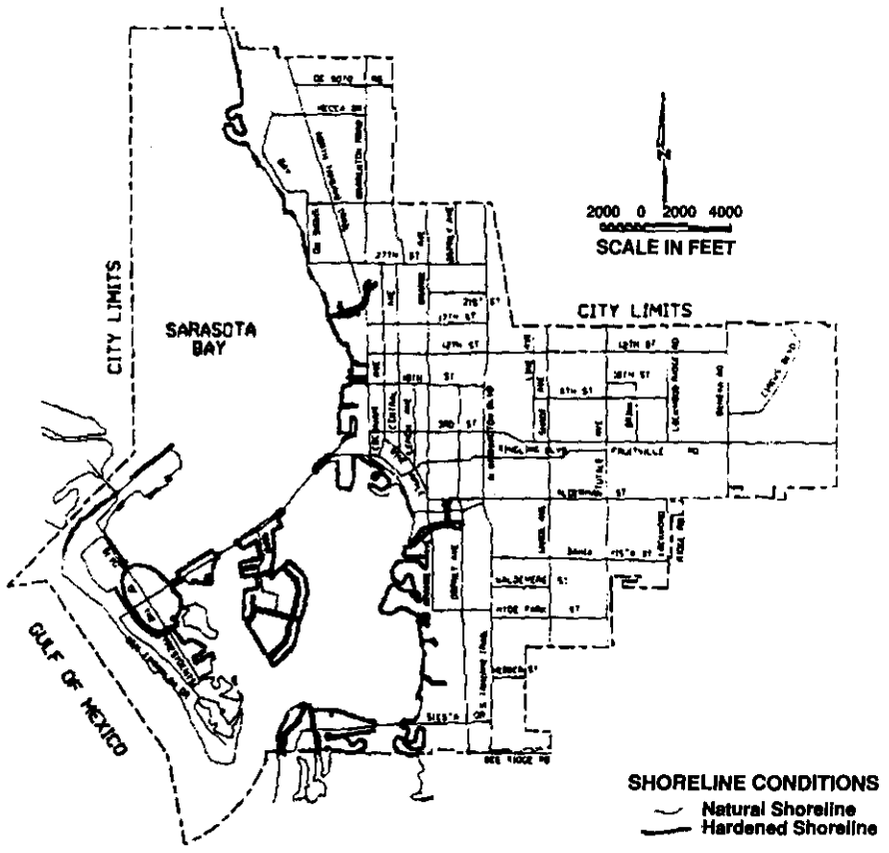
Transportation

The City of Sarasota currently maintains a transportation system in coordination with Sarasota County, the Sarasota-Manatee Airport Authority and the Florida Dept. of Transportation. Several principal and minor arterials within the City limits are located very near Sarasota Bay and connect the mainland and barrier islands. These roads could be severely impacted by the impending rise in sea level. While the City is working on strategies to improve the level of service, future conditions will require great strides and renovations within the transportation system to avoid severe problems in transportation within the City. Increased population and inundation of roadways from sea-level rise will take its toll in the future if great improvements are not made to the transportation system.

Cultural and Historical Resources

The present study identified 264 cultural-resource sites and structures within the proposed sea-level rise effective impact zone (*Table 4*).

Figure 15. Shoreline features in the City of Sarasota (City of Sarasota, 1991).



Summary of Cultural-Resource Sites

Specific sites include the Cortez midden, Roser Church, the Out-of-Door Academy, Oscar Scherer Park, the John and Mable Ringling residence and dock and others.

A projected effective sea-level rise by the year 2115 could destroy many of the study area's cultural resources if anticipatory management plans and funding mechanisms are not in place prior to even incipient effects. It must be appreciated that the scenario of the present study does not project a sudden, complete inundation, but rather a relatively imperceptible and gradual rise – with all the concurrent erosion such a rate would entail. Particularly in the case of archaeological sites, such creeping erosion would, in the end, be far more destructive than a catastrophically sudden and complete flooding. While historic structures would indeed be swept away by such an event, some cultural-resource sites would be afforded a level of protection from vandalism that many are lacking in their present terrestrial rather than submarine circumstances.

Methods available for addressing the negative impacts of sea-level rise on coastal cultural-resource sites and structures include structural and nonstructural approaches to shoreline protection, physical relocation and mitigation by data recovery. Economic considerations on a site-/structure-specific basis will typically decide which approach or mixture of approaches is taken.

At least in the case of some historic structures, physical removal and relocation to higher ground is an available preservation option. It may be feasible to elevate structures in place on pilings or fill to maintain structure/site context without the additional expense of acquiring property at a higher elevation elsewhere.

Mitigation of impact via data recovery may often be the most cost-effective approach. While the cultural-resource site or structure itself is ultimately lost, at least some of the knowledge it contains can be saved by various techniques of excavation and documentation. The dynamic nature of knowledge mandates that at least a sample of our limited supply of intact cultural resources be preserved for future investigations.

Specific remedies for test cases will be suggested at such time as selections are made. As noted above, site-specific approaches will be necessary, whether structural, nonstructural or a mix of mitigative techniques are necessary. The choice of which if any of the listed 264 cultural resources will be preserved from the destruc-

tive effects of sea-level rise will ultimately reside with the communities in which they are located. If selections are made and funding mechanisms established in advance of immediate and pressing needs, some sample, at least, of our past may be saved for the future.

Management Options for Sea-Level Rise

Comprehensive Planning

In 1985, the population growth and related development experienced by the Tampa Bay region, and Florida as a whole, prompted the Florida legislature to take a historic step by passing the State and Regional Planning Act (Chapter 186, Florida Statutes). The legislature established an integrated planning process designed to manage future growth, comprised of the State Comprehensive Plan, state agency functional plans, comprehensive regional policy plans and local governments' comprehensive plans.

In accordance with Chapter 163, Part II, Florida Statutes, and Chapter 9J-5, Florida Administrative Code, local governments in the Tampa Bay region and throughout the state are required to prepare and adopt local comprehensive plans that are consistent with and further the state plan and the applicable regional plan. Although not required to address specific state and regional plan goal areas, local plans must address a minimum number of "elements" (e.g., future land use, coastal management and conservation elements) that are directly related to the state plan, agency functional plans and the regional plan. As an example, the purpose of the coastal-management element is to have local governments plan for, and where appropriate restrict, development activities where such activities would damage or destroy coastal resources.

Local-government plans provide the conduit to construct and implement basinwide resource-protection goals and policies that then can be implemented though local zoning and land-use ordinances. Land-use designations should also consider locations within the watersheds. Staggered densities along tributary systems will buffer runoff impacts, wetland losses and maintenance of habitats from often unintentional impacts.

Permitting Considerations

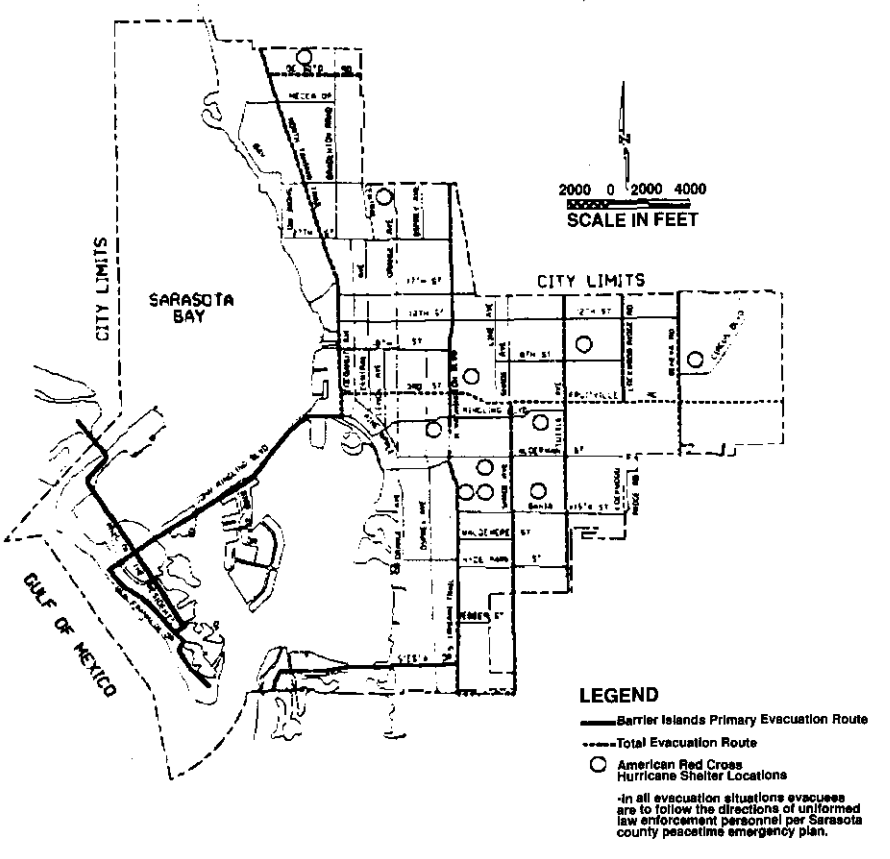
Resource-protection efforts were greatly expanded in the 1980s with adoption of wetland-protection and stormwater-management regulations by the Florida Legislature. Water-Use Permits (WUPs) administered by SWFWMD are used to govern freshwater withdrawals from ground and surface water sources. The WUP process offers the opportunity to evaluate major activities that affect freshwater distribution to the Sarasota Bay estuary and groundwater withdrawals. WUP renewals and new applications need to be tied to the Sarasota Bay Framework for Action to maintain inflows and prevent additional saltwater intrusion.

The stormwater permitting process, through Chapter 17-25, F.A.C., administered by the Florida Dept. of Environmental Regulation (FDER), and Chapter 40D-4, administered by the Southwest Florida Water Management District (SWFWMD), provides the conduit to balance freshwater flows in tributaries and buffer water-quality impacts while increasing wetland habitats. An environmentally sound

Summary of Cultural Resource Sites		
Location	No. Prehistoric	No. Historic
Unincorporated Manatee County	8	
City of Anna Maria		17
City of Bradenton Beach		8
Longbeach/ Longboat Key		8
Village of Cortez		119
Unincorporated Sarasota County	38	47
City of Sarasota	16	3

Table 4.

Figure 16. Hurricane evacuation routes and shelters in the City of Sarasota (City of Sarasota, 1991).



stormwater-treatment system can provide water-quality treatment through construction of vegetated littoral shelves while gradually releasing freshwater to the receiving water body. The treatment height of the pond can be designed to enhance adjacent wetland communities by restoring historic hydroperiods.

Domestic wastewater permits, administered by FDER, can be a source of AWT wastewater effluent to supplement underground aquifer systems for either potable supplies or irrigation. However, public perception may limit the use of AWT effluent in potable water supplies. Highly treated effluent can also enhance freshwater flow to the estuary in areas where flow has been reduced. Highly treated effluent can be used to achieve ideal salinity gradients in impacted or manmade tributaries, or to improve circulation and flushing.

Septic-tank permitting is also required by the Dept. of Health and Administrative Services and local governments. Future permit actions should limit septic-tank siting to areas above the 100-year floodplain and areas containing soil conditions and groundwater levels sufficient to treat generated effluent for the next 50 years, the anticipated structure life. Expansion of WWTP service lines should give priority consideration to transmission of effluent from older septic-tank areas to reduce the potential contamination of surface and ground waters.

Wetland-modification permits (or dredge-and-fill permits) administered by the US Army Corps of Engineers, FDER and local governments should be coordinated with stormwater permits to restore channelized tributaries by reducing shoreline slope, increasing cross-sectional area and planting with native aquatic plants. Developments can combine wetland mitigation and stormwater treatment in some cases by constructing a meandering tributary alignment with a high- and a low-flow passage from a previously channelized system. Agricultural ditches and flood-control channels recontoured along one side will allow habitat and water-quality improvements, while maintaining the other side for future maintenance activities.

Wetland permits must provide a front-line defense to prevent additional loss of shoreline vegetation to buffer a rise in sea level. Hardened shorelines will not migrate, and therefore will drown any existing vegetational communities. The wetland permitting process needs to consider upland uses adjacent to the wetlands as a buffer zone or described transitional area; this would require legislative authorization to enhance the Warren Henderson Wetlands Protection Act of 1984. Local governments often have the best tools to manage upland transitional areas through regulation of land use and wetlands together.

Demonstration Projects

Many projects to buffer or monitor a potential rise in sea level have been identified within the text. The following section is intended to serve as a listing of recommended projects that can be accomplished by the Sarasota Bay National Estuary Program and included within the Comprehensive Conservation and Management Plan for future implementation by Bay managers.

Monitoring Ongoing Sea-Level Rise:

To observe the timing and extent of a rise in sea level, the continuous recording of sea levels is required. The closest station is the St. Petersburg NOS Station (No. 872-6520). The two oceanic stations used in the rate projections for accuracy are the Cedar Key Station (No. 872-7520) and the Key West Station (No. 872-4580) (NOAA, 1990). Periodic analysis of the water-level gauges will document current conditions and detail required response.

Estuary Restoration:

The Sarasota Bay NEP, FDER-PRTF, SWFWMD-SWIM and local governments have accelerated shoreline habitat-restoration initiatives along the periphery of the Bay. Recent projects include the City Island project, Leffis Key Bayside Park, Caples shoreline restoration and Centennial Park. All these projects not only support habitat enhancement today, but will additionally supply shoreline fringes where marsh and mangrove communities can migrate in the event of a rise in sea level. All future projects should include an upland buffer element to secure future transitional areas.

Projects that remove hardened shoreline areas will benefit intertidal habitats as well as future seagrass communities. The armored shoreline will potentially drown advancing inter- or subtidal wetlands as water levels increase. Additionally, the structures create a higher-energy environment, through wave deflection, which restricts mangrove or seagrass colonization. The Caples shoreline project and Centennial Park initiative are good examples of projects that will mitigate the effects of sea-level rise.

Currently, the SWFWMD-SWIM program provides a series of aerial photographs of Sarasota Bay and Tampa Bay every two years. The inventory provides excellent seagrass information, which over time will detail trends in coverage. A demonstration project in future years will be an evaluation of seagrass migration along the landward fringe of seagrass beds. Care should be taken in separation of species, since *Ruppia maritima* tends to grow in shallower water (intertidal at times) than most other

species. As previously described, an analysis of mangrove migration was accomplished using historic information. However, future trend analysis may be limited due to the extent of development of shoreline areas.

Bay-bottom dredging activities have created borrow holes in many areas of the Bay, which can be restored through capping. Filled holes have been successfully replanted with subtidal seagrass beds (Fonseca *et al.*, 1990). Restoration of the Leffis Key holes are currently under consideration by SBNEP and Florida SeaGrant (J. Culter, personal communication, 1992). Capping and revegetation of dredged holes will create new benthic areas and assist in mitigation of a sea-level rise.

Tributary Protection:

Tributaries to Sarasota Bay have received significant development pressures from agricultural uses and urbanization over the last 100 years. One important demonstration project entails undertaking a historic analysis of tributaries including the following parameters (from Clark, 1991):

1. Evaluate historic and existing freshwater flows and salinity patterns in the larger tributaries to Sarasota Bay.
2. Analyze remaining natural communities and potential restoration areas to reestablish communities that have been displaced, and consider management of the saltwater wedge/ productivity zones to coincide with remaining structural habitat.
3. Combine established optimum salinity gradients and habitat elements onto existing land-use maps and develop a list of tactics for each responsible agency to enhance the tributary systems.

This project will help identify those areas in need of habitat restoration or enhancement of freshwater flows. The variety of benefits provided by tributaries (water-quality enhancements, circulation/flushing improvements, fishery restoration and others) make tidal-creek restoration one of the most critical, beneficial forms of habitat renovation.

Septic-Tank Removal:

In areas containing septic systems, which have created water-quality problems in Sarasota Bay or have the potential to do so during a rise in sea level, efforts should be taken to remove the systems and replace with public transmission and treatment systems. Currently, the City of Sarasota has sewers serving 97 percent of the community (City of Sarasota, 1991); Longboat Key does not have any septic systems (Reynolds, Smith and Hills, 1989). Future analysis should focus on Little Sarasota Bay, where older development and reduced flushing make septic-tank removal an important consideration.

Shoreline Erosion:

Establish a coastal control area with natural beaches and beaches with hardened structures. Measure erosion rates, for a set period of time, for both areas. Compare with historical records to see changes from sea-level rise, then remove some hardened structures and measure changes in erosion rates.

Historical and Archaeological Sites:

As previously discussed, the choice of which mitigative techniques to apply must be determined on site-specific bases. Whether any action at all will be taken will depend on local governmental policy and the choices of individual site owners. It seems probable that unless some public incentives are offered, individuals will largely ignore the potential destructive effects of sea-level rise on the cultural-resource portions of their private properties.

In Longbeach/Longboat Key, the three pressed-block structures, by the nature of their construction and sizes, would not be likely candidates for relocation. Data recovery via photographic documentation and research would be the recommended approach. The remaining five wooden-frame structures could be relocated elsewhere or elevated in place.

The fishing village of Cortez in Manatee County contains 48 FMSF-listed and 71 potentially listable historic structures, as well as portions of an archaeological shell midden site. If Cortez is to survive, as is the very strong desire of many of its native inhabitants, the only apparently feasible approach would appear to be in-place vertical "relocation." Placement of its structures on pilings would in fact mirror historical construction techniques previously used in this important Florida fishing village.

The Cortez shell midden, while largely destroyed by dredging and condominium construction, nonetheless still contains potentially significant scientific data. It is recommended that systematic archaeological testing of the site be conducted.

Within the boundaries of the City of Sarasota, only three identified historic structures are located within the projected sea-level-rise impact zone: the dock of the John Ringling residence and two homes on St. Armands Key. Structural reinforcement of the Ringling dock may be an effective approach for its protection; the St. Armands Key structures should be subjected to a program of architectural data recovery.

Summary

As a result of the greenhouse effect and local conditions in the Sarasota Bay region, we can anticipate the following to occur:

- The consequences of atmospheric loadings of greenhouse gases are likely to increase global temperatures and accelerate rising sea levels above normal climatic cycles. If emissions of CO_2 and other greenhouse gases continue unabated, the earth will warm five to 10 times faster than during the retreat of the last ice age, resulting in an average global temperature increase of one degree C. by the year 2025 and three degrees C. before the end of the next century. Global sea level is expected to ascend due to ocean warming, creating thermal expansion as ice sheets and glaciers thaw.
- In Sarasota Bay, the calculated position of mean higher high water (MHHW) in 2115 AD may reach 64 cm (2.1 feet) above present MHHW.
- Tidally influenced wetlands may be greatly affected by rising seas due to shoreline development that prevents migration of wetland communities into higher lands. Already, mangroves have been observed migrating into tidal flats in response to existing sea-level changes.
- Shallow groundwater systems could experience additional saltwater intrusion, which would affect shallow aquifers and septic-tank efficiencies.
- The barrier-island community of Longboat Key may experience increased incidence of flooding as sea level rises. The beach system is expected to require additional renourishment activities in order to maintain this important recreational and natural resource. Eventually, development on this barrier island will need to consider alternatives to maintain or abandon development that is affected by increasing flooding events.
- The City of Sarasota will experience increased flooding along coastal areas. However, due to the topographic elevations in many areas, flooding should not be as widespread as along the barrier islands. The City infrastructure may require additional maintenance to prevent saltwater intrusion or prevent flooding from affecting services.

Management of sea-level rise will require proactive planning to lessen future problems and reduce capital expenditures. Comprehensive planning, natural-resource permitting and infrastructure design are all tools that are available to mitigate impacts created by rising seas. Demonstration projects and water-level monitoring are necessary to determine the extent of rising seas and identify approaches to reduce impacts. The opportunity is available now to ensure maintenance of our resources while buffering urbanized areas from the potential detrimental effects of a rise in sea level.

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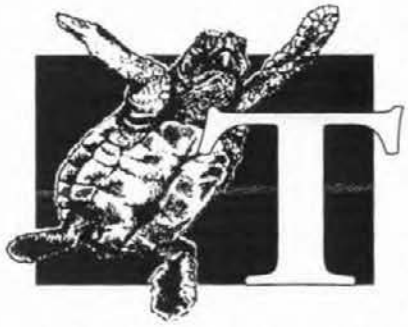
Bay Bottom Habitats

Estuarine Bottom Habitat Assessment

by James Culter
Mote Marine Laboratory

Executive Summary



The greatest single form of physical disturbance to the Sarasota Bay bottom has been dredge-and-fill activity for waterfront development, followed by dredging for the Intracoastal Waterway and access channels to shoreline docks. Approximately 15 percent of the Bay's bottom has been directly impacted by these activities. Boating activity (i.e., channelization for boat access and travel, and damage due to propellers) has been extensive throughout the Bay.

This type of disturbance results in a restructuring of the Bay bottom's sediment composition. Most dredged areas contain large quantities of silt/clay-sized particulates that are easily resuspended and remain in the water column for a relatively long period of time, contributing to Bay turbidity. In addition, many of these areas do not contain productive habitat and are a liability to the overall health of the Bay system.

Historic loss of seagrass meadows is believed to be a result of a general deterioration of water quality (in addition to physical removal), although long-term data to support this assumption are generally lacking. Approximately 8,300 acres of seagrass habitat, of all types and quality, exist within the Sarasota Bay system. Seagrass beds appear to have expanded in the vicinity of the passes. For example, for the period 1984-88 seagrass habitat in the vicinity of New Pass showed an apparent gain of 19 percent. However, this gain was primarily in the category of "patchy" on the New Pass flood-tide shoal and, to a lesser extent, the "sparse" category. Of major concern is the nine-percent loss of dense seagrass beds for unknown reasons. The expansion of seagrasses on the flood-tide shoal is cause for cautious optimism, because of the ephemeral nature of pass habitats. The long-term stability of this area will depend on a number of factors decided by pass management policy.

The south Bay region (Little Sarasota Bay to Roberts Bay) has exhibited a distinct change in biotic conditions since this study began. A notable shift in seagrass species has occurred in the vicinity of the former Midnight Pass, with former *Thalassia - Halodule* seagrass beds being replaced by *Ruppia*, which is more tolerant of lower salinities. In the absence of increased circulation, this area will continue to experience wide seasonal salinity fluctuations, and will be dominated by *Ruppia* at depths limited by water clarity. The management choice of closing Midnight Pass has significantly altered the nature of the southern Bay, without regard to any predisposed management plan.

For impacts caused by dredging disturbance, the ability of the benthos to recover and support some variation of a normal Bay flora and/or fauna depends on: 1) the depth of dredging beyond the existing grade; and 2) the relative flushing or water-exchange ratio and the velocity of exchange. Recovery of the benthos from the effects of poor water quality will be more subtle, since the combined effects of multiple water-quality parameters in promoting a healthy estuarine community are still poorly defined. In reality, the type of "desired" community (for which management practices are selected) needs to be defined in greater detail. This type of definition may be possible through synthesis of the Sarasota Bay National Estuary Program studies.

As described in this report, not all disturbed Bay bottom types exhibited equal habitat value. Impacts associated with boating activity create physical changes in the bottom structure and habitat; this type of "disturbed" habitat is expected to gradually increase throughout the Bay, in some proportion to the level of boaters and Bay use.

Relatively few disturbed areas exist that are suitable for some type of restoration. In addition, any restoration that would involve depositing large quantities of fill material would likely be cost-prohibitive, unless coordinated with dredging maintenance or uplands-restoration projects. Nevertheless, improvements in habitat quality are quite feasible through a process of limited capping (covering the fine-grained material with a coarser-grained substrate) and in some cases increasing habitat complexity through artificial reef structures.

The verdict on seagrasses is split. Undoubtedly, improvements in wastewater treatment are a significant plus, as are ongoing and planned retrofitting of stormwater control. However, continued loss of vegetated upland communities, the lack of potential wetlands-restoration sites and projected increases in all types of Bay use may offset gains in other areas.

Estuarine Bottom Habitat Assessmant

James Culter

James Culter's professional experience began in 1974 at the University of South Florida, where he worked as a student assistant on environmental impact studies within Tampa Bay and received benthic invertebrate taxonomic training.

In 1976, Mr. Culter joined the consulting firm of Conservation Consultants, Inc. (CCI) as a benthic-invertebrate taxonomist for a study of the thermal effects of power-plant effluent on Tampa Bay.

In 1979, Mr. Culter joined Mote Marine Laboratory, where he has specialized in marine/estuarine ecology and environmental assessment, with emphasis on benthic systems. As a staff scientist, he is program leader for the Environmental Assessment, Benthic Studies Program. Mr. Culter served as an invited instructor (mollusk taxonomy) for EPA Region IV Marine Invertebrate Workshop in Athens, GA, and authored a "Manual for Identification of Marine Invertebrates," published by the EPA. He also served on the Governor's panel to the Presidential Task Force to gather information on proposed offshore oil leases in June 1989.

Introduction to the Benthos

Benthos is a Greek word that refers to the depths or bottom of the sea. The science of benthic ecology is the study of the plants and animals that inhabit the benthos, together with their environmental requirements. Benthic organisms are excellent indicators of general habitat conditions. The distribution of the plants and animals that live on or within the aquatic substratum is regulated by a variety of environmental factors, the most important of which are salinity, temperature, tidal inundation (intertidal or subtidal) and substratum composition.

Benthic organisms are generally not highly mobile; the majority of the individuals in the benthic community will live their adult lives within a relatively small area, as opposed to many fishes that range over wide areas. It is due to this restricted mobility that benthic organisms are considered excellent indicators of habitat conditions and, in some cases, environmental quality.

Benthic organisms contain representatives of nearly every major life form. The most conspicuous elements are the plants, consisting of algae and seagrasses; the invertebrates, which include barnacles, shrimp, clams, corals, worms, etc.; and the vertebrates, represented by certain species of fishes.

Types of Benthic Habitats

Benthic habitats are classified according to salinity regimes (freshwater, estuarine, marine), type of substratum (hard or soft bottom) and presence or absence of aquatic vegetation.

Within the Sarasota Bay study area, five major types of bottom habitat are found, as follows (ranked from most- to least-common):

- unvegetated subtidal sand, muddy/sand
- intertidal and subtidal seagrass meadows
- artificial hard bottom (reefs, seawalls and bridge pilings)
- natural rock outcroppings (including the nearshore Gulf)
- oyster bar habitat

Relevance of Benthic Habitat

Benthic habitats are an important component of the coastal ecosystem. Seagrass beds are one of the most publicized habitats because of their role as primary producers, as habitat for commercial and recreational fish and shellfish, and in stabilization of sediment. Because of their vulnerability to coastal development, seagrass meadows have declined by 30 percent statewide (Livingston, 1985).

Non-vegetated benthic habitats also play a very important part in the coastal ecosystem, but no systematic analyses have been made of habitat alteration or loss.

Most benthic organisms have complex life cycles, including a planktonic egg or larval stage, that can provide an immense food resource for pelagic organisms. The benthic fauna recycle the detritus and nutrients that result from primary production, which prevents buildup of organic material on the Bay bottom. A variety of human food organisms, such as shrimp, clams, oysters, crabs and certain species of fish, can be found on unvegetated bottoms.

The diversity of organisms living on and within the bottom is much greater than in the water column. Within the Sarasota Bay study area (including the nearshore Gulf of Mexico) live approximately 500-1,000 species of macroscopic benthic invertebrates, representing most of the major animal phyla. Because of their great diversity, limited mobility and specific habitat requirements, benthic invertebrates are used as a measure of habitat quality by federal and state regulatory agencies. From a resource-management perspective these areas are important for the following reasons:

- Soft bottoms act as the major source of turbidity through wave-generated resuspension in most bay systems. Therefore the location, surface-grain size composition and relative areal extent of the soft-bottom areas is a major management concern.
- Soft bottoms act as a major sink or source for nutrients and toxic substances.
- Soft bottoms are not "barren;" invertebrate productivity is equivalent to and

sometimes greater than the benthos associated with submerged aquatic vegetation communities. This productivity translates into "fish food" for both bottom-feeding and pelagic fishes. These productive soft-bottom areas are affected by many of the same factors that affect aquatic vegetation, such as turbidity, urban effluent, pollutants, etc.

• Modified or disturbed soft-bottom areas can be the source of chronic environmental problems. Dredged areas such as canals and boat basins can act as sinks for fine organic particulates, resulting in anaerobic conditions and the production of hydrogen sulfide (a noxious, toxic gas). Periodic disturbance can result in fish kills, reduced turbidity and reduction in overall water quality.

Bay Bottom Habitat Assessment

The specific objectives of this project were to define the status of submerged aquatic vegetation (SAV) and other submerged benthic habitats within the project area relative to historic conditions, in a manner that would serve as an environmental planning aid.

Photointerpretation

The most recent and complete set of aerial photographs available to the project were from the Surface Water Improvement and Management (SWIM) Program, Southwest Florida Water Management District. These photographs covered the complete study area as outlined by the Sarasota Bay NEP guidelines, and were available in true color at a scale of 1:24,000.

Identification of features visible on the SWIM aerial photographs concentrated on seagrass coverage and identification of "disturbed" Bay bottom. Acetate overlay drawings of these features were constructed for each segment of Sarasota Bay.

Estimates of the coverage of both seagrasses and disturbed bottom were obtained by processing the acetate drawings with a computerized image-analysis system, capable of calculating the area of complex shapes. The areas thus measured were then converted to units of acres and hectares for each segment of the Bay. More-detailed characterizations of the Sarasota Bay seagrass meadows are presented in later sections. Descriptions of the types of "disturbed" Bay bottom are presented below, followed by the mapping results for both the seagrasses and disturbed areas.

Disturbed Bay Bottom

This category included only currently existing inter- or subtidal habitats; for classification purposes, it was considered to be the exclusive result of removal or redistribution of substratum, and took into account only relatively large disturbances that have become permanent features of the Bay bottom.

The greatest single form of disturbance to the Bay bottom has been dredge-and-fill activity for waterfront development, followed by dredging for the Intracoastal Waterway and access channels to shoreline docks. Areas that were historically inundated but are now uplands due to such activity as dredge and fill are not considered as disturbed Bay bottom. For example, most of what is now Bird Key (off Ringling Causeway in Sarasota) was at one time a subtidal seagrass flat; for this survey, however, only the Bird Key canal system was considered a disturbed Bay-bottom habitat.

The relative level of recovery for disturbed areas varies greatly within the Bay. (Recovery was defined as a return to a flora and fauna characteristic of natural, undisturbed areas within the Bay system.) Any dredged area can be considered to be 100 percent altered at the time of dredging. The recovery of the bottom and the ability to support some variation of the Bay's normal flora and/or fauna depends on 1) the depth of dredging beyond the existing grade; 2) the relative flushing or water-exchange ratio and velocity of exchange; and 3) degree of re-disturbance and time between successive disturbance events.

Types of Disturbed Bay Bottom

Various levels of habitat value were associated with disturbed Bay bottom. Disturbed areas fell into the following categories:

Deep-dredged, quiescent water. This type of bottom was typically created by dredge-fill land-building activity, or for boat access or traffic. "Deep-dredged" is an arbitrary designation, but it usually refers to depths of 7-20 feet (2.1 - 6.1 meters). Typically these areas are considerably deeper than the adjacent natural Bay bottom. Most are located in conditions of moderate to very low circulation; as a result, they act as depositories for very fine particulates and organic debris. The result is a substratum consisting of very soft, fine particulates (classified as silt/clay material) with a high organic content. Almost without exception within Sarasota Bay, this type of bottom material is anoxic (without oxygen), produces hydrogen sulfide gas and lacks any significant infauna or flora. Epifauna are usually absent, as are any macrophytes. Blue-green algal mats, sulfur bacteria and fungi often provide a thin (1 cm or 0.4 inch) mat-like covering over the substratum. The

sediment often exhibits a pudding-like consistency.

This type of habitat is a liability to the Bay system. Many of these areas could be restored to some extent, and at a few locations it would be technically feasible to completely restore the bottom to a functional native habitat.

Deep-dredged, moderate to good circulation. This habitat was typically limited to the passes of the Intracoastal Waterway (ICW) system. For this type of habitat, tidal circulation keeps the bottom scoured clean of the fine particulates associated with the previously described deep-dredged areas. These areas are characterized by a coarse-sand and shell substrate (depending on current speed). Epifauna may be common, attached to large shell or rock, but are not usually abundant. In a few areas where concrete rubble or rock was present, a productive "reef" fauna with species typical of the Gulf was present.

Overall, the deep-dredged areas with high circulation were not highly productive bottom types, but probably represent a net asset to the Bay system.

Shallow-dredged, poor circulation. This classification is typical of many of the finger canals on Longboat Key and the Siesta Key canal system. The quality of the habitat within canals of this type varies greatly, depending on relative degree of flushing, which is dependent on total canal length as well as the circulation null zones present within the Bay.

Generally, these types of canals were classified as poor to moderate habitat quality. The bottom consisted of fine, muddy sand or organic silt/clay material. In many instances the sediment was anoxic, with a distinct hydrogen-sulfide odor.

Shallow-dredged, moderate to good circulation. This classification is typified by many of the canals of Anna Maria Island. These areas were observed to support a normal, unvegetated bottom community, and in some instances sparse macroalgae or seagrass growth. The plant growth usually occurred near the banks (or seawalls), which tend to be shallower and removed from the scouring action of propwash.

Propeller-dredged. This classification consisted of areas in which the nature of the substratum was altered by chronic exposure to propwash. Active propeller dredging is an illegal activity conducted by anchoring a boat in a fixed position to remove sediment from a particular location by directing the stream of water from the boat propeller. A prop-dredged channel can be recognized in aerial photographs by a slight elevation (lighter in color and often unvegetated) of the substratum on one or both sides of the channel, which is where the sediments from the washout were deposited. Prop-dredged access channels from shoreline docks to deep water were a commonly observed feature along much of the perimeter of the Bay system.

Tidal channels. Tidal channels are features created by the flood and ebb of tidal-water masses, associated with any shallow Bay system. The channels are typically deeper (to a varying degree) than the adjacent Bay bottom, and unvegetated due to the scouring action of currents; in this respect, tidal channels are not "disturbed" habitat.

In Sarasota Bay, most tidal channels are also heavily used as boat navigation routes. In this respect many of the tidal channels are disturbed habitat due to the high level of boat activity, being wider and deeper than in an undisturbed condition. In addition, these channels are maintained by the scouring activity of boating, and are not likely to exhibit significant colonization of macrophytes even in areas where currents and depths are favorable.

Deep water, high circulation. These are areas that have been dredged, are located in the vicinity of passes, and may have relatively good circulation due to tidal currents. In these situations the currents provide a flushing action that prevents the accumulation of detritus and fine particulates. The substratum of these areas is typically a coarse sand/shell hash mix. These areas are typically devoid of macroflora; the fauna are relatively diverse and "healthy," although the scouring action of the tidal currents may result in reduced densities of organisms.

Results - Photointerpretation

Mapping of seagrasses proved more difficult than mapping of disturbed areas of Sarasota Bay's bottom. While the SWIM photos were generally of good quality, Baywide differences in water transparency were evident. The southern portions of the study area encompassing Little Sarasota Bay (southern end), Roberts Bay and Blackburn Bay had poorer transparency as represented in the photographs.

Disturbed Bay Bottom

Table 1 presents the area of disturbed Bay bottom for each segment of the Bay and an estimate of the percentage of each segment that has been impacted; areas include canal systems. Excluding passes as disturbed area, slightly more than 4,400 acres of Bay bottom (6.9 square miles) have been im-

pacted by human activity. This represents more than 13 percent of the total estimated area of the Bay under consideration.

The majority of the disturbed bottom areas were found in shallow water adjacent to the shoreline. However, several locations were further from shore, areas that apparently served as borrow sites for fill material. *Figure 1* illustrates a disturbed-bottom map for a portion of the Sarasota Quadrangle, containing Bay segments 9, 10 and 11. Most of these features are not recognizable from water level, but become apparent from an aerial perspective.

Seagrasses

Seagrass habitat area by Bay segment is presented in *Table 2.* A total of 8,318 acres (13 square miles) of Bay bottom were characterized as seagrass habitat. With the exception of the City Island segment (10), the majority of high-quality seagrass habitats were contained in the north Bay. The role of Gulf influence in maintaining abundant seagrasses was obvious.

Seagrass Coverage Trend Analysis - Selected Sites

A trend-analysis comparison of the seagrass mapping conducted in 1987 for Sarasota County (Mangrove Systems, Inc. 1988) with the current project was conducted for the New Pass area. *Figures 2* and *3* illustrate seagrass coverages for the 1987 project (using 1984 aerials) and the present study (1988 aerials) respectively. *Table 3* shows the changes in the categories of seagrass coverage. The same categories of seagrass density (dense, sparse/medium and patchy) were used for both mapping products. Areas of sparse to medium coverage are designated "1" (light to medium color on aerial photo), areas of dense grass are labeled as "2" (very dark on aerial photo) and areas of small patches are listed as "3" (numerous small dots on aerial photos). From 1984-88 seagrass habitat in this area had a net gain of approximately 19 percent, due primarily to increases in the patchy (+149 percent) and sparse (+45 percent) classifications. The dense category declined by 9.4 percent.

Some interpretative error doubtless comes into play, but real gains in coverage are apparent on the flood-tide shoal and in the deeper waters off the eastern and southeastern edge of City Island. Over the course of the project a relatively large die-off of a portion of the large central *Thalassia* meadow of the City Island segment was noted. Sometime between November 1988, when the SWIM aerials flights were con-

Area of disturbed Bay bottom by Bay segment.

See text for description.

Segment	Description	Aerial Nos.	Area Acres	Percent of Segment Area
1	Anna Maria	606, 688, 690	512.9	28.6
2	W. Palma Sola	688, 690, 692	583.3	26.8
3	E. Palma Sola	768, 766	380.8	21.3
4	Longboat Pass	692	167.6	NA *
5	N. Longboat	692, 772	219.1	9.5
6	Tidy Island	692, 768, 772, 942	440.0	9.4
7	Mid-Longboat	774, 860	247.5	4.4
8	E. Sarasota B	942, 944	162.2	4.8
9	New Pass	948	157.9	82.2
10	City Island	949 & 2014	706.1	21.7
11	Ringling Bridge	2008, 2010	436.0	17.9
12	Big Pass	950	299.0	66.7
13	Philippi Creek	2014	92.9	NA **
14	Roberts Bay	2014 & 2018	313.8	20.4
15	Little Sarasota Bay	2018, 1256, 1258 & 1260	238.2	13.3
16	Midnight Pass	1258 & 1256	65.2	50.9
17	Blackburn Bay	1260 & 1369	31.8	4.1
		TOTAL:	5,054.3	15.5
TOTAL NOT INCLUDING EXISTING PASSES:			4,429.9	13.5

* Not calculated due to different areas used in segmentation.
** Not calculated.

Table 1. The area of disturbed bottom for each Bay segment, and an estimate of the percentage of the total area of each segment that has been impacted. Areas include canal systems.

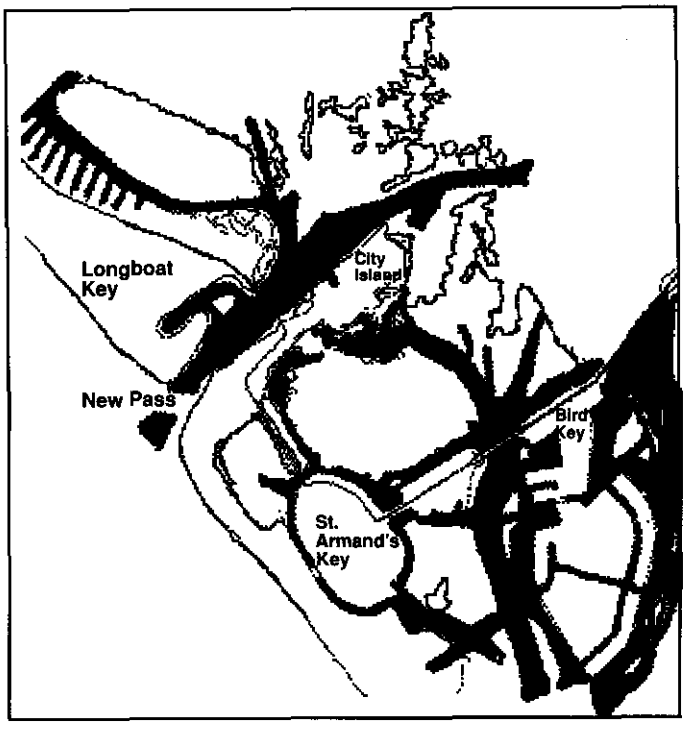


Figure 1.
A disturbed-bottom map for a portion of the Sarasota Quadrangle, containing Bay segments 9, 10 and 11.

Table 2. Seagrass habitat area by Bay segment.

Area of seagrass habitat by Bay segment.

See text for description.

Segment	Description	Aerial Nos.	Area Acres	Percent of Segment Area
1	Anna Maria	606, 686, 688, 690	909.8	50.8
2	W. Palma Sola	690, 688, 686	1,101.7	50.6
3	E. Palma Sola	768, 766	624.4	34.8
4	Longboat Pass	692	30.3	23.7
5	N. Longboat	692, 772, 774	513.2	22.3
6	Tidy Island	692, 772, 770, 856	1,665.0	35.6
7	Mid-Longboat	774, 860, 858	712.7	12.7
8	E. Sarasota B	942, 944	225.9	6.7
9	New Pass	948	7.2	3.8
10	City Island	948, 950, 2010	1,038.4	32.0
11	Ringling Bridge	2010	134.4	5.5
12	Big Pass	950	10.4	2.3
14	Roberts Bay	2014 & 2018	257.8	16.8
15	Little Sarasota Bay	2018, 1260, 1258	646.9	36.1
16	Midnight Pass	1256	126.0	48.8
17	Blackburn Bay	1260, 1262, 1369	314.4	40.9
		TOTAL:	8,318.5	

1. Not calculated due to different areas used in segmentation.

ducted, and the summer of 1991, when ground truthing was initiated, a portion of the meadow died and as of June 1992 had not revegetated.

Submerged Aquatic Vegetation (Seagrasses and Algae)

Submerged aquatic vegetation (SAV) refers to seagrasses and rhizophytic algae, and also to accumulations of drift algae where these are management issues. Seagrasses, which form conspicuous and highly productive meadows throughout the Sarasota Bay estuary, have long been recognized as an important estuarine resource, both as a food source and as habitat for fish and benthic invertebrates.

The importance of seagrasses to the ecology of estuarine systems is well-established and manifested through a host of valuable attributes. Through their complex physical structure, seagrass meadows serve as habitat by providing shelter for both adult and juvenile crabs, shrimp and fish. Seagrass blades act as a substrate for an entire community of marine organisms, including microalgae, microinvertebrates, protozoa and diatoms. Herbivores that graze directly on the seagrass blades include fishes, manatees, sea turtles and sea urchins, while the attached epiphytes provide a valuable food source for a host of other marine life. Dead leaves and epiphytic growth falling to the Bay bottom make up the majority of the material in the detrital food web.

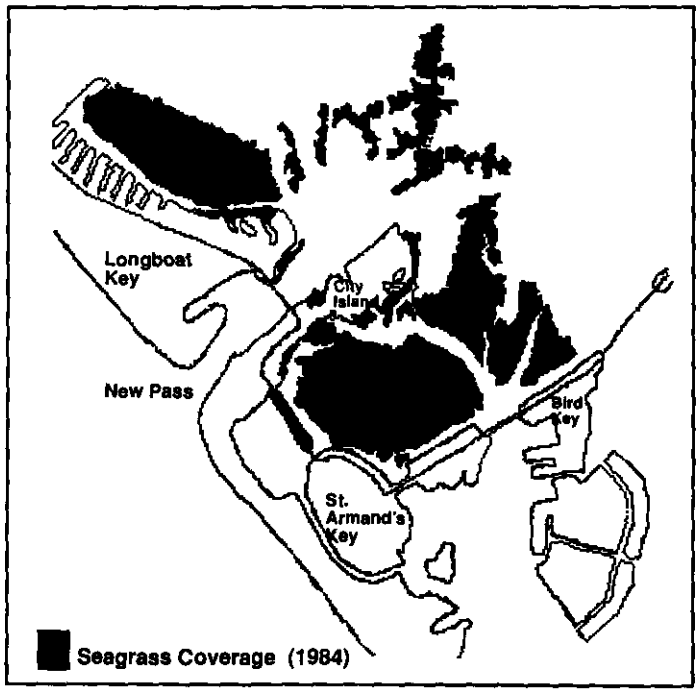


Figure 2. Seagrass coverages for the 1987 aerial photo-interpretation project (using 1984 photography) for the New Pass area.

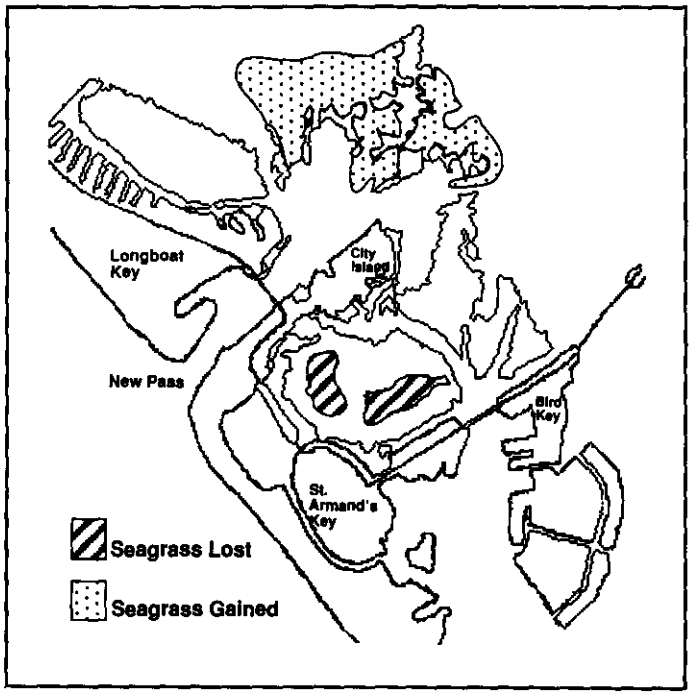


Figure 3. Seagrass coverages for the present aerial photo-interpretation project (using 1988 photography) for the New Pass area.

Seagrass leaves slow the water current and promote the deposit of organic and inorganic particles in the water column; their presence also inhibits the resuspension of sediments. Roots, runners and rhizomes form an interlocking grid that tends to lock in the accumulated sediments and retard erosion of the Bay bottom. The physical energy of waves and currents tends to be dissipated by the presence of seagrass leaves, helping to protect adjoining shorelines from erosion. With their photosynthetic ability, seagrasses are a major contributor of dissolved oxygen to the water column.

Finally, seagrasses play an important role in the nutrient cycle. Seagrass leaves take up dissolved nutrients from the water column, while the roots take up and store nutrients from the bottom sediments. The removal of excess nutrients improves water quality with respect to light penetration by potentially reducing phytoplankton populations.

Table 3. Seagrass coverage changes for the area defined by Figures 2 and 3, for the period 1984-88.

Seagrass coverage changes (acres)			
	dense	patchy	sparse
1984	464.9	83.1	98.3
1988	421.3	206.9	142.8
Net Change and (percent) 1984-1988 (acres)			
dense		patchy	sparse
43.63 (-9.4)		123.82 (149)	44.50 (45)

Total Coverage 1984 (MSI): 646.30 acres
Total Coverage 1988 (MML): 771.00 acres
Net Gain 1984-1988: 124.70 acres (19.3% gain)

Table 3. A trend-analysis comparison of the seagrass mapping conducted in 1987 for Sarasota County (Mangrove Systems, Inc. 1988) with the current project for the New Pass area, showing the changes in the categories of seagrass coverage. The same categories of seagrass density (dense, sparse/medium and patchy) were used for both mapping products.

Methods

Study Design

This study was designed to address several concerns relating to seagrass habitats within Sarasota Bay. One objective was to qualitatively evaluate the species composition of seagrass meadows (including attached macroalgae), including identifying meadows that were monospecific versus those with mixed seagrass assemblages.

A second issue involved describing the general condition of major grassbeds to determine their current condition or "health." Information gathered included aerial extent of the seagrass bed, relative density of seagrass species, morphometric measurements of blades and shoots, sediment characteristics and the relative cover of epiphytic growth and macroalgae.

The third purpose was to determine seasonal changes in seagrass beds and macroalgal communities. This was accomplished by making two visits to each site, one during maximum foliage (spring-summer) and another during minimum seagrass growth (winter). These data may also provide clues to short-term changes in grassbed composition.

Finally, this study attempted to relate visual observations of grassbed density (i.e., dense versus sparse) to the various biological components. Collectively, these results will help to estimate the historic loss of submerged aquatic vegetation, provide detailed descriptions of their present status and offer opportunities for seagrass-habitat restoration and protection.

Station Locations

A total of eight seagrass sites were investigated. Four locations – Whitaker Bayou, Midnight Pass, Tidy Island and Bowlees Creek – were based on areas identified by the Sarasota Bay National Estuary Program Nomination Document to be of special concern due to localized stress or nutrient enrichment. Two locations were chosen on the criterion that they were relatively undisturbed "healthy" sites; two sites in the vicinity of Longboat Pass and New Pass were also selected to address the potential for short-term changes in seagrass cover. Based on the selection criteria, the following sites were selected for seagrass evaluation accompanied by reasons for their inclusion.

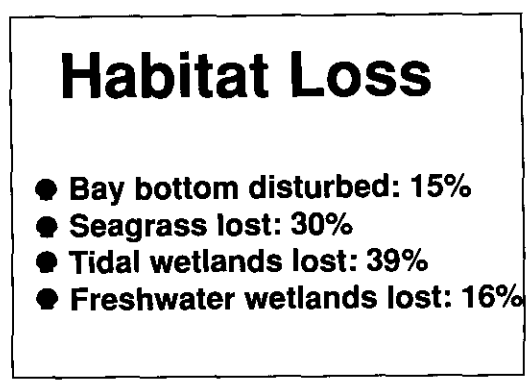


Figure 4.

Sister Keys-North
(Loran Coordinates 14179.9/44516.0). Located on the north side of the northwest island, it was representative of mid-Bay shoal/healthy fringe perennial seagrass meadows. This area constituted an undisturbed "healthy" grass bed that was also under the influence of Longboat Pass. It was located in the northern portion of the Program study area and was the most northern of the seagrass sites. This site also coincided with station 4 of the Sister Keys Conservancy study of 1990.

Sister Keys-South
(Loran Coordinates 14181.4/44502.4). This site encompassed the extensive meadows to the south-southeast of the Sister Keys. It was chosen because it represented one of the largest monospecific stands of *Thalassia testudinum* within the study area. It was considered a "healthy" meadow, and served as a control site for the Gladiola Fields/Tidy Island area to the east. This site coincided with station 8 of the Sister Keys study.

Gladiola Fields-North
(Loran Coordinates 14183.3-644502.4-5). This site was located at the northern end of the Gladiola Fields, approximately 300 meters south-southeast of Tidy Island. This site was subdivided into two sections: a nearshore "Inside" section and a section along the deeper fringe of the bed called "Outside." An additional site at the southern end of the Gladiola Fields (Loran Coordinates 14183.8-44492.1) was examined during the winter/spring sampling for comparison.

Bowlees Creek
(Loran Coordinates 14186.5-7.8/44460.0-2.2). This site was delineated by the channel markers of Bowlees Creek to the south and the channel markers for Trailer Estates to the north. Several observations were made within this area, which was also considered a "hotspot" by the Baywide monitoring program (runoff, boat traffic and contaminants). Conditions found here may well represent conditions of seagrass beds along the eastern shore of Big Sarasota Bay. Conner's 1974 study was conducted in this area.

New Pass
(Loran Coordinates 14188.2/44429.3). This site was located on the inside of New Pass to the northeast of the tip of City Island. Sampling was conducted on the largest of the seagrass beds to the north of the sandbar lining the channel. It was representative of a mid-Bay shoal/perennial seagrass meadow and was under the direct influence of New Pass. This site was near the fringing seagrass meadows studied by Dequine in 1969 along the southern portions of Longboat Key.

Midnight Pass-North
(Loran Coordinates 14167.0-1/44356.6). This site was located in a small, shallow embayment on the northeast side of the Bird Keys. Located in Little Sarasota Bay, it was within the Bay segment that includes the Midnight Pass area, situated between seagrass quadrants 1 and 2 of the two previous Midnight Pass studies.

Midnight Pass-South
(Loran Coordinates 14166.1-2/44348.1-2). This site was located in the area that has been referred to as the "Midnight Pass back-Bay area," at the southern tip of the Bird Keys, in shallow water just north of the channel leading to the beach at Midnight Pass.

Blackburn Bay
(Loran Coordinates 14162.7/44328.6). This site was located in the northern portion of Blackburn Bay, in a small embayment west of the ICW at Marker 29A. This area supported a large meadow of *Halodule* and was considered a "healthy" control site for this seagrass. It was also fairly representative of the grassbeds in the southern portion of the Program area..

Sampling Procedures - Qualitative Observations
At each site, seagrass meadows were surveyed for species composition, including attached and drift macroalgae; this was accomplished by extensive underwater observation. During these surveys, notes were recorded on the general condition of the entire seagrass community. The following observations were made:

- Relative density of seagrasses (and attached algae) was determined by observing the percentage of sediment visible through the canopy. Density ranged from sparse (greater than 50 percent of bottom visible) to moderate (50-25 percent of bottom visible) to dense (less than 25 percent of bottom visible).
- Relative density of drift macroalgae was determined by observing the percent of bottom visible through the algal layer. Density ranged from sparse (greater than 50 percent of bottom visible) to moderate (50-

25 percent of bottom visible) to dense (less than 25 percent of bottom visible).

- Percentage cover of epiphytes on the grass blades was estimated for each season. Values ranged from light to heavy.
- Sediment characteristics were classified as either mud, sand, shell or a combination of the three. The presence of surface features, including the presence of algal mats or flocculent layers, was noted. Biogenic activity (burrows, tubes, mounds, etc.) was recorded as well.
- *Conspicuous macrofauna* were noted along with their relative abundance.

Quantitative Measurements

Quantitative measurements were made on the two major seagrass species, *Thalassia* and *Halodule*, (when present) from each site. For *Thalassia*, shoot density was determined by random sampling with a 1/4-meter-square quadrant and counting all emergent shoots. Mean maximum blade length was calculated from 10 shoots at each station. *Halodule* shoots do not lend themselves to accurate and reliable density measurements in the field except under optimum conditions; therefore, biomass measurements for this grass were determined by dry weight of blades (including short shoots) and roots (which includes roots and rhizomes). Coring instruments (13 x 13 cm) were used to collect six replicates at each site. In the laboratory, samples were washed and gently scraped to remove loose and attached epiphytes, then split into blades and root/rhizome portions. Each portion was dried to constant weight at 105° C . Biomass values are expressed as grams dry weight per meter square.

Results and Observations

Meadow Description

Sister Keys-North. Luxuriant stands of *Thalassia*, *Halodule*, and *Syringodium* were present. Drift algae were absent in winter to very light during summer. All seagrasses were sparsely covered with epiphytes, although they were slightly heavier in the summer. Sediments were cleaner (less mud) than most of the other seagrass meadows.

Sister Keys. This site was located within the expansive *Thalassia* grassbed surrounding Sister Keys, with most of the bed extending east and south. This bed was continuous in coverage, with average to high shoot densities. Drift algae were present in isolated, large clumps. Sulphur sponges and *Mercenaria* clams were abundant. Sediment within the grass beds was muddy sand, while outside sediments were well-sorted sands (due to tidal currents through nearby Longboat Pass). Numerous propeller scars were visible throughout this meadow. No *Halodule* was present within this seagrass meadow.

Gladiola Fields. Shallow grasses nearest to shore were isolated patches of well-developed *Halodule*. These grasses graded into patches of moderately dense *Thalassia*. Drift algae, present throughout the year, was very dense throughout this section during spring and summer. Grassbeds further offshore became more continuous (less patchy) and were comprised of a mix of *Thalassia* and *Halodule*. Epiphyte loads were light (spring) to moderate (summer) and both species had long blades and well-developed root structures. The deep, leading edge of seagrasses contained a mix of *Syringodium*, *Thalassia* and *Halodule*. Many of the deeper seagrasses in this section appeared to be receding, based on changes in cover since 1988 and photointerpretation. Sediment in the deeper, unvegetated portions of this segment was moderately well-sorted sands and muddy sands.

Bowlees Creek. Unvegetated mud flats extended outward from shore for approximately 300 feet; intertidal oyster bars were common throughout this unvegetated mudflat zone. Sediment within the mud flats (including the oyster bars) was high in silt/clay content. This zone was followed by a shallow zone of pure *Halodule*, followed by a deeper zone of mixed *Halodule*/ *Thalassia*. Beyond this zone, bottom topography varied in a rise-and-swale pattern, with *Thalassia* occupying the swales and *Halodule* the rises in predominantly monotypic stands. Sediment was generally muddy sand, with coarse shell hash scattered throughout. Drift algae were moderate to heavy; seagrass epiphytes were generally light. Sampling within the Bowlees Creek grassbeds was separated into the nearshore shallow stands of pure *Halodule* ("inside") and the stands of *Halodule* from the deeper rises ("outside").

New Pass. This bed was unique in that it was established on the flood-tidal delta of a major pass. In this regard, it was similar to North Sister Keys' grassbeds. The substratum is subjected to intense transport and loading mechanisms. Both New Pass and North Sister Keys have major navigational channels along their axis. This bed contained a mixture of all major seagrass species, although *Thalassia* and *Halodule* were dominant. The bed tapered into deeper waters at its northern end. The area is not stable, with erosion of existing *Thalassia* occurring on the channel edge off Quick Point. This area is used as a shortcut from

the pass to the open Bay; as a result, the beds have suffered significant prop scarring and destabilization. The New Pass meadows appeared to have expanded, colonizing many of the bare sandy areas, over the past three years. The center of this bed was shallower and the grasses appeared less dense than those from the deeper perimeter. Consequently, one station (referred to as "sparse") was located within the shallow interior of the bed, while a deeper station ("dense") was positioned in the deeper, perimeter bed.

Midnight Pass. Stations were located within the subtidal area surrounding the Jim Neville Marine Preserve (Bird Keys). This area supported extensive monotypic *Halodule* seagrass meadows. The most dense grassbeds were found to the south and east of the Bird Keys, while more sparse beds were found in the northern portions of this segment. Since the initial surveys were conducted, in 1990 and 1991, the grass beds in this area have largely undergone a transition to *Ruppia maritima*, a seagrass species that is a rapid colonizer and is often found in brackish water.

Figure 5. *Halodule wrightii* biomass (grams dry weight/square meter) for winter 1990, for six sites within Sarasota Bay.

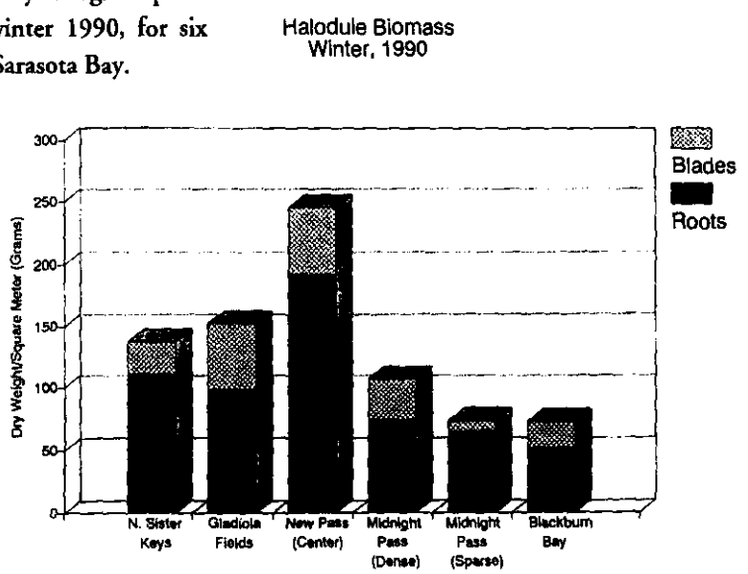
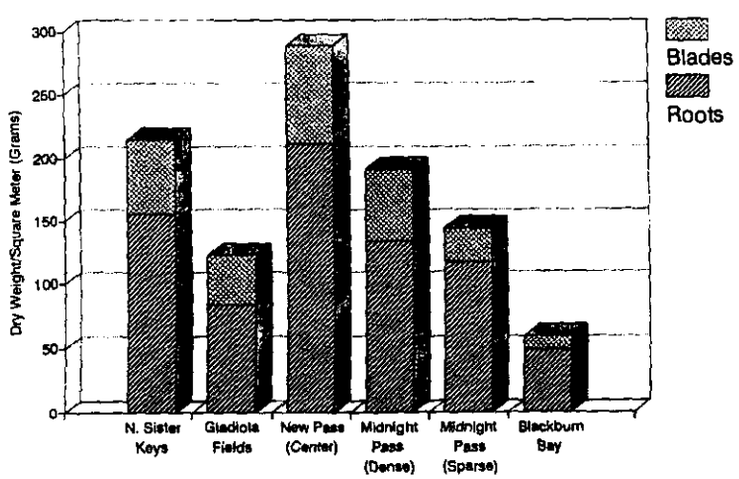


Figure 6. *Halodule wrightii* biomass (grams dry weight/square meter) for summer 1990, for six sites within Sarasota Bay.



Midnight Pass-South. Seagrasses in the southern section consisted of dense, continuous beds in deeper water and sparse patches in the shallows; because of this spatial arrangement, dense and sparse areas were sampled separately. *Halodule* from both areas had a growth of moderately heavy epiphytes, especially during the warmer months, when large "blobs" of blue/green algae were found attached to the blades. Sediments were highly variable; some areas were soft mud, others mud and sand, while others included shell fragments as well. *Diopatra* tube worms were very common among the grasses, as were, to a lesser degree, *Melongena* (common crown conch). Numerous prop scars were evident throughout these grassbeds.

Midnight Pass-North. Seagrass distribution in the northern portion was very patchy and uneven, consisting of sparse, clumped areas of seagrass. Epiphyte loads were lighter than comparable stands to the south, and few drift algae were present. Sediments in this area were extremely soft, consisting entirely of very fine sand and silt/clay.

Blackburn Bay. This shallow-water station supported the growth of a monotypic stand of *Halodule*, which was the predominant seagrass in northern Blackburn Bay. These *Halodule* beds were located near shore and behind the spoil bars created during dredging of the Intracoastal Waterway. During the winter, seagrasses were moderately dense, evenly distributed and continuous, with no large patches observed. Epiphyte cover was sparse. During the summer, grass blades had medium to extremely heavy epiphytic growth and large loads of blue/green algae. Seagrass cover was less continuous, with patches of sediment present. The attached green alga *Caulerpa aschmedii* were present during summer. Drift algae were sparse, and few conspicuous macroinvertebrates were present, except for the crown conch (*Melongena corona*).

Halodule Condition

Dry weights of *Halodule* during the winter of 1990 are presented in *Figure 5*. Total grass biomass (blades and roots) was highest at New Pass (245.36 grams dry weight/square meter) and lowest at Blackburn Bay (73.02 g dry wt/m^2). Total biomass was low at the Midnight Pass (sparse) station (73.53 g dry wt/m^2). Stations in the northern project area (N. Sister Keys and Gladiola Fields) had similar, relatively high total biomass during the winter. Roots

comprised the majority of plant biomass. Root biomass ranged from a low of 65 percent of total biomass at the Gladiola Fields station to a high of 89 percent at Midnight Pass (sparse).

Dry weights of *Halodule* during the summer of 1990 are presented in *Figure 6.* New Pass had the highest total plant biomass (288.73 g dry wt/m^2); Blackburn Bay had the lowest (59.92 g dry wt/m^2). North Sister Keys and Midnight Pass (dense) had similar total biomass (191.41 and 214.84 g dry wt/m^2, respectively). Overall, the percentages of total plant biomass attributable to roots during summer were similar to values recorded during the winter. Root biomass ranged from a low of 68 percent at the Gladiola Fields to a high of 81 percent at both Blackburn Bay and Midnight Pass (sparse).

Seasonal differences in *Halodule* blade biomass (grams dry weight/square meter) are shown in *Figure 7.* While most stations had higher blade biomass in the summer, two stations (Gladiola Fields and Blackburn Bay) had higher blade biomass in the winter. From winter to summer, the greatest relative gain in blade biomass occurred at Midnight Pass (sparse) (+230 percent), followed by North Sister Keys (+119 percent) and Midnight Pass (dense) (+72 percent). Blackburn Bay experienced a 48-percent relative loss of blade biomass from winter to summer.

Seasonal comparisons of *Halodule* root biomass (grams dry weight/square meter) are shown in *Figure 8.* Station differences and seasonal changes in root biomass were similar to differences in blade biomass. *Halodule* from the Gladiola Fields and Blackburn Bay exhibited net losses in root dry-weight biomass from winter to summer, while all other stations showed increases. Seasonal changes in relative root biomass were less dramatic than changes in blade biomass. The greatest change in root biomass occurred at both Midnight Pass stations: +80 percent at the dense site and +79 percent at the sparse site. Very little change occurred in root biomass at the Gladiola Fields and Blackburn Bay.

Shoot density of *Halodule* was determined for the summer sampling period. Results are shown in *Figure 9.* The highest shoot density (5920/m^2) was found at the inside grassbed at Bowlees Creek. Several stations had relatively high shoot densities (3500-400/m^2): New Pass (center), North Sister Keys and Midnight Pass (sparse). Lowest densities were found at stations in the southern portions of the study area.

Average blade *Halodule* length is shown in *Figure 10.* Blade length was not determined for grassbeds in the southern regions. Average blade length was greatest for the deeper grassbeds from Bowlees Creek and New Pass; all other stations had similar blade lengths.

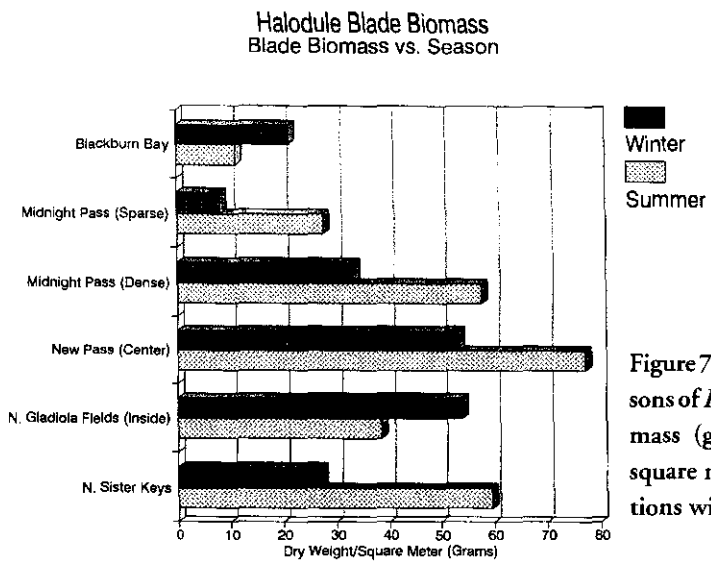


Figure 7. Seasonal comparisons of *Halodule* blade biomass (grams dry weight/square meter), for five stations within Sarasota Bay.

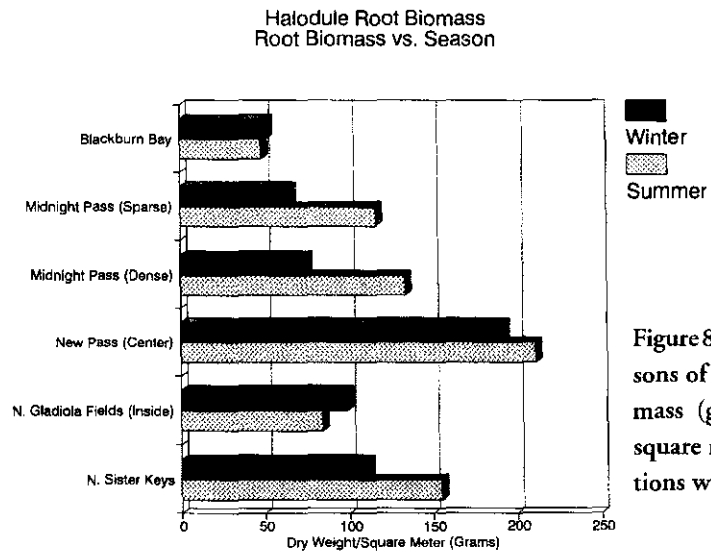


Figure 8. Seasonal comparisons of *Halodule* root biomass (grams dry weight/square meter), for five stations within Sarasota Bay.

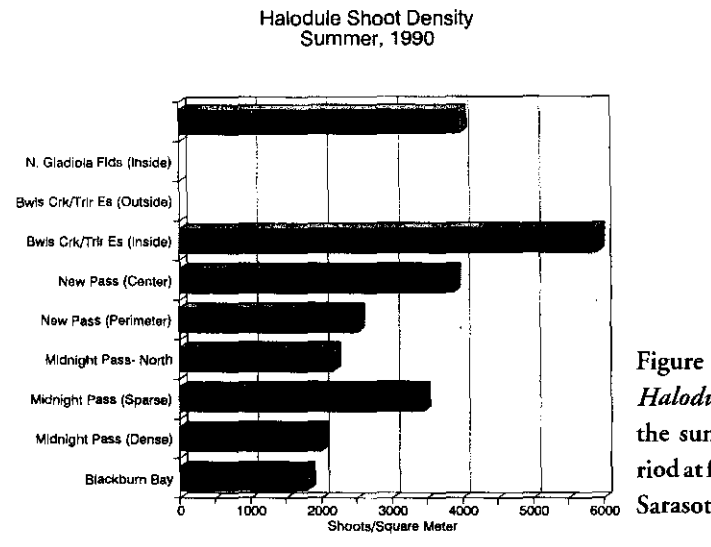


Figure 9. Shoot density of *Halodule* determined for the summer sampling period at five locations within Sarasota Bay.

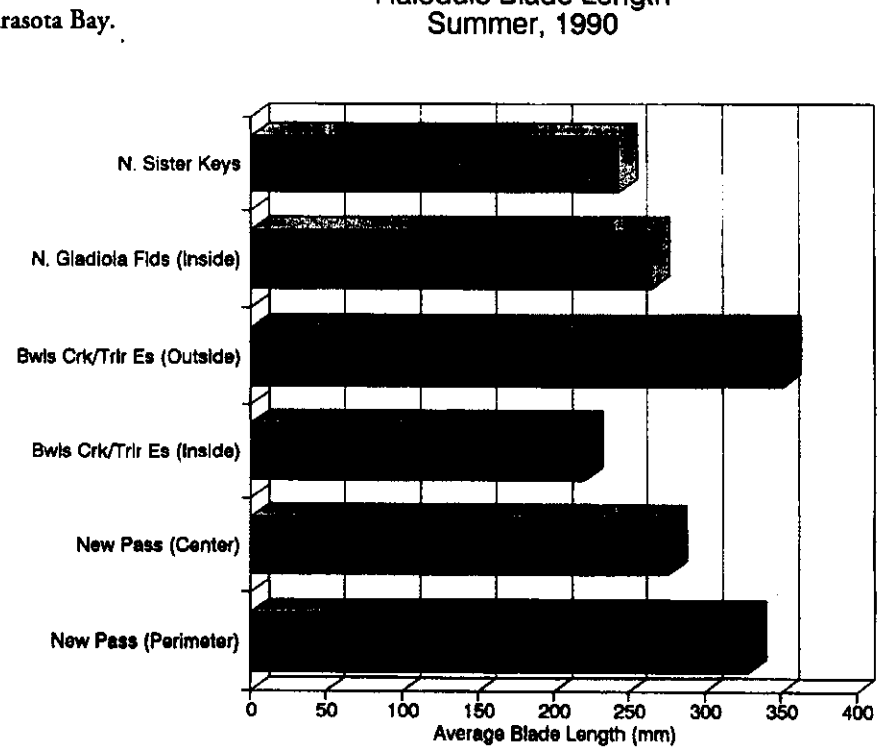
Thalassia Condition

Short shoot densities of *Thalassia* for summer and winter 1990 are shown in *Figure 11.* In winter the greatest densities coincided with qualitatively "dense" grassbeds from Bowlees Creek (429 shoots/square meter) and New Pass (413 shoots/square meter). Correspondingly, "sparse" meadows from Bowlees Creek and the Gladiola Fields had the lowest densities (136 and 168 shoots/square meter, respectively). Relative station values of summer short shoot densities corresponded to winter values. Dense grassbeds from Bowlees Creek had the highest summer densities (2,848 shoots/square meter). High densities were also found at North Sister Keys (1,968 shoots/square meter) and New Pass (dense) (1,766 shoots/square meter). Low shoot densities were found at "sparse" *Thalassia* meadows throughout the study area as well as at South Sister Keys (989 shoots/square meter).

A comparison of shoot densities between winter and summer shows in all cases that summer densities were higher than winter densities *(Figure 11).* Overall shoot densities for the study area increased by roughly 65 percent. Dense grassbeds from the Gladiola Fields exhibited the greatest relative increase (98 percent) from winter to summer; shoot densities from New Pass dense beds, on the other hand, increased only seven percent during the same period. In terms of absolute densities, dense grassbeds from Bowlees Creek showed the largest increase.

Seasonal changes in maximum *Thalassia* blade length from these same grassbeds were much more dramatic *(Figure 12).* Average blade length from all stations during winter was 15 cm; average summer blade length was 42 cm. Dense beds from Bowlees Creek had the shortest blades (especially during the summer) followed by Gladiola Fields (sparse). All other stations had very similar blade lengths.

Figure 10. Average blade length for *Halodule* for six sites within Sarasota Bay.



Seagrass Faunal Utilization

A seagrass faunal survey was recently conducted for select seagrass beds within the study area. This study (Leverone and Marshall, 1992) was designed to provide data on the utilization of seagrass meadows by local populations of fish and invertebrates. Habitat utilization is a critical link between habitat structure and environmental factors such as water quality and circulation. Additional data on the faunal component of seagrass beds throughout the study area would help to establish the functional role of these habitats and provide a clearer basis for the development of the Framework for Action.

This survey focused on shallow (less than one meter water depth), monospecific stands of turtle grass (*Thalassia testudinum*) and shoalgrass (*Halodule wrightii*). For each seagrass species, two beds exhibiting lush, dense growth served as control sites, while two beds with abundant epiphytic algae and macroalgae served as "stressed" or impacted sites. The selection of study sites was determined by a review of field notes taken during the Bottom Habitat Assessment seagrass surveys conducted during 1990 and by reconnaissance trips by Mote Marine Laboratory scientists and Dr. David Tomasko of the SBNEP office. The seagrass faunal survey was conducted during May 1992.

In summary, this survey showed no difference in abundance of fauna (crabs, shrimp and fish) between stressed and lush beds of *Thalassia,* while very large differences were noted between stressed and lush beds of *Halodule.* These differences were largely due to the greater abundance of caridean shrimp in the healthy beds as compared to the stressed beds, most likely due to the recurrent, low dissolved-oxygen levels found in meadows overgrown with algae.

Sediment Distribution

Grain size analysis was conducted for more than 100 surface sediment samples taken throughout the Bay. This type of analysis reveals the various proportions of shell, coarse sand, medium sand, very fine sand and silt/clay

material. Samples of the distributional trends in surface sediment structure are represented by the pie diagrams illustrated in *Figure 13.* The sites from which the samples were obtained are illustrated in *Figure 14.*

Grain size is primarily determined by the physical forces in an area. Dredged areas tend to have a much finer overall grain size (depending on depth and circulation) than do natural open bay areas. The ability of seagrass beds to trap fine particulate material was also illustrated.

Discussion

Seagrasses

Sarasota Bay supports five of the seven species of seagrasses known in Florida: *Thalassia testudinum* (turtle grass), *Syringodium filiforme* (manatee grass), *Halodule wrightii* (shoal grass), *Ruppia maritima* (widgeon grass) and *Halophila engelmannii* (star grass). Furthermore, seagrasses form five different types of meadows in our area which have been defined and illustrated by Lewis (1985). These meadow types are: 1) mid-bay shoal perennial, 2) healthy fringe perennial, 3) stressed fringe perennial, 4) ephemeral, and 5) colonizing perennial. Healthy and stressed fringe perennial meadows are the most common types in Sarasota Bay, and extend from the mean low-water mark into water depths of approximately six feet below mean low water.

Losses of seagrass have been documented throughout the region, and have been attributed to two principal factors: direct mechanical destruction by dredge-and-fill and boating operations, and indirect losses due to deteriorating water quality. Changes in water quality can be attributed to multiple causes associated with coastal development. Losses of upland and wetland vegetation affect the rainwater-runoff filtering capacity. Expansion of agriculture and industrialization increase sedimentation and suspended particles in the water column; urbanization generates wastewater- and stormwater-disposal problems. Dredging causes long-term release of fine sediments into the Bay environment and restructures circulation patterns (Haddad, 1989).

In Sarasota Bay, barring direct physical impacts, seagrass meadows decline in diversity and abundance at an increasing distance from open Gulf waters.

The observed increases of seagrass coverage on the New Pass shoal and east and southeast deep-water areas off City Island can be interpreted with cautious optimism as a result of improved water quality due to advanced wastewater treatment and reduced nutrient and sediment loads from Whitaker Bayou.

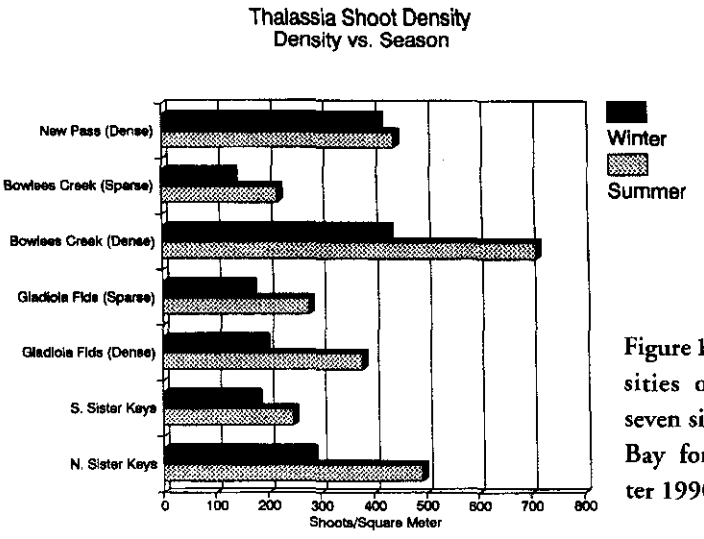


Figure 11. Short shoot densities of *Thalassia* from seven sites within Sarasota Bay for summer and winter 1990.

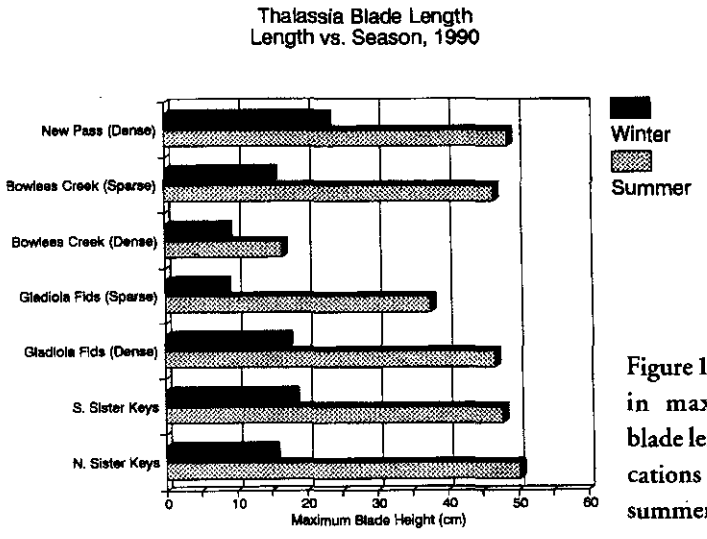
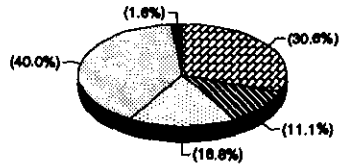


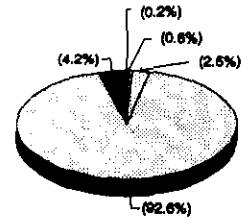
Figure 12. Seasonal changes in maximum *Thalassia* blade length from seven locations in Sarasota Bay, for summer and winter 1990.

Halodule

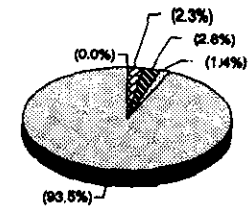
- *Halodule* was found within meadows where it is typically reported – along fringes and in shallows.
- Root systems were most developed at New Pass, which may help secure the grasses in this shifting environment.
- Grasses were more developed in open, northern regions of the Bay, more so during winter. During summer, the Gladiola Fields area appeared "depressed" with respect to other grassbeds.
- The Blackburn Bay beds, although moderately extensive, were the least developed in terms of standing crop.
- Blade length was greater at deeper stations; grasses may be limited by mean low water, even though their blades have the ability to lay over during low tides. Shallow



S. Blackburn Bay
Intracoastal Waterway

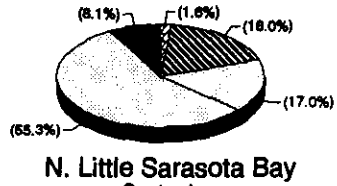


Manatee Av Bridge

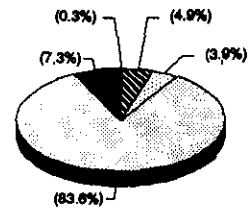


Jewfish Key
Channel near grassbed

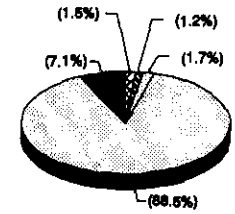
Samples from areas of high water flow illustrating coarser sediments with relatively low levels of silt/clay material.



N. Little Sarasota Bay
Oyster bar



Sarasota Bay
Open bay



Jewfish Key
Seagrass meadow

Samples from areas of moderate water circulation. Note the trapping effect of fine particulates in the seagrass bed of Jewfish Key compared to the channel area of adjacent to the grassbed (above).

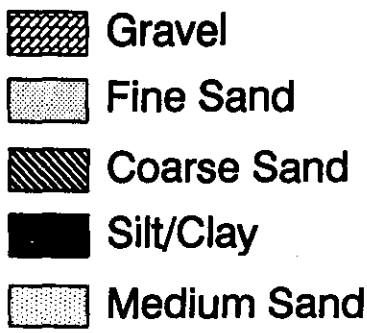
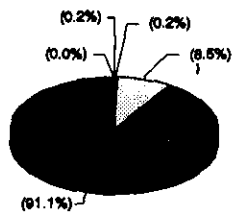
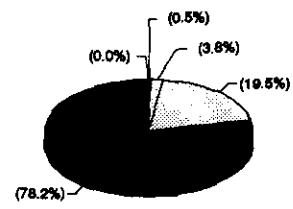


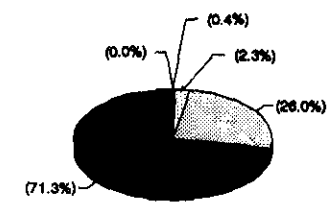
Figure 13. Examples of surface-sediment grain size composition for select locations within Sarasota Bay.



Leffis Key
Hole near boat ramp



Whitaker Bayou
Inside channel



Hudson Bayou
50 m from Orange Av

Samples from dredged locations that now serve as sinks for fine particulates, illustrated by the high percentage of silt/clay material.

water beds seemed to have higher shoot densities. Grasses along the perimeter of beds were observed to be more sparse or patchy.

• Winter conditions were mild during 1990. Sampling did not take place until March. Grasses had an early start to the growing season, and no severe dieback from winter storms (from prolonged exposure during lower low tides) was noted. However, seasonal increase in seagrass biomass during summer is typical. Changes in Blackburn Bay and the Gladiola Fields area (Blackburn Bay because of reduced circulation and flushing, Gladiola Fields due to fetch during summer) may be due to severe conditions during summer. Heavy epiphyte loads and drift algal cover may stress these grasses during summer, while conditions for high standing crop during winter are better.

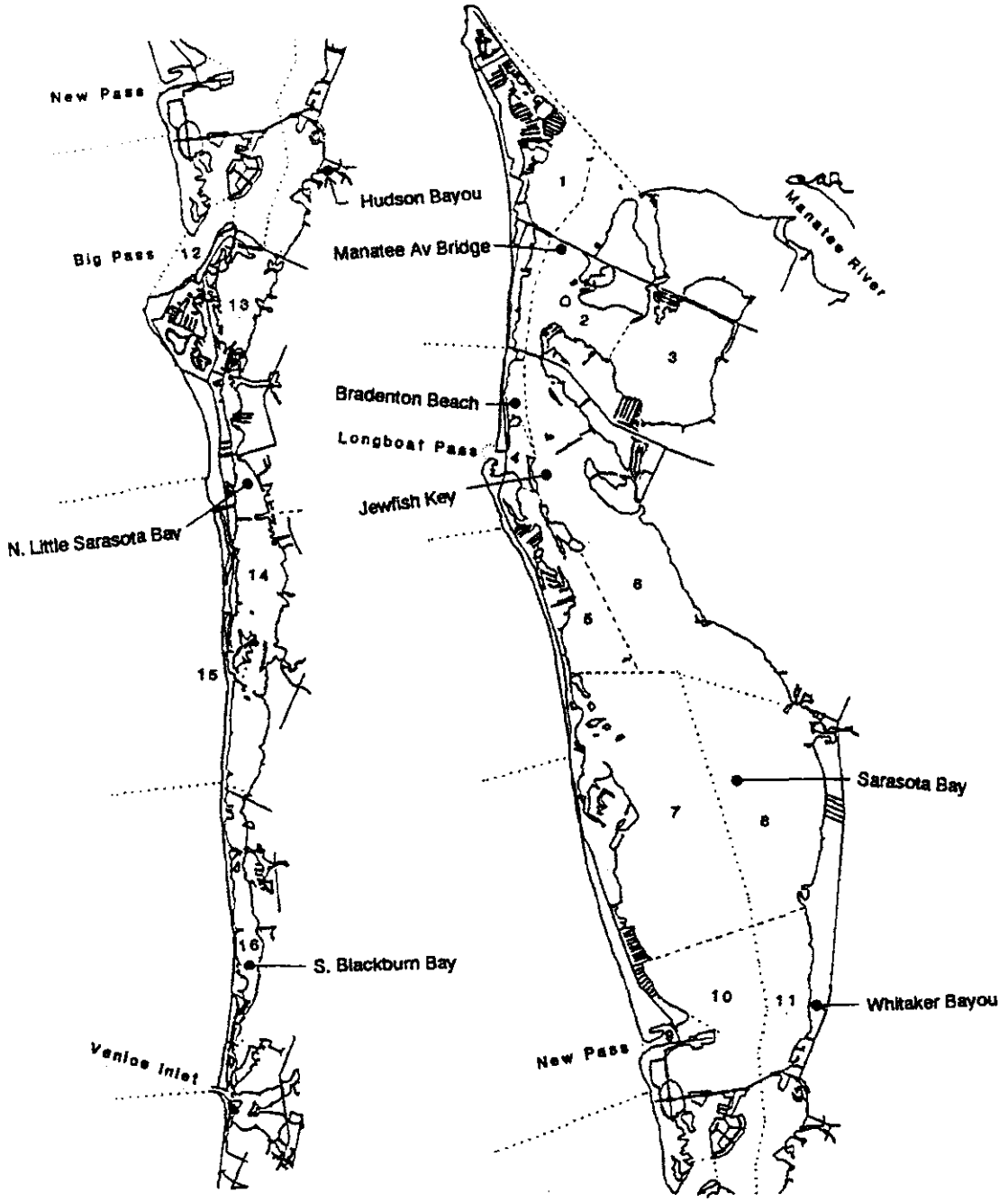


Figure 14. Map showing the locations from which the samples illustrated in *Figure 13* were obtained.

Thalassia

• Low shoot densities from South Sister Keys reflected the conditions observed at this meadow during field surveys. This meadow did not have dense clumps, patches or fringes of *Thalassia.* Cover was continuous throughout the meadow, with much of the substratum visible through the canopy. Numerous prop scars cut through this meadow, although no effect on the arrangement or distribution of short shoots was apparent. This meadow would probably benefit from a signage program similar to those instituted in other regions of the study area.

• *Thalassia* blade lengths were very reduced during winter. During this time, seasonally low tides expose *Thalassia* beds, causing blades to break off. However, underground components (roots and rhizomes) typically survive such exposure. Shoot densities were not as drastically reduced during winter, as was noted for *Halodule.*

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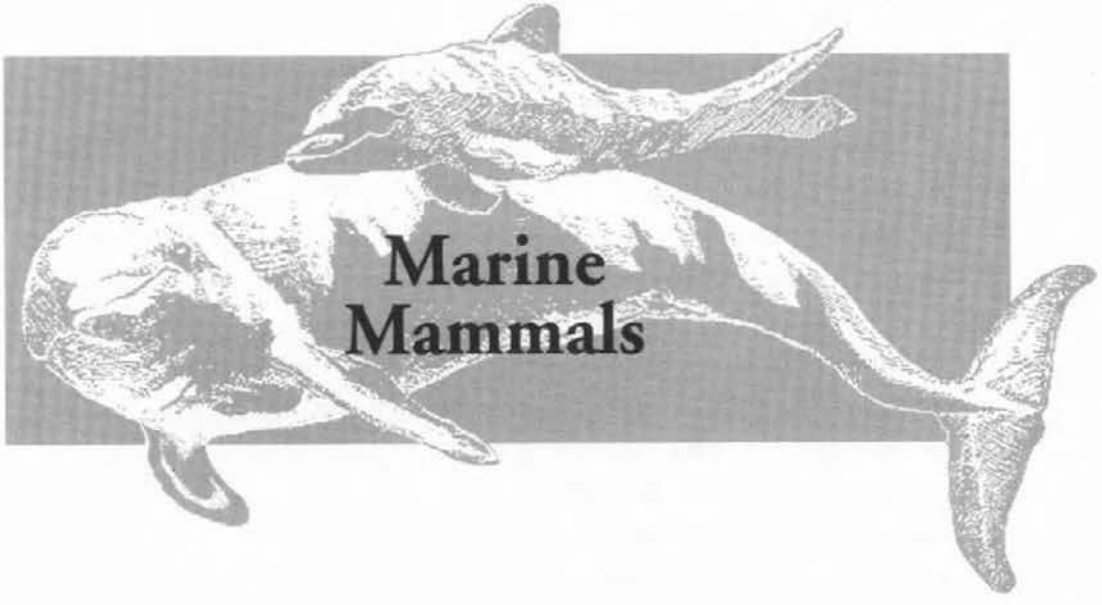


Marine Mammals

The Marine Mammals of Sarasota Bay

by Randall S. Wells, Ph.D.
Chicago Zoological Society and
Mote Marine Laboratory

Executive Summary

Two species of marine mammals inhabit Sarasota Bay on a regular basis: the Atlantic bottlenose dolphin, *Tursiops truncatus*, and, in smaller numbers, the West Indian manatee, *Trichechus manatus*.

The Sarasota Bay NEP study area forms much of the home range of a year-round resident population of approximately 100 bottlenose dolphins of all ages and sexes. Rates of immigration and emigration for the Sarasota dolphin community are low, about three percent, although the area is occasionally visited by dolphins from other communities. The resident community's home range includes shallow inshore waters extending southward from the southern edge of Tampa Bay to Siesta Key. Seasonal variations in dolphin distributions within the home range are correlated with changes in the distribution and abundance of prey and potential predators, and with the dolphins' reproductive season. Throughout the year, dolphins' use of the open waters of Sarasota Bay, especially in the highly altered southeast portion, appears to be much less frequent than most other portions of their home range. Differential use of habitats within the home range has been reported for different age and sex classes.

Manatees are reported in small numbers in the Sarasota area during much of the year, but are most abundant from mid-spring through early autumn. Several areas of preferred use have been identified as a result of Mote Marine Laboratory's aerial surveys over the past six years.

The marine mammals of Sarasota Bay face a number of potential threats. During 1991-92, two to three times the normal number of dolphins died along the central west coast of Florida. In most cases the cause of death has not yet been determined, pending analyses of stored tissues.

Increased coastal development has resulted in habitat degradation, which in turn could have direct and indirect detrimental effects on the mammals. Pollutants, in the form of organochlorine compounds such as

pesticide residues and heavy metals, have been found to accumulate to dangerous levels in the tissues of bottlenose dolphins in other parts of the world, and initial findings indicate that high levels of contaminants such as mercury occur in Sarasota dolphins as well. Boat traffic has resulted in injuries or mortalities from collisions, especially in the case of manatees. During the period 1985-92, 13 of 34 manatee deaths in the study area were attributed to boat collisions. The possibility that boat traffic may result in acute or chronic disturbance responses by dolphins, in the form of shifts in habitat use or other behavioral changes, as have been reported for other marine mammals elsewhere, remains to be examined systematically. Dolphins occasionally become entangled in fishing gear by accident and drown, but most activities resulting in these mortalities take place in the coastal Gulf of Mexico. The reproductive potential of the Sarasota dolphin community may have been diminished due to commercial live-capture operations during the 1960s-70s. A quota for live capture of up to seven dolphins each year from the Gulf coastal waters included in the home range of the resident Sarasota dolphin population still exists.

Two kinds of studies are strongly recommended. Existing census programs for dolphins and manatees in the study area should be continued, to establish a baseline against which changes in distribution and abundance can be assessed. The data from these censuses should be integrated with data from research programs monitoring the quality of the Sarasota Bay environment. Thus it may be possible to use top predators such as bottlenose dolphins as biological indicators of changes in the environment. Systematic studies of the potential impacts of human activities on the mammals should also be conducted, and contingency plans developed to mitigate these impacts.

The Marine Mammals of Sarasota Bay

Randall S. Wells, Ph.D.
Dr. Wells coordinates the Marine Mammal Program of Mote Marine Laboratory and is a conservation biologist with the Chicago Zoological Society in Brookfield, IL. Dr. Wells also is an adjunct assistant professor of Marine Sciences at the University of California, Santa Cruz and a guest investigator at the Woods Hole Oceanographic Institution. Much of his present research examines the behavior, ecology, health and population biology of bottlenose dolphins along the central west coast of Florida. Dr. Wells received his B.A. in Zoology from the University of South Florida and his M. Sc. in Zoology from the University of Florida. He received his Ph. D. in Biology from the University of California, Santa Cruz and was awarded a postdoctoral fellowship in biology at Woods Hole Oceanographic Institution.

Introduction

One measure of the health of an ecosystem is the status of the members of its highest trophic levels, the top-level predators. In terrestrial ecosystems these levels are occupied typically by mammals; in marine ecosystems the higher trophic levels are composed largely of carnivorous fish and seabirds, but marine mammals are nonetheless considered among the most important consumers.

Two species of marine mammals inhabit Sarasota Bay on a regular basis. The piscivorous, or fish-eating, Atlantic bottlenose dolphin (*Tursiops truncatus*) is relatively abundant in the area throughout the year. The West Indian manatee (*Trichechus manatus*), a highly endangered herbivore, is found in the area in small numbers seasonally.

The home range, social, health and demographic patterns of bottlenose dolphins are known in greater detail for the dolphins in and around Sarasota Bay than for any other study site in the world. The bottlenose dolphins of the Sarasota area have been the focus of a research program initiated in 1970 and continuing to the present. A pilot tagging study was conducted through Mote Marine Laboratory during 1970-71 (Irvine and Wells, 1972). This work was followed by an expanded tagging, radiotracking and observational study during 1975-76, through the University of Florida (Wells, 1978; Wells, Irvine and Scott, 1980; Irvine, Scott, Wells and Kaufmann, 1981; Irvine, Wells and Scott, 1982).

Since 1980, work conducted through the University of California at Santa Cruz, Dolphin Biology Research Institute, the Chicago Zoological Society, Woods Hole Oceanographic Institution and since 1990, Mote Marine Laboratory, has involved behavioral observations, censuses and a capture, sample, mark and release program to examine the demographical, social and genetical structure of the local dolphin community, as well as to monitor the health, body condition and environmental contaminant loads of individual dolphins (Wells *et al.*, 1981; Wells, 1982, 1985, 1986a, 1986b, 1989, 1991a, 1991b, 1991c; Duffield and Wells, 1986, 1991; Hohn *et al.*, 1989; Scott, Wells and Irvine, 1990; Sayigh *et al.*, 1990; Wells and Scott, 1990; Wells, Scott and Irvine, 1987).

Mote Marine Laboratory's Marine Mammal Stranding Program has been recovering stranded whales and dolphins on a regular basis in Sarasota, Manatee and Charlotte counties since 1984. Post-mortem examinations and analysis of tissue samples provide information on mortality patterns, pathologies and levels of environmental contaminants accumulated in tissues (Gorzelany *et al.*, 1991; Hofmann *et al.*, 1991; Patton, Rawson and Brooks, 1992; Buck *et al.*, 1991; Rawson *et al.*, 1991; Walsh *et al.*, 1988).

What little is known of manatees in Sarasota Bay is primarily the result of two kinds of research efforts. Aerial surveys to assess distribution and abundance of manatees were conducted by the U.S. Fish and Wildlife Service during 1979 (Irvine, Caffin and Kochman, 1982). Aerial surveys initiated by Mote Marine Laboratory in 1985 (Patton, 1986; Kadel and Patton, 1992) have continued through 1992. In addition, a statewide carcass-recovery program initiated by the U.S. Fish and Wildlife Service during 1976 has been continued by the Florida State Dept. of Natural Resources (DNR); Mote Marine Laboratory is the DNR recovery agent for the Sarasota Bay area.

The purposes of this section are threefold. First, it will review the available information on the status and habitat-use patterns of the marine mammals of Sarasota Bay. For the bottlenose dolphins this review is based primarily on data summarized for the 1987 Sarasota Bay Area Scientific Information Symposium, supplemented where possible with more recent data. For manatees, the information is based primarily on a recent summary by Kadel and Patton (1992). No marine-mammal research has been conducted specifically as part of the Sarasota Bay National Estuary Program, so the informa-

tion presented in this section is drawn from the results of research conducted for purposes other than the specific interests of the NEP. The second purpose of this section is to relate this information to the health of the Sarasota Bay ecosystem; the third is to make recommendations for future efforts to ensure the continued coexistence of humans with the other mammals of Sarasota Bay.

Bottlenose Dolphins

Data Base

The data base from which we have developed our understanding of the biology of bottlenose dolphins (hereafter referred to simply as dolphins) in the Sarasota area results from a variety of research efforts over the last 22 years. Twelve dolphins were tagged in southern Manatee and northern Sarasota counties during 1970-71. During 1975-76, radio transmitters were placed on 10 dolphins, visual tags were placed on 37 others and 12 dolphins with distinctive natural markings were monitored. We conducted boat-based censuses on 423 days from 1975-January 1984. From 1975-78, 695 dolphin schools were observed, including approximately 3,413 dolphins. During 1980-84, the period for which the data have been summarized for this review, 1,074 sightings of dolphin schools containing approximately 7,806 dolphins were recorded. We identified 466 individuals; of these, 116 were seen five or more times (up to 96 times), accounting for 49 percent of all dolphins sighted.

Observation and capture, sample, mark and release efforts have continued to date. We can now recognize more than 1,300 individual dolphins inhabiting the waters from Tampa Bay through Charlotte Harbor. As of September 1992, our database included sightings of more than 6,000 dolphin groups; individuals have been resighted in local waters as many as 328 times each. From 1984-91, we handled 133 dolphins in our capture, sample, mark and release program.

Distribution

Bottlenose dolphins have been observed in nearly all parts of the Sarasota Bay study area and adjacent waters. Several patterns of distribution have been identified for dolphins along the central west coast of Florida. Many of these animals reside in population units described as "communities," defined here as being composed of dolphins that share a given range and associate with each other to a much greater extent than they associate with dolphins from adjacent waters (Wells, 1986a,b). Three communities have been identified provisionally in the waters of Sarasota and Manatee counties: a Gulf of Mexico community, a Passage Key Inlet-Tampa Bay community and the Sarasota community *(Figure 1)*. These three communities occupy ranges that share contiguous borders, and much overlap occurs in the use of these border waters by dolphins of adjacent communities.

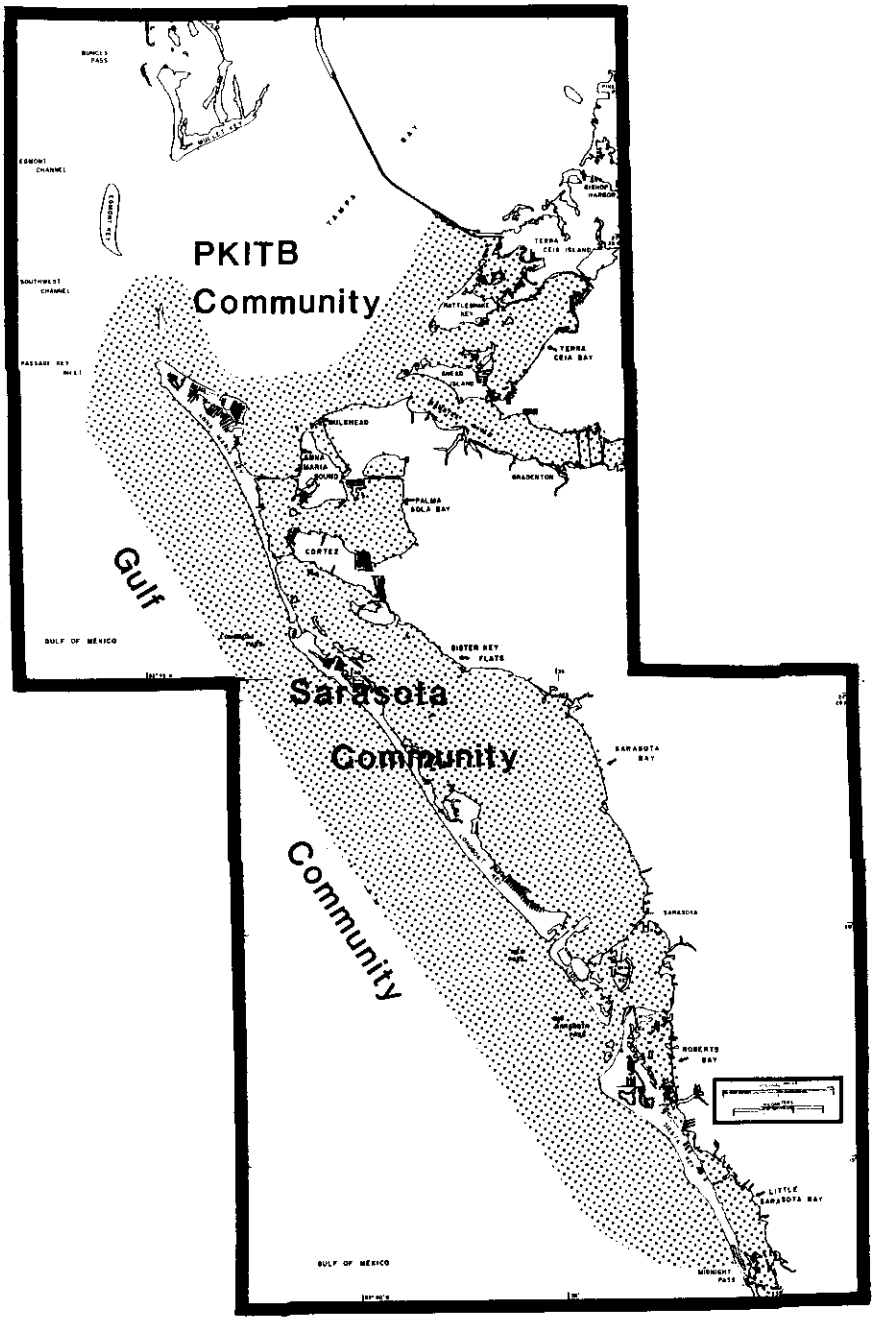


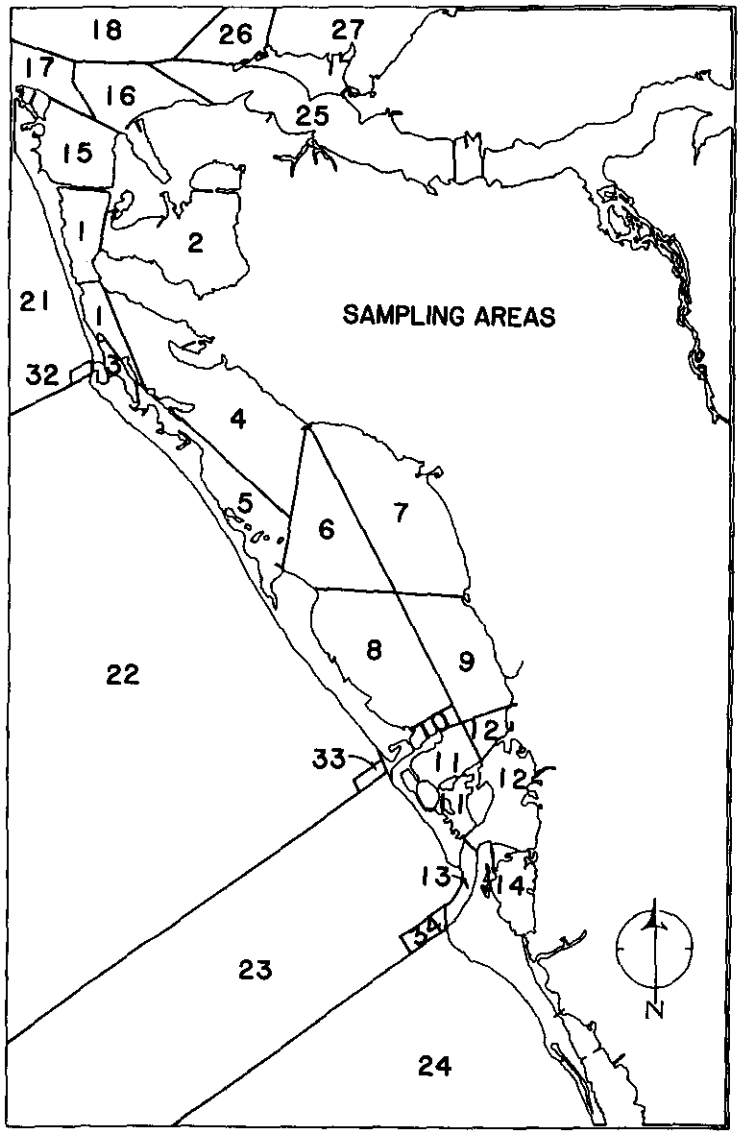
Figure 1. Approximate home range of the Sarasota bottlenose-dolphin community (shaded region) relative to adjacent dolphin communities. "PKITB" indicates the home range of the Passage Key Inlet-Tampa Bay dolphin community.

Community Home Ranges

Members of the Gulf community have been observed repeatedly, some over more than 17 years, primarily in the waters west of the barrier islands from Siesta Key northward to Anna Maria Island. Individuals occasionally penetrate the waters east of the barrier-island chain, but the vast majority of sightings is in the Gulf. The northern, western and southern bounds of the range of the Gulf community have not yet been determined.

The Passage Key Inlet-Tampa Bay community inhabits the waters to the north of Anna Maria Sound. Some members of the community were resighted throughout the region of Tampa Bay extending from Anna Maria Sound northward to Mullet Key over a period of more than 17 years. Most sightings through 1984 of dolphins in this community have been concentrated along the southern edge of Tampa Bay and especially in the vicinity of Passage Key Inlet. This was probably an artifact of our surveys, as the waters north of Passage Key were surveyed much less frequently than the waters to the south. Only the southern boundary of this community had been defined through 1984 (Wells, 1986b; Weigle, 1987), but annual surveys conducted during 1988-91 indicate that these same dolphins range regularly northward to Mullet Key, and to the east of the Sunshine Skyway. These recent surveys have identified several other dolphin communities in Tampa Bay, forming a mosaic of slightly overlapping home ranges.

Figure 2. Sampling areas used for quantitative analyses of dolphin distributions.



Of the three communities listed above, the Sarasota community has been the most intensively studied, due initially to its proximity to Mote Marine Laboratory, and subsequently to the value of enhancing an existing database. Preliminary tagging and resighting results by Irvine and Wells (1972) suggested that dolphins might be resident to the Sarasota area, and that the southern edge of Tampa Bay might form a northern boundary of their range. Intensified tagging and resighting efforts and radiotracking in 1975-76 confirmed these earlier impressions and allowed a more complete definition of the resident community's range. Since 1980, regular censuses and photographic identification have provided further evidence for the permanency of the range and refined our understanding of how the dolphins use the area.

We have identified the home range of the Sarasota community as extending from the southern edge of Tampa Bay southward to about Siesta Key *(Figure 1)*. It includes all of the shallow inshore waters from Terra Ceia Bay, southward to the approximate location of Midnight Pass, and extends one to two kilometers offshore of the barrier island chain.

The home range and composition of the Sarasota community appears to have remained stable over at least 22 years. Eleven of 12 (92 percent) dolphins tagged during 1970-71 were recaptured in the same area during 1975-76; nine (75 percent) of these were observed in the area during 1986, and eight (67 percent) were still present in 1991. Thus, some of the community members are known to have inhabited the Sarasota community home range for more than 21

years. Similarly, of 47 dolphins tagged during 1975-76, 29 (62 percent) were observed during 1986-87, and 27 (57 percent) were still present in 1991.

The waters of Terra Ceia Bay and the Manatee River were added to the description of this home range after 1976. We do not know whether this has been an actual range extension or if it was simply an artifact of slightly different survey routes during 1975-76 vs. 1980-84. The inclusion of these areas is further confirmed by the work of Weigle (1987) during 1983-84, and by our own annual surveys since 1988 and during monitoring observations of two re-introduced captive dolphins during 1990-92.

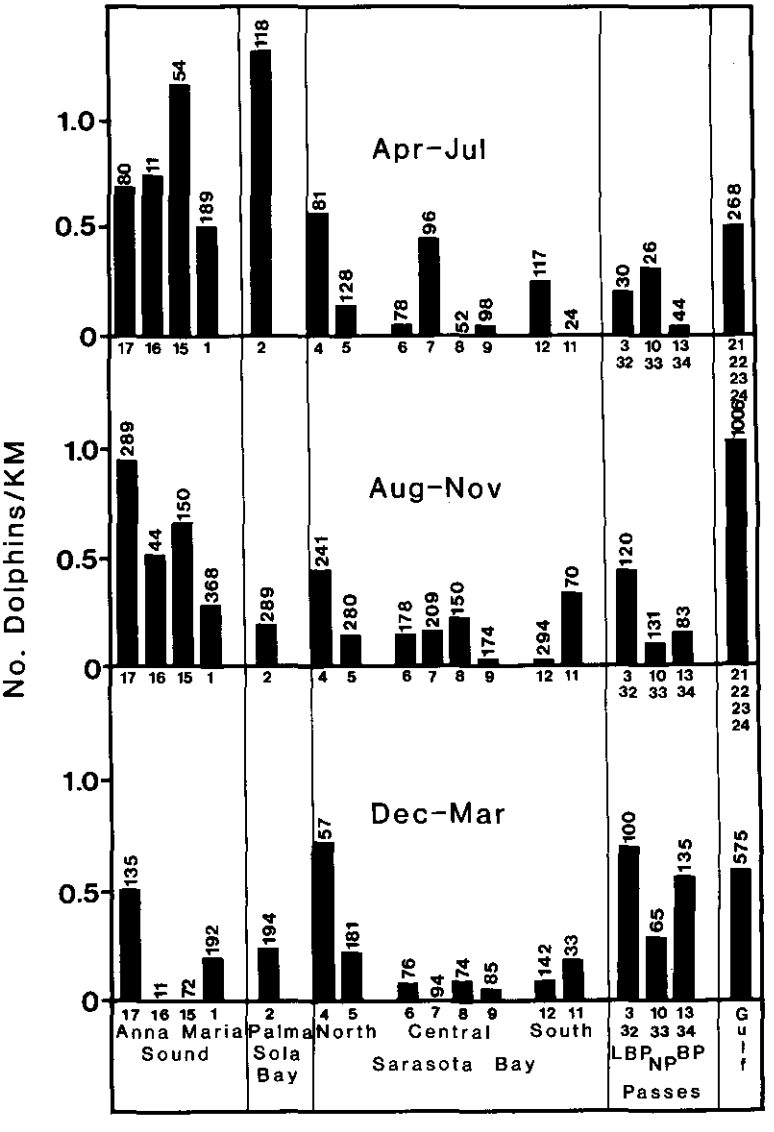
Habitat Use

The apparent stability of the home range and the consistency of resightings of identifiable dolphins over the years suggest that this range is capable of meeting the resource needs of the resident dolphin community. While resident dolphins may move through the entire home range over the course of a year, they seem to prefer some areas. In general, dolphin density is much greater north of a line from about Buttonwood Harbor, on Longboat Key, to Long Bar Point, on the mainland, than to the south. Seasonal patterns of habitat use have been identified; these patterns appear to be correlated with prey movements, the distribution of potential predators and the dolphins' reproductive condition. In addition, dolphins' use of particular parts of the area varies by age, sex and familial relationships. There also appear to be roughly inverse correlations between dolphin use of some areas and the degree of human impact in these areas.

An index of habitat use was calculated as the number of dolphins seen per kilometer of transect through designated sampling areas on 83 "complete survey days" during April 1980-January 1984. Complete survey days were those during which the boat covered at least the 25 km distance between Cortez and Siesta Key. Sampling areas *(Figure 2)* were defined on the basis of physiographic uniformity, and were delineated from adjacent areas by significant physiographic features or readily replicable artificial boundaries based on permanent landmarks. In this way, sampling areas could be categorized and compared on the basis of similarities of features. Four habitat categories were considered: (1) open Bay (areas 6, 7, 8, 9 and 18); (2) shallow areas of seagrass meadows bordering narrow channels (areas 1, 2, 4, 5, 11, 12, 14, 15, 16, 17, 26 and 27); (3) passes between barrier islands (inshore side: areas 3, 10 and 13; Gulf side: areas 32, 33 and 34); and (4) open Gulf (areas 21, 22, 23 and 24).

The number of kilometers of transect conducted within each sampling area was measured from boat routes drawn on sighting charts each day. Only the initial passage was scored if repeated passages were made through the same area within 15 minutes. Transect routes through each area were not fixed; rather, boat routes depended on a number of conditions, including tide and sea state. Different boats and variable numbers of observers with different levels of experience have been used over the years. Thus while these transects can provide a rough indication of distribution patterns, they were not appropriate for detailed statistical analyses based on line-transect theory.

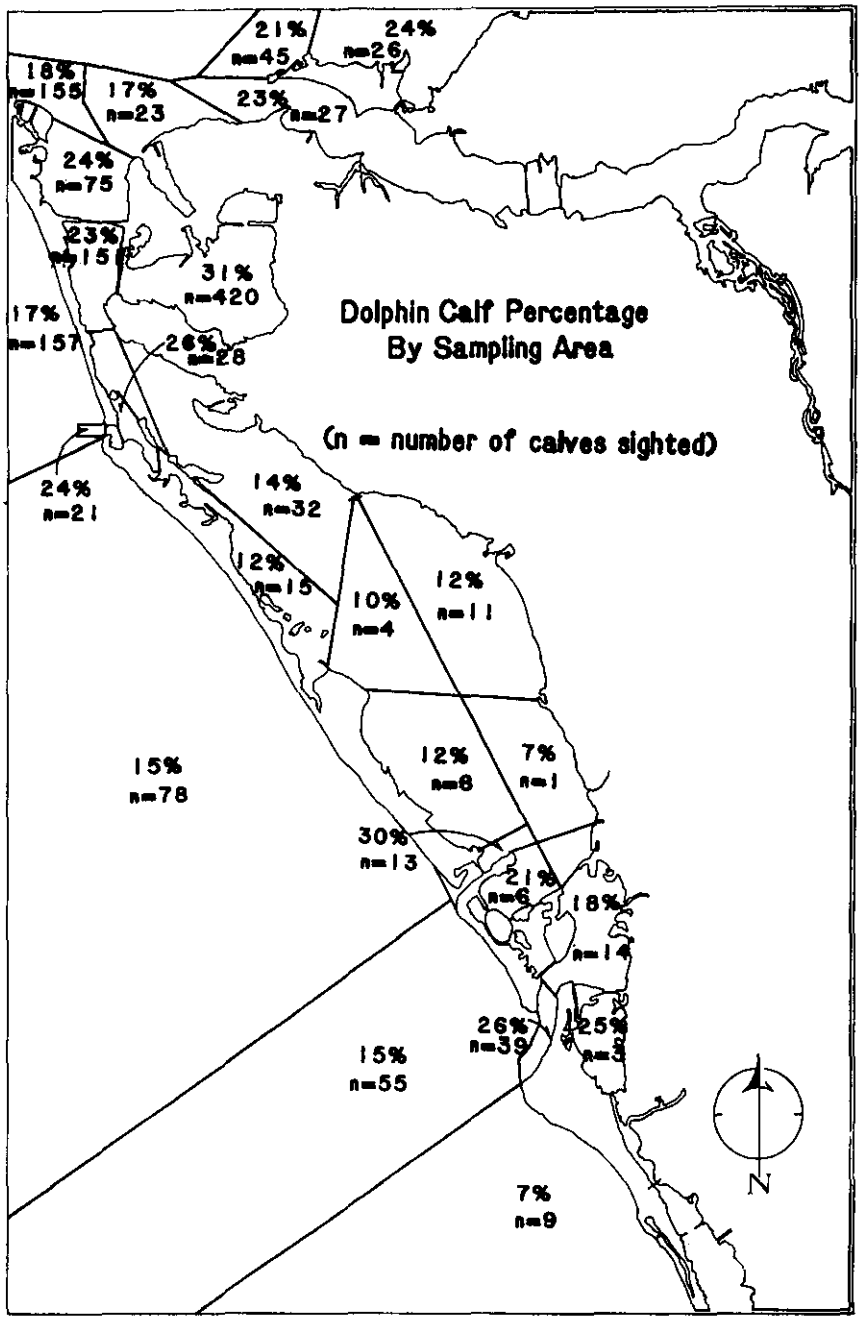
Figure 3. Index of seasonal distribution of dolphins in the Sarasota Bay area: 1980-84. Bars indicate the calculated number of dolphins seen per linear kilometer of survey transect through each sampling area. Number of transect kilometers is indicated above each bar. Sampling area number is indicated below each bar. LBP=Longboat Pass, NP=New Pass, BP=Big Sarasota Pass.



mary of the seasonal distribution of dolphins within the Sarasota home range is presented in *Figure 3*. The values shown in this figure are cumulative over all 83 complete survey days; they were calculated by dividing the total number of dolphins seen in each sampling area by the total number of kilometers traversed in each area.

The most marked seasonal variations apparent in *Figure 4* are a decrease in the index of dolphin density in many of the shallow inshore areas (e.g., Anna Maria Sound and Palma Sola Bay) during winter and spring; during this same period the density index increased for the three passes.

Figure 4. Distribution of dolphin calves through the study area: 1980-84. Calves as a percentage of the total number of dolphins in each sampling area are presented with the total number of calves recorded from each area.



A similar seasonal shift in habitat use was described qualitatively by Irvine *et al.* (1981) for the same waters during 1975-76.

Behavior patterns of an animal like a dolphin, such as seasonal shifts in habitat use, are not likely to be simple responses to a single environmental stimulus. The seasonal shift from the shallow inshore waters to the passes and their associated shallow fringing Gulf waters correlates with at least three aspects of the dolphins' ecology and biology: the movements of their prey, presence of their predators and their reproductive condition.

Habitat Use for Feeding

Bottlenose dolphins are opportunistic feeders, taking advantage of a variety of fish species as prey. A community of bottlenose dolphins can consume large quantities of fish each year. Captive adult bottlenose dolphins consume approximately 3.5-5 percent of their body weight in fish each day (personal obsevation). If we assume an average of four-percent consumption rate and a 403-lb. average dolphin weight (based on those dolphins handled in the Sarasota area during 1987-88), then the Sarasota community of about 100 dolphins consumes an estimated 588,380 lbs. of fish annually.

The three most common prey of dolphins in the Sarasota area, based on analyses of stomach contents of nine stranded residents, are pinfish (*Lagodon rhomboides*), pigfish (*Orthopristis chrysoptera*) and striped mullet (*Mugil cephalus*) (N. Barros, personal communication, May 1992; manuscript in preparation). Mullet has been described previously as the presumed primary prey of bottlenose dolphins in the coastal waters of the Gulf of Mexico (Gunter, 1942; Caldwell and Caldwell, 1972; Leatherwood, 1975; but see Barros and Odell, 1990 for a different ranking that indicates mullet to be of lesser importance in other areas). Mullet are the fish upon which we most often observe the dolphins to be feeding, and they also form the basis of the most important Sarasota Bay commercial fishery (Edwards, 1987). Approximately two to six million pounds of mullet are landed each year in Manatee and Sarasota counties, with the vast majority being caught in Manatee County (Edwards, 1987). The greatest dolphin densities are also seen in Manatee County; thus, the dolphins appear to be found in greatest numbers in the regions of greatest abundance of one of their primary prey.

The dolphins' seasonal movements appear to be correlated with those of the mullet in the Sarasota Bay area (Irvine *et al.*, 1981). During summer months mullet are found in

greatest numbers over the shallow seagrass meadows, where they feed on epiphytes associated with the grasses. At these times we observe dolphins spending much more of their time over the shallow flats than at any other time of the year, often obviously feeding on mullet.

With the arrival of the cold fronts in the fall, mullet begin to form large schools, which move through the passes to spawn offshore (Springer and Woodburn, 1960; Edwards, 1987). At about the same time, the distribution of dolphins in the Sarasota area shifts from the shallow inshore waters to the passes and associated Gulf waters. We believe the dolphins may be shifting their habitat preference to the passes at least in part to prey upon mullet while the fish are in large schools in fairly predictable locations. Additionally, in the absence of the mullet the shallow inshore flats may be less desirable in terms of food availability.

Habitat Use for Predator Avoidance

The dolphins' seasonal movements may also be correlated with the seasonal abundance of potential predators, particularly bull sharks *(Carcharhinus leucas)*. Wood, Caldwell and Caldwell (1970) reported that dolphin remains were not infrequently found in the stomachs of large sharks such as tiger (*Galeocerdo cuvieri*), dusky (*Carcharhinus obscurus*) and bull sharks; all three shark species were found offshore of the Sarasota area. According to the catch records of Clark and von Schmidt (1965) for the central Gulf coast of Florida, bull, tiger and dusky sharks were the first, seventh and ninth most abundant, respectively, of 16 shark species recorded from the area. Springer and Woodburn (1960) reported that bull sharks were commonly caught in the bays, passes and Gulf in the Tampa Bay area. Tiger sharks were present in smaller numbers in the deeper waters throughout the year; dusky sharks were most abundant during November-January.

Bull sharks were found by Clark and von Schmidt (1965) to be more abundant than any other species of shark offshore of Sarasota during the summer months, when the Sarasota dolphins are found in the shallow inshore waters. The presence of bull sharks is linked to their breeding season. Bull sharks use shallow brackish-water bays and estuaries as nursery areas in the northern Gulf of Mexico (Springer, 1967). During mid-summer, only newborn bull sharks were captured in these shallow areas, while large bull sharks were the most commonly caught sharks on baited longlines in deeper (10-35 m), more saline waters. Springer (1967) suggested that the use of shallow waters in the summer by newborn bull sharks may be a mechanism to reduce predation on these small sharks by larger sharks.

The increased use of shallow waters by the Sarasota dolphins during the summer months may also be, at least in part, a response to the increase in abundance of large bull sharks in the offshore waters of the home range. Wells (1978) reported that of seven dolphins with shark-bite scars, the season of attack was known for three, which were known to have been attacked during the summer. This season coincides with the peak calving season for local bottlenose dolphins; thus, the shift in habitat preference may be in part an attempt by the adult female dolphins to protect their highly vulnerable newborns from predation.

Resident Sarasota dolphins are occasionally attacked by large sharks. A high incidence of healed scarring from apparent shark attacks, without significant tissue loss, was reported by Wood *et al.* (1970). Nearly 22 percent of the bottlenose dolphins handled in the Sarasota area that were above the age of dependent calves bore well-healed scars that were apparently from shark bites (Wells, 1986a). In spite of the high incidence of scarring from apparently serious wounds, low dolphin-mortality rates for the adult age classes in the Sarasota community support the idea that sharks are either frequently unsuccessful in completing their predation attempts on dolphins, or that they inflict wounds for some other reason. Wood *et al.* (1970) suggested that wounds might be inflicted accidentally when sharks and dolphins feed on the same schools of fish, or perhaps as a result of a territorial conflict. Baldridge (1974) suggested that as many as 50-75 percent of shark attacks on humans were motivated by a drive other than feeding, such as territoriality.

Wood *et al.* (1970) found little evidence from shark-bite scars that the original wounds penetrated the blubber layer into the muscle. Healthy larger dolphins may be more capable of surviving an attack than young dolphins. The young animals may be less capable of detecting and/or evading sharks, a greater proportion of their body might be included in a shark bite or the lack of a protective, thick blubber layer may increase the calf's vulnerability. Shark-bite scars were rarely observed on dolphin calves younger than about three to six years of age in the Sarasota area (Wells, 1986a). This may be because the calves did not survive such attacks, or because the large schools in which young calves typically were found provided effective protection from sharks. In

one case in 1989, a five-month-old calf being raised by his mother without the benefits of a nursery school was attacked by a shark and died. In general, calf survivorship is directly related to school size and stability (Wells 1991c).

It is not known if the recent decline in shark populations in general is reducing the risk of mortality for dolphins in the Sarasota area. A reduction in predation pressure may not necessarily lead to an increase in dolphin population size; a reduction in shark populations may increase the population levels of species of shark prey, such as stingrays, whose barbs are also a source of dolphin mortality (Walsh *et al.*, 1988). Stingray barbs were found in seven of the 109 dolphins necropsied by Mote Marine Laboratory during the period 1987-92, and four of these appeared to be the cause of death. It may also be hypothesized that a reduction in the culling of sick dolphins by sharks may increase the level of exposure of healthy dolphins to disease agents, perhaps leading to some of the recent dramatic increases in dolphin mortality levels reported from several parts of the species' range.

Habitat Use for Calf Rearing

Some portions of the community home range were used more extensively than others by females with calves. An index of calf density was calculated for each sampling area by dividing the number of calves by the total number of dolphins recorded *(Figure 4)*. During the summer months, high proportions of calves were recorded from shallow areas such as Palma Sola Bay, Anna Maria Sound and the Manatee River. During the winter months, the mothers and calves were most concentrated in the passes.

The shallow, inshore waters may provide a number of benefits to mothers during the rearing of their young calves. In addition to relatively greater protection from predation, these areas may (1) limit the movements of calves if they become separated from their mother, (2) provide calmer conditions during the initial period of development of efficient breathing behavior for newborns, (3) provide the necessary resources for the increased energetic demands of lactating females and calm conditions for nursing the young and (4) limit exposure of newborns to members of their own community.

Calves may be capable of learning their home range at quite a young age. For example, in 1985 a nine-month-old calf was accidentally separated from her mother when she became entangled in a mullet fisherman's net in northern Anna Maria Sound (area 15). When she was removed from the net she was briefly held in a boat; upon release, the calf turned south, away from the original heading of her mother's school, and swam to Palma Sola Bay, the core area of her mother's home range. By the next day she was reunited with her mother. In a second case, in 1991, a 15-month-old calf was orphaned when its mother was apparently stabbed by humans. The calf spent the next 10 months in its mothers' home range, emphasizing the Palma Sola core area. While the sample size is small, these incidents suggest that the calves may have recognized home-range boundaries and their mothers' core area.

Calm waters may facilitate breathing during the early stages of calf development. Newborn calves are not capable of the slow, rolling surfacing for respiration that is typical of older dolphins (McBride and Kritzler, 1951; McKenzie, 1983). During the first few months, the newborn typically breathes by bringing the entire anterior half of its body clear of the water.

The selection of particular nursery areas may, in part, reflect the energetic needs of the mothers. During summer months, the nursery areas primarily included the areas of the greatest expanses of seagrass meadows. These highly productive regions may meet the increased energetic demands of the mothers more effectively than would other portions of the home range. At the same time, the calm waters of these areas may facilitate nursing.

Wells (1986b) reported that mixing between different dolphin communities generally occurred in the peripheral waters of the Sarasota community, and that this mixing was least frequent during the peak calving season. Thus, newborns would tend to be both temporally and spatially removed from contact with non-community members. This isolation may be important during the period of initial development of the mother-calf bond. If reports from captivity about aggression directed toward infants by dolphins other than the mothers (McBride and Hebb, 1948; McBride and Kritzler, 1951; Essapian, 1963) can be extrapolated to the wild, then mothers may reduce the risk of injury to their calves by limiting their exposure to other, unfamiliar dolphins.

Habitat Use by Different Sex Classes

Males and females used the home range in different ways. The females showed a high degree of fidelity to fairly limited areas, only occasionally visiting the extremes of the community home range. Four home-range patterns were described by Wells (1986b, 1991) for female members of the Sarasota

community, based on frequency of usage of portions of the community range.

The majority of the females were accounted for by two distribution patterns. One group of seven females and their offspring emphasized the waters near the north tip of Anna Maria Island as their core area; these were referred to as the Anna Maria Female Band. Another group of about 14 females and their offspring used Palma Sola Bay as their core area; these were referred to as the Palma Sola Female Band. Smaller groups of females either emphasized Terra Ceia Bay and the Manatee River, or moved with relatively equal frequency throughout the community range. While these females emphasized particular core areas in their daily movements, these areas were non-exclusive, and mixing between females from different core areas was not uncommon.

Males traveled between both extremes of the community range much more frequently than females. Adult males typically traveled between female schools within the community home range; they occasionally disappeared for months at a time, and have been observed on occasion with females in adjacent communities. Wells (1986b) speculated that the occasional disappearance of adult males, if reciprocated by visits to the Sarasota community by adult males from other communities, might be indicative of a mechanism for genetic exchange between otherwise seemingly discrete or distinct dolphin communities. Thus the adult males did not appear to be as tied to particular regions of the community home range as were the females.

Habitat Use and Human Activities

The present pattern of habitat use by the members of the Sarasota bottlenose dolphin community during the summer months shows strong ties to the highly productive regions of extensive seagrass meadows. Over all seasons, fewer dolphins were seen per kilometer of survey transect in Sarasota Bay than in the surrounding inshore and Gulf waters *(Figure 3)*. Thus the resident Sarasota dolphins appear to use the non-Sarasota Bay portions of their home range to a greater degreee than they use Sarasota Bay proper. Compared to the heavily used areas of Palma Sola Bay and Anna Maria Sound, the waters of Sarasota Bay to the south have shown a much greater decline in seagrass meadow coverage over a period of 39 years (Lewis and Sauers, 1987). Sauers and Patten (1981) reported an 83-percent loss of seagrass communities in the waters around Whitaker Bayou, the main wastewater discharge for the city of Sarasota, in 1948-79. Whitaker Bayou empties into sampling area 9, where dolphin sightings are among the least frequent of any of the sampling areas throughout the year. Recently, the waters discharged into Whitaker Bayou began receiving advanced treatment, resulting in decreased concentrations of nitrates and phosphates, increased water clarity, increased seagrass coverage and survival of transplanted grasses. It may be that the present distribution pattern of bottlenose dolphins in Sarasota Bay reflects a past decline in the area covered by seagrass meadows due to human activities. Only continued monitoring will allow us to determine if this pattern has now been reversed.

Shoreline alteration has been more extensive in central and southern Sarasota Bay than in the northern portions of the dolphins' home range; in particular, the shorelines of sampling areas 8, 9, 11 and 12 have been drastically altered over the last century through extensive dredge-and-fill operations. These areas have been used very infrequently by dolphins in comparison to the less-altered areas to the north. Shoreline alterations probably have directly or indirectly reduced the productivity of the nearby waters. Other effects, such as increased access to powerboats, may also influence dolphin distribution to these areas, but specific effects are uncertain.

In summary, it appears that the resident dolphins tend to use the portions of their home range that have been less altered by human activities. This apparent relationship should be considered with caution, however, until appropriate analyses have been completed relating dolphin distribution patterns since the mid-1970s to existing water-quality and seagrass-coverage data.

Present Status

Population Size

The size of the Sarasota bottlenose-dolphin community appears to have remained stable, since at least the mid-1970s. Irvine *et al.* (1981) estimated 102 dolphins (95-percent confidence level (CL) = 90-117) in the community in 1976. An estimate of 98 dolphins (95-percent CL = 89-108) was obtained from 1983 surveys (Wells, 1986b), 87-94 were counted in the population during 1984-87 (Wells and Scott, 1990), and an estimated 97 dolphins were present as of May 1992 (R. Wells, unpublished data). The stability of population size has been maintained through the 1991-92 mortality increase due to unusually high numbers of births during this period.

The Sarasota community may consist of fewer dolphins now than in the early to mid-1960s as a result of commercial dolphin collections. At least three commercial dolphin collectors, based out of Nokomis, Sarasota and St. Petersburg, removed dolphins for research and public display in oceanaria. While it is known that these collectors removed offspring of current residents of the Sarasota community (personal observation), the total number of dolphins removed from the area is unclear. R. Corbin, one of the most active collectors in the area, estimated that during 1966-71, 18-25 dolphins were removed from the region extending between Charlotte Harbor and the southern edge of Tampa Bay (personal commumincation, May 1987). Corbin estimated that roughly 25 percent of the dolphins were collected from the Sarasota area; however, precise records of numbers and capture locations were not kept. A federal quota for removal of two dolphins per year from Sarasota Bay existed until recently (Scott, 1990). As of 1990, an interim quota was established by the National Marine Fisheries Service that eliminated removals from Sarasota Bay waters, but continued to allow the removal of up to seven dolphins per year from Gulf coastal waters (*Federal Register*, 31 May 1990, Vol 55(105), pg 22054).

If the local bottlenose dolphins responded to the decrease in population size by increasing birth rates in a manner similar to that exhibited by other large mammals (Fowler, 1981), then it is possible the Sarasota community had recovered from the impact of the commercial collections prior to our 1976 population estimate. Given the stable community size at present, continued low levels of commercial collection through the 1970s, long generation times and the low birth rates for the community, however, the prospect of complete recovery by the time we made our first population estimate in 1976 is unlikely.

During 1980-87, a mean annual crude birth rate of 0.055 was calculated (no. of births/total population size, Wells and Scott, 1990). In other words, five or six calves were recorded as being born to the population each year, on average (range = 1-11 calves per year). Other calves may have been born, but were lost before they could be recorded by observers. After accounting for known calf mortalities during the first year of life, the mean annual recruitment rate was calculated to be 0.048 ((no. of calves surviving to age one)/(total number of dolphins in the population) Wells and Scott, 1990).

Mortality rates for older age classes were difficult to measure. Some carcasses were recovered by the Mote Marine Laboratory Marine Mammal Stranding Network, but other individuals simply disappeared. In these cases it has not been possible to determine if they died, emigrated or if their identifying characteristics changed to preclude re-identification. Assuming that all losses indicate mortalities, then the mean annual maximum mortality rate for dolphins greater than one year of age was 0.038 during 1980-87 (Wells and Scott, 1990). In other words, about four dolphins (older than one year of age) per year are lost from the population on average. Wells (1986b) and Wells and Scott (1990) reported that rates of immigration and emigration were low and roughly balanced for the Sarasota community, at a level of two to three percent per year. The essentially unchanged community size estimates from 1976-91 therefore indicate that the present birth rate offsets annual mortalities, but has not greatly increased the size of the community.

Part of the reason for the lack of increase in the size of the community may be related to the removal of much of an age cohort of dolphins from the community during the most intensive period of collection. Given that the most intensive collecting occurred during the six-year period 1966-71, and that the collectors preferred animals of sizes that correspond to two to six years of age, then the dolphins most likely to have been removed would have been born during approximately 1964-69. This age class appears to be under-represented in the Sarasota community. Of 45 Sarasota community dolphins of precisely known age and sex that were handled during 1984-87, only two, a female and a male, were born during that period. The male was captured repeatedly by a collector in 1970-71, but was returned to the wild each time because of a jaw deformity. Subsequently, one of these is known to have died and the other has disappeared. By comparison, six of the dolphins handled during 1984-87 were born during the six years preceding 1964, and nine were born during the six years after 1969.

The full effect of the loss of most of this cohort has likely yet to be felt by the Sarasota community. The missing cohort of females would now be in their reproductive prime; thus, the reproductive potential of the Sarasota community may have been diminished due to commercial collection. As another potential effect, the community may now be more sensitive to additional perturbations than would an unexploited community.

Recent increases in bottlenose-dolphin mortality in the Sarasota area are of particular concern. From 1985-90, an average of 13 bottlenose dolphins were recovered each year by the Mote Marine Laboratory Marine Mammal Stranding Program. During 1991, this value doubled to 26 dolphins. As of 30 September 1992, 24 bottlenose dolphins had already been recovered, suggesting a continuation of the pattern of increase noted in 1991. While these mortality trends include dolphins recovered from a broad area – the inshore waters and Gulf coastlines of Sarasota, Manatee and Charlotte counties – the trend applies more specifically to the Sarasota residents as well. From 1985-90, an average of one carcass of a Sarasota resident has been recovered each year by the MML Marine Mammal Stranding Program. During 1991, this value increased to four, and through September 30 six carcasses of known residents had been recovered in 1992. Of the 10 known Sarasota residents recovered during 1991-92 (three male, seven female), eight were 10 years old or younger, representing the age class in which highest mortality rates tend to occur under normal circumstances. To date no single agent has been identified as the cause of death for these animals. In many cases the cause of death has not been obvious, or evaluation of cause of death is awaiting funding to conduct analyses of tissue samples.

Dolphin Population Structure

The Sarasota community is composed of dolphins of both sexes and a wide range of ages, from newborns to males in their mid-forties and females in their early fifties (Wells, 1986b; Hohn *et al.*, 1989). These dolphins form a number of schools at any given time. The mean size of schools in which only Sarasota community members were identified was 7.04 dolphins (S.D. = 6.008, n = 536, Range = 1- 39; Wells, 1986a). Age, sex, reproductive condition and familial relationships have been found to be important determinants of school structure (Wells *et al.*, 1980; Wells, 1986a). Some associations between members of the same age and sex classes are more frequent than others, and the animals often share congruent home ranges within the community home range. These groups of regular associates often have persisted over many years; however, groups are not discrete, permanent or of constant composition. Not all community members have belonged to distinguishable groups. Three kinds of groups are seen most commonly: females and young, adult males and subadults.

The most stable groupings were females with their young calves. Three female groups were distinguished in the Sarasota area on the basis of use of similar core areas and occurring together 20-70 percent of the times they have been seen. For example, as of 1984, the two largest groups were the Palma Sola females (14 adults) and the Anna Maria females (seven dolphins) and their offspring, as described above. Another smaller group (two adults) used the Manatee River and Terra Ceia Bay to a much greater extent than did the other groups. These three groups accounted for 79 percent of the Sarasota community females.

Within the female groups, associations were often correlated with the presence and age of calves. Females without calves tended to swim together, while females with calves of similar age often swam together; changes in reproductive status tended to change female affiliations within groups. As many as three generations of females have been observed within the same group, and four adult females with a unique chromosomal structure (Duffield *et al.*, 1985; Duffield and Wells, 1991) were members of the same group, suggesting a high degree of relatedness between members of a female group. Examination of mitochondrial DNA has demonstrated that several different matrilines may comprise a single female group, but the associations between these matrilines have continued over several generations (Duffield and Wells, 1991).

Adult males tended to swim alone or formed very strong social bonds with other males. Typically, they swam as pairs that were together 70-95 percent of the times they were seen. These groups were often seen traveling, and they moved from one female school to another.

Young dolphins typically remained with their mothers for at least the first three to six years of their lives; upon separation from their mothers, they joined subadult groups. Subadults formed groups that frequently interacted with other similar groups. These groups were composed mostly of males, probably because females reach sexual maturity before males and thus were recruited into the breeding population (and therefore back into the female groups) after a much shorter period of time than were males.

The period of time spent in subadult groups may be important for establishing long-lasting relationships and dominance orders. Males tend to associate most closely with other males of the same age. The appearance of strongly bonded pairs within these subadult groups occurs at about the time that sexual maturity is attained.

Males may reach sexual maturity well before social maturity. Older males tended to associate with adult females to a greater extent than did maturing males. The mating system for these animals is not known. The question of which males are siring the calves has important implications in the management of bottlenose-dolphin communities. Is more than one male siring the four or five calves produced within the community each year? Are the calves sired by local males, or are some sired by visiting males from other communities? What features distinguish a breeding male from a non-breeding adult male? To what extent does female choice play a role in determination of paternities? Our continuing studies are attempting to unravel paternity patterns through examination of genetic factors in the dolphins' blood. To date, our genetics studies have shown that more than one male is siring calves during a given year, that females may use different males to sire subsequent calves and that most of the fathers tend to be more than 20 years old.

In summary, the local dolphin community provides the social context within which dolphins born in the Sarasota area spend much, if not all, of their lives. A mosaic of social patterns is overlaid on patterns of interactions with the local environment to shape the lives of these animals within the community. The dolphin community should be considered to be the appropriate management unit.

Potential Impacts on the Sarasota Dolphin Community

Leatherwood and Reeves (1982) stated, "Definitive research has not been done to test the effects of chemical pollution and harassment on bottlenose dolphins and other cetaceans. Nevertheless, it is reasonable to expect changes in behavior, distribution and movement, and reproductive success as the quality of the coastal environment deteriorates." Human activities in the Sarasota Bay area provide a number of potential impacts on the well-being of the resident dolphins: (1) habitat alteration, (2) commercial collection, (3) pollution, (4) disturbance and (5) incidental mortality from entanglement in fishing nets.

Habitat Alteration

As discussed above, destruction of natural shorelines and seagrass meadows probably has reduced the distribution and abundance of the bottlenose dolphins' prey by eliminating important feeding and nursery areas for these prey species. Present dolphin distribution patterns emphasize regions of seagrass meadows in the Sarasota area. However, analyses of variations in dolphin distribution over the years relative to changes in seagrass coverage during the same periods would be helpful in assessing the importance of these regions to the dolphins.

The local dolphins do not appear to be facing limiting food resources at this time. Results of assessments of dolphin body condition during 1986-91, by means of the weight and an ultrasonic measurement of blubber-layer thickness of individuals, have not shown any obvious indication that the dolphins were undernourished compared to captive dolphins. The possibility exists that food is not presently a limiting resource in part because fewer animals are using the resources now than before commercial collections began. It is also possible that the carrying capacity of the environment has been reduced, and that a stable but lower community size is a response to the effects of altered habitat.

Commercial Collection

Given the extremely conservative balance sheet for recruitment vs. losses, the removal of one or two dolphins through live capture could result in a net loss in population size for the year. In addition to demographic concerns, the removal of individuals could lead to the disruption of social groups, resulting in long-term impacts on reproductive success (Wells, 1991c). With the elimination of the two dolphin per year live-capture quota for Sarasota Bay, the pressure on the local population is much reduced. A quota remains, however, for collection of seven dolphins per year in the Gulf coastal waters between Charlotte Harbor and Crystal River. It is possible that activities under this quota could result in the removal of Sarasota residents. Though few commercial collectors are active at the present time, this remains a serious potential impact on the population.

Pollution

The direct and indirect effects of pollution on bottlenose dolphins have not been well-studied. Pollution has been suggested as one reason for the reduction in frequency of sightings of bottlenose dolphins in San Diego Bay, CA, and Biscayne Bay, FL (FAO, 1978), and in the decrease in abundance of bottlenose dolphins in the North Sea (Mitchell, 1975). Howard *et al.* (1983) have suggested that environmental pollution may have an insidious, unmeasured effect on

marine mammals, resulting in a greater susceptibility to bacterial, mycotic and viral infections.

Stranded bottlenose dolphins from Californian and South African waters and elsewhere have been found with extremely high concentrations of organochlorine pollutants, such as pesticide residues, in their tissues (O'Shea *et al.*, 1980; Cockcroft *et al.*, 1989). The long lifespan of the bottlenose dolphin and its position at the top of the food chain should contribute to the accumulation of pollutants. The direct cause-and-effect relationships resulting from long-term exposure to low concentrations of organochlorine pollutants have not been documented for dolphins, but in the words of Britt and Howard (1983), "...it is difficult to believe that there are no long-term detrimental effects, particularly since comparable low levels have been shown to have measurable toxic effects in laboratory animals." Cockcroft *et al.* (1989) found that off South Africa females transfer 80 percent of their body burden of contaminant residues to their first-born offspring, perhaps leading to reduced calf survivorship, while adult males continue to accumulate these compounds throughout their lives, achieving concentrations hypothesized to reduce testosterone production and impair reproduction. In Sarasota, samples of tissues from stranded dolphins and blood and milk from live dolphins are currently being examined for concentrations of organic contaminants; many more samples are in storage at Mote Marine Laboratory pending funding support for analysis.

Heavy-metal contamination is also a source of concern in the Sarasota area. Hofmann *et al.* (1991) identified possible links between liver damage and high concentrations of mercury in a sample of stranded dolphins. Additional samples of tissues from stranded dolphins and blood and milk from live dolphins are being examined or are in storage pending funding for analysis for concentrations of a variety of heavy metals.

Air pollution may also be a health factor for dolphins in the Sarasota area. Anthracosis has been identified in the lungs of a sample of stranded dolphins, but the implications of this finding are not yet clear (Rawson *et al.*, 1991).

Disturbance

Geist (1971) summarized general disturbance responses of mammals are follows: "Mammals learn to minimize encounters with humans if harassed enough by reducing activity to areas, habitats and time of day where encounters with humans are minimal." Much of the systematic-disturbance study effort involving mammals has examined responses of ungulates – it is only within the last few years that comparable studies have been initiated with marine mammals.

Human interactions with free-ranging cetaceans usually involve the use of vessels. The bottlenose dolphin is the most common cetacean along much of the coast of the United States, and it is therefore exposed to human activities to a greater degree than probably any other cetacean; no systematic studies of disturbance of bottlenose dolphins have been conducted to date, however. Until disturbance-response data are available specifically for bottlenose dolphins, we are limited to speculation, based largely on the results of studies involving other species. The few systematic studies of disturbance of cetaceans that have occurred have typically demonstrated strong avoidance responses by these animals to approaches by vessels. Avoidance of vessels has been shown for bowhead whales (Richardson *et al.*, 1984, 1985), humpback whales (Baker *et al.*, 1983) and gray whales (Swartz and Jones, 1978). Pelagic dolphins, killer whales and beluga whales also have been shown to be negatively affected by boat traffic (Au and Berryman, 1982; Stewart, 1983; Kruse, 1991).

Irvine *et al.* (1981) reported that dolphin schools in the Sarasota area bunched together tightly and fled at high speed when approached by fast-moving vessels that had been involved in previous captures. Odell (1976) considered heavy use of Biscayne Bay, off Miami, FL, by boaters to be one factor in the apparent decrease in abundance of bottlenose dolphins in recent years. Shane (1987) considered 37 percent of the encounters with boats near Sanibel Island, FL, to result in negative responses by the dolphins.

Encounters between boaters and dolphins in the Sarasota area are frequent. Human activity on the waterways has been increasing steadily with the growth of the local population, such that as of June 30, 1992, 30,949 boats were registered in Sarasota and Manatee counties. Miller (1987) reported that 98.7 percent of boaters surveyed had seen dolphins in the Sarasota Bay area. Dolphins in the Sarasota area can often be seen riding in the bow or stern wakes of boats. However, this behavior may not be as common as it might appear. Our experience has been that, more often than not, local dolphins appear to ignore or avoid approaching recreational boaters, typically by diving and then surfacing some distance away.

Preliminary analyses indicated that members of the Sarasota dolphin community avoided channels used by boaters during

periods of heavy boating traffic.

Sighting data from 24 survey days during the summers of 1985 and 1986 were analyzed relative to dolphin distribution patterns. Significantly fewer dolphins were seen in the marked channels on weekends and holidays, when boat traffic was heaviest in these channels, than during the week (Mann-Whitney U Test, $p < 0.05$). On the other hand, significantly more dolphins were seen over the shallows outside of the channels during the heavy traffic days than during the week (Mann-Whitney U Test, $p < 0.05$).

Based on this small sample, it appears that members of the Sarasota dolphin community may avoid boats under conditions of heavy boat traffic. Avoidance of vessels may be related to a number of factors. For example, dolphins may be attempting to reduce the potential of collisions for themselves or their young. At least three of the Sarasota community members bear clear evidence of having been struck by boats. One of these, a young calf, was struck during the period when the Fourth of July powerboat races were conducted during 1988. Powerboats also introduce intense levels of sound into the water. To acoustically oriented animals such as dolphins, intense sounds from boat engines may be a source of discomfort at close range. Boat-engine noise may also mask biologically important sounds or communication signals in the low-frequency portion of the dolphins' hearing range (see Richardson *et al.*, 1983, for a review). Barros and Odell (1990) suggest that many of the primary prey items of bottlenose dolphins may be located because of the sounds they produce through stridulatory mechanisms (rubbing of tissues), hydrodynamic phenomema (e.g., mullet leaps) or muscular contraction involving the swim bladder. In summary, while indications exist that dolphins can be disturbed by boats, the specific characteristics of boat activities that may result in disturbance responses remain undefined. A pilot study was conducted during the summer of 1992 to examine the potential disturbance responses of bottlenose dolphins to boats in Sarasota waters; the data were being analyzed at the time of this writing.

Fishing Gear Entanglement

Incidental dolphin mortality as a result of entanglement in fishing gear, especially nets, is a major problem in many parts of the world. In the Sarasota area, a significant number of the carcasses recovered by the Marine Mammal Stranding Network each year bear marks suggesting entanglement in fishing gear. Of 162 bottlenose-dolphin carcasses examined by the Mote Marine Laboratory Marine Mammal Stranding Program during 1985-92, 11 percent bore fresh indications of entanglement (another 27 percent could not be evaluated for entanglement involvement due to condition of the carcasses). We found evidence of apparent gear entanglement on eight percent of the 146 live dolphins we handled during 1975-90. A disproportionately high percentage of the dolphins involved in entanglements were subadults. We have examined two dolphins killed by entanglement in commercial fishermen's nets; both mortalities occurred along the Gulf beaches, where nets are often set perpendicular to shore and left untended for extended periods of time.

In summary, a number of potential impacts on local dolphins have been identified. In most cases, however, accurate assessment of these impacts will require additional field study or analysis of existing samples and data.

Manatees

Distribution

Manatees are found in fresh, brackish and saltwater habitats, primarily in peninsular Florida. Because they are herbivores, manatees frequent shallow waters containing aquatic vegetation. During warm months they are dispersed as individuals or in small groups, but during cold-water months they tend to congregate at warm-water sources.

Specific published references to manatees in the Sarasota Bay area were uncommon until relatively recently. Moore (1953) described the northward range of manatees on the Gulf coast of Florida to be south of latitude 27 degrees N, or well south of Sarasota and Manatee counties. One of the first published reports of manatees in Sarasota County was from a carcass washed up on Siesta Key in 1959 (Layne, 1965; Clark, 1969). Hartman (1974) reported manatees as being uncommon in Sarasota County and somewhat more plentiful in Manatee County. No manatees were found in Sarasota or Manatee counties during aerial surveys in the winter and summer of 1976 (Irvine and Campbell, 1978).

In recent years, reports of manatee sightings in the Sarasota Bay area have been more common. Whether this reflects a true increase in abundance of manatees in the area or is merely an artifact of increased survey effort is uncertain. During aerial surveys in 1979, Irvine, Caffin and Kochman (1982) found manatees in

Sarasota County throughout the year, with a peak in abundance during October-November. Subsequent Mote Marine Laboratory aerial surveys found manatees to be present during most months (Patton, 1986; Kadel and Patton, 1992). The MML data indicated manatees were most abundant during mid-April through mid-December, and nearly absent during January-February, when manatees tend to be found elsewhere at warm-water refugia.

Habitat Use

Manatees prefer warm, shallow waters. Patton (1986) reported that he did not see manatees in the open waters of Sarasota Bay; instead, the manatees tended to be found around the fringes of the Bay in waters less than three meters in depth. This may have been due in part to the fact that manatees tend to spend time in waters shallow enough to support their food, seagrasses, and/or that the poorer visibility of deeper waters in the open areas of Sarasota Bay may have obscured manatees during dives. Patton (1986) noted that he saw manatees more frequently in some areas than in others, including the area between Coon Key and City Island, Roberts Bay, Little Sarasota Bay, southern Anna Maria Sound and the waters surrounding Sister and Jewfish Keys. Pansy Bayou and Buttonwood Harbor have shown consistent increases in manatee usage in recent years (Kadel and Patton, 1992).

Manatee presence and abundance in the Sarasota area appear to be related at least in part to environmental factors such as water temperature and the distribution of seagrasses. Unlike bottlenose dolphins in the Sarasota area, manatees do not appear to have any natural predators except man (Hartman, 1979), and reproduction is year-round, so these factors probably have little influence on the manatee's presence in the area.

Movement Patterns

No evidence exists to suggest that particular manatees are year-round residents of the Sarasota Bay area; this is also indicated in part by the seasonal variations in abundance described above. The Sarasota Bay area does not offer the warm-water refugia that result in large winter manatee congregations elsewhere, such as at springs and power-plant effluents. Manatees may instead use the Sarasota area as a transit area or as a part of a large home range during the warmer months. Some evidence for this is derived from U.S. Fish and Wildlife Service radiotagging results: one of 16 manatees tagged with radio transmitters at a power plant at Fort Myers in January 1985 was seen off Bird Key in Sarasota Bay in March 1985, and subsequently with a calf in the Manatee River. In October 1985 this same individual was seen near Osprey, FL, suggesting a return movement southward.

Feeding Patterns

Manatees feed on a variety of marine and freshwater plants (Husar, 1977; Hartman, 1979). No single species of plant extends throughout the manatee's range (Campbell and Irvine, 1977). Campbell and Irvine suggest that manatees may utilize whatever available food species are present in different areas. Sarasota Bay waters contain a number of the marine plants upon which Hartman (1979) observed manatees feeding. The manatee distribution patterns reported by Patton (1986) and Kadel and Patton (1992) correspond to areas of good seagrass coverage.

Status and Potential Impacts

The manatee is highly endangered. It is believed that several thousand manatees existed when the Europeans first arrived on the coast of North America (Caldwell and Caldwell, 1985). Estimates of present population size range from 800-1,000 manatees in Florida waters in the 1970s (Brownell, Ralls, and Reeves, 1978) up to 1,856 animals in 1992 (Ackerman, FDNR unpublished data, as cited by Kadel and Patton, 1992). Trends toward increasing or decreasing population size are unclear. At any given time only a very small proportion of the Florida manatee population is present in the Sarasota Bay area; however, if the area serves as either a transit area or part of a large home range, the condition of Sarasota Bay could hypothetically affect the movements and distribution of western Florida's manatee population.

The most important source of mortality for manatees is humans. Manatees were originally depleted through overhunting for meat, oil and leather (Campbell and Powell, 1976). The single most frequent cause of death and injury for manatees today, however, is collision with powerboats (Hartman, 1979). Non-fatal collisions are evidenced by parallel scars on the backs of practically all manatees (Hartman, 1979). During the period 1985-92, 13 of 34 manatee mortalities in the NEP study area have been attributed to boat collisions (source: Florida Marine Research Institute). Drowning in flood-control gates is another major source of mortality in south Florida, but not in the Sarasota Bay area.

Habitat alteration is a source of concern

for the future of manatees. Manatees appear to prefer unaltered habitat. Most of the manatees (58.5 percent) observed by Irvine, Caffin and Kochman (1982) were found in the relatively unaltered waters of Everglades National Park and Ten Thousand Islands. Caldwell and Caldwell (1985) state that man has indirectly contributed to manatee deaths by altering habitats through sewage and other waste-disposal and dredge-and-fill projects, thereby reducing available food resources. Habitat alteration in the form of creation of warm-water effluents from power plants has both extended the winter range of the manatee northward, and caused additional mortalities when insufficient heat is produced during severe cold (Irvine, 1983). The effects of past declines of seagrass meadows in Sarasota Bay on the use of the Bay by manatees may be a source of concern, but recent improvements in seagrass coverage and survival are encouraging.

Conclusions

The marine mammals of Sarasota Bay must survive in an ecosystem that has been significantly altered through human activities. The bottlenose-dolphin community is largely comprised of permanent residents, which have been present during much of the gradual degradation of their environment through bulkheading and pollution. The dolphins use much the same home range now that they did 22 years ago, despite the apparent loss of seagrass meadows and the associated resources, pollution, a history of commercial collection pressure and increased boat traffic. This suggests that the local dolphin community is quite resilient. There are likely limits, however, to the adaptability of dolphin communities to habitat deterioration, as suggested by the observed loss of dolphins from Biscayne Bay, FL. It is only by learning the requirements of the local dolphin community that we can hope to monitor and ameliorate the conditions that could eventually lead to the loss of dolphins from the waters of Sarasota Bay.

We are fortunate in Sarasota to have a solid base for learning the needs of these animals. The background data on the dolphins of Sarasota are more detailed and have been collected over a longer term than in any other location in the world – this information can be used to formulate questions and refine hypotheses that would require many years of preliminary work elsewhere. The natural laboratory situation of Sarasota Bay offers a thoroughly studied community of recognizable individual dolphins of known backgrounds. The use of this laboratory to obtain the answers necessary for improving conditions for the resident dolphins, and for further application to bottlenose dolphins in other areas, is limited only by levels of available research support.

Because of the small numbers of manatees present at any given time, systematic studies of their needs while in the Sarasota area are more difficult than for dolphins, but the need for the information is no less crucial. As is the case of the dolphins, a unique long-term database exists for distribution and abundance of manatees in the Sarasota area. These data provide the basis for identifying areas of critical habitat; continued data collection provides the means for assessing the effectiveness of management practices.

Collection of appropriate information about the requirements of the marine mammals of Sarasota Bay is the first step toward understanding the roles of these animals in the Bay ecosystem. Wise decisions by management agencies, based on sound information from the field, should lead to an overall improvement in the quality of the Bay, and towards the ideal of successful coexistence of all of the mammals that use the waters of Sarasota Bay.

Potential Management Options

Both bottlenose dolphins and manatees are protected by federal regulations, under the Marine Mammal Protection Act of 1972 and, in the case of manatees, by the Endangered Species Act. State protection of manatees in the form of establishing speed zones for boaters was implemented by the Florida Dept. of Natural Resources in December 1991. Local management efforts taking into consideration the habitat requirements of the animals in local waters might be implemented to provide effective complementary protection for the animals. Suggestions for local management initiatives include:

- Refine our understanding of the habitat requirements of dolphins and manatees in the Sarasota area in order to evaluate the need for establishing protected areas for the animals.
- Require commercial fishermen to constantly attend any nets that are set, to be able to come to the immediate assistance of any marine mammals that entangle themselves.
- Establish a "no-harvest" area to prohibit the live-capture removal of dolphins from Sarasota waters.
- Establish ongoing support for the

Sarasota area Marine Mammal Stranding Program to ensure that samples will continue to be collected and analyzed for assessment of the health of these animals, as biological indicators of the health of local dolphin population as well as the ecosystem. All stranded dolphins in the area should be recovered, examined and sampled to determine cause of death. Based on the findings of post-mortem examinations and sample analyses, appropriate management actions should be taken to mitigate impacts from human activities. For example, the sources of the environmental contaminants found in the tissues from local dolphins should be identified, and steps should be taken to eliminate these sources.

• Establish and maintain a local facility for rescuing, holding, treating, monitoring and rehabilitating sick and injured marine mammals. In recent years, attempts to identify the agents of large-scale dolphin die-offs along the Atlantic seaboard of the United States, in the northern Gulf of Mexico and in the Mediterranean Sea have suffered from an inability to care for debilitated dolphins, monitor the course of the illness and devise treatment protocols.

• Establish boater-education programs to inform the public of the regulations protecting marine mammals, and of the specific needs of the animals in the Sarasota area.

Further Data Needs

Bottlenose Dolphins

• Existing data from the 1970s through the present should be subjected to time-series analyses to identify distributional trends relative to such relatively fixed habitat features as depth and physiography. The dolphin data should also be integrated with existing data on water-quality parameters, seagrass coverage and other dynamic features of the habitat.

• Existing data on dolphin activities should be examined to develop hypotheses about how dolphins in the Sarasota area use particular habitats and features.

• Behavioral observations should be implemented specifically to obtain more detailed information on temporal and spatial patterns of habitat use.

• A regular boat-survey program should be established to monitor distributional patterns, and to monitor the status and population trends of the local dolphin community (Perrin and Reilly, 1984). These surveys should be combined with a detailed environmental monitoring program.

• Hypotheses about dolphin habitat-use patterns relative to prey and predators, developed as a result of analyses of existing data and ongoing monitoring, should be tested through field studies of ecological relationships. For example, how do daily and seasonal dolphin distribution patterns relate to those of specific prey and potential predator species? How do dolphin abundance and body condition relate to resource availability? This research would involve quantitative sampling of prey and predators within the dolphin home range, as well as telemetric tracking of their movement patterns. These data would be integrated with data from monitoring of the dolphin distributions, as well as body condition data from ongoing capture-release dolphin health-monitoring efforts.

• Building on the preliminary results presented in this report, responses of dolphins to potential disturbances such as boats and jet skis should be examined in detail. Behavioral responses to vessel traffic should be quantified relative to vessel size, engine configuration, underwater noise production and nature of approach. Distribution patterns of dolphins relative to vessel traffic should be quantified.

• The acoustic components of dolphin communication signals, prey, predators and vessel engine emissions should be recorded and compared to assess the nature and degree of acoustic interference by human activities.

• Habitat-use and disturbance-response data should be integrated to develop recommendations for protection of areas of critical habitat, if appropriate.

• Analyses of samples from stranded dolphins, including histopathology, microbiology, toxicology and assessment of levels of organic and inorganic pollutants, should be performed. Stored samples should be processed.

• To provide perspective for the findings from examination of stranded dolphins, life-history data from teeth and gonads should be collected, stomach contents should be collected and analyzed quantitatively and efforts should be made to identify the origin of stranded dolphins through comparison with existing photographic identification catalogs.

Manatees

• Regular, systematic aerial surveys should be continued to monitor distribution patterns and abundance, and to identify areas of preferred use. Increased frequency of surveys would be useful in assessing the effects of newly established speed zones.

• Areas of preferred use should be examined in detail to characterize the habitat.

- Individual identification studies using scars and marks on manatees should be initiated to determine patterns of residency, both within and between years.
- Behavioral observations should be conducted to aid in defining patterns of habitat use.
- Given that one of the primary causes of manatee mortalities is collision with vessels, efforts to study the hearing capabilities of manatees should be continued. The possibility of developing acoustic means of warning manatees about approaching vessels should be explored.

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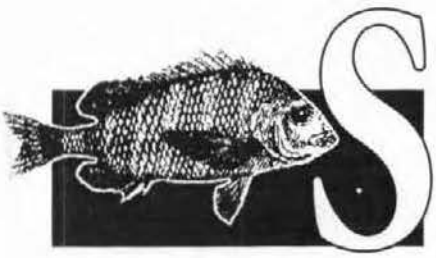
Fishery Resource Assessment

Fishery Resource Assessment

by Randy E. Edwards, Ph.D.
Mote Marine Laboratory

Executive Summary



Sarasota Bay supports important commercial and recreational fisheries. Historical commercial landings data are available, but are broken down by county and not by bay system. Almost no information about recreational landings was available prior to this study.

Commercial landings for Sarasota and Manatee counties include large amounts of species that depend on Sarasota Bay as juveniles or adults. The black- (striped-) mullet fishery is the largest commercial fishery in the Bay, but it has declined to 50-60 percent of its historical (1960s) peak levels. The black-mullet fishery declines are primarily attributable to environmental degradation; the effects of commercial fishing are unknown.

The commercial spotted-seatrout fishery was important historically, but has declined to one-quarter or one-third of its peak levels. Spotted seatrout are also important in the recreational fishery, so the extent to which declines in commercial landings have been related to increasing recreational landings could not be estimated prior to this study.

A Baywide trawling survey of fishes and important invertebrates, conducted in 1990, found that Sarasota Bay is dominated, in terms of abundance, by a few species, such as pinfish (46 percent), pink shrimp (11 percent), pigfish (11 percent) and mojarras (10 percent). A Baywide seining survey, also conducted in 1990, similarly determined that shoreline communities are also numerically dominated by a few species, including mojarras (30 percent), silversides (14 percent), anchovies (13 percent) and pinfish (12 percent).

Comparisons with other southwest Florida estuary systems that have been similarly studied by trawling and seining indicate that dominance by this group of species is probably "natural," and does not indicate gross ecological stress or dysfunction. Comparison with results of a previous (1979) ichthyological survey of Sarasota Bay indicates that the fish community has not changed greatly during the last 10 years, although one potentially signifi-

cant change – the present relative scarcity (as compared to the earlier survey) of juvenile groupers (gag and red grouper) – was noted.

Valued fishery species were found around the Bay; their abundances (with the exception of striped mullet) were lowest in the main central portion (away from passes) of Sarasota Bay. Relatively high overall abundance of significant numbers of young stages of important species at the Midnight Pass trawl-and-seine stations indicates that at least some of the Midnight Pass area is now functioning as a productive nursery.

A year-long creel survey of recreational anglers found that those fishing from boats caught an average of 1.32 fish per hour and harvested 0.58 fish per hour. Spotted seatrout (26 percent) and sand seatrout (14 percent) contributed most to the boat-angler catch; sand seatrout (25 percent), sheepshead (17 percent) and spotted seatrout (16 percent) contributed most to the boat-angler harvest. Zones of the Bay where private boat-angler catch was highest included the western Bay near New Pass and other zones that were near passes and/or included extensive areas of seagrass beds.

Anglers fishing from shore caught an average of 1.66 fish per hour and harvested 1.00 fish per hour. Pinfish and pigfish dominated the shore-angler catch (27 percent and 14 percent, respectively) and harvest (25 percent and 12 percent).

More than half of all (shore and boat) fish caught were released, with release rates very high for certain species, such as snook (87 percent released), red drum (87 percent) and spotted seatrout (70 percent).

Total harvest rates (catch per unit effort = CPUE) of Sarasota Bay boat anglers were comparable to rates measured for Texas bay systems that have been documented to have previously experienced substantial fisheries declines, suggesting that Sarasota Bay fisheries may have undergone similar declines in the past. Spotted-seatrout harvest rates (CPUE) by Sarasota Bay boat anglers were extremely low (0.08 fish landed per angler-hour), which is about 10-50 percent of those reported for unaltered systems with low angling pressure.

Analyses using extrapolated annual Baywide recreational-landings estimates and recent commercial-landings data suggest that the Sarasota Bay spotted-seatrout fishery presently may be around half or less as productive as it was three or four decades ago. Available evidence indicates that declines in spotted-seatrout landings are probably not due to overfishing. Environmental alteration and degradation of the Sarasota Bay system is the most likely cause of the spotted-seatrout fishery decline, with the fishery declines paralleling, in timing and magnitude, the declines of important fishery habitats such as seagrasses, mangroves and natural shorelines.

Additional characterization and continued monitoring of Sarasota Bay fisheries are strongly recommended, because otherwise it will impossible to directly appraise the effectiveness of the Sarasota Bay National Estuary Program in attaining its stated goal of restoring and sustaining fishery resources. For this goal to be most fully attained, it is recommended that direct management options relative to fisheries (including focus on fisheries habitat and involvement in fishery-management issues) be accepted as integral parts of the Sarasota Bay National Estuary Program.

Fishery Resource Assessment

Introduction

Fishery Resources and the Sarasota Bay National Estuary Program

Sarasota Bay NEP Goals

The Sarasota Bay National Estuary Program established seven primary goals, one of which was: "To restore and sustain fish and other living resources in Sarasota Bay."

To effectively work toward accomplishing this goal, much information about fish and fisheries in Sarasota Bay is needed.

Characterization Needs

For any component of any system to be managed, it must be understood. Characterization is an important component of all NEP programs (Edwards, 1991a). The project described below was largely aimed at providing characterization information about Sarasota Bay fish and fisheries. In the short term, such characterization is essential to determine what additional studies are needed under the five-year work plan, to prepare the Framework for Action document and to develop a Comprehensive Conservation and Management Plan (CCMP) for the Bay.

Additionally, in the long term this characterization was needed to provide baseline information against which future conditions can be assessed so as to evaluate the status of the Bay and the effectiveness of the program and the CCMP with regard to fisheries. As described below, very little information about the Bay's fish and fisheries had been gathered previously.

Prior Knowledge About Sarasota Bay

Commercial Fisheries in the Sarasota Bay Area

Sarasota Bay supports important and valuable commercial fisheries. However, exact statistics of volume and value of the commercial landings from the Bay are not available, because Florida landings statistics (by the National Marine Fisheries Service until 1986 and by the Florida Dept. of Natural Resources [FDNR] thereafter) have been collected and compiled by county and reflect only the location at which fish were landed, and do not distinguish landings on the basis of location at which catch the catch was made. Thus, the portion of the Sarasota and Manatee landings that may have come from outside the Sarasota Bay system cannot be determined. This is particularly important with regard to Manatee County landings, which may include catches taken from the Tampa Bay system. For example, a large portion of the Manatee County black- (striped-) mullet landings come from the Manatee River and other parts of the Tampa Bay system. Despite this shortcoming, the landings statistics provide valuable information about past trends in the important commercial fisheries of the area.

Commercial fisheries landings for Sarasota and Manatee counties include large amounts of fish caught from areas of the Gulf of Mexico outside the Sarasota Bay system. Landings of species such as gag (*Mycteroperca microlepis*) and red grouper (*Epinephelus morio*) come predominately from catches made outside the Sarasota Bay system. Landings of other species, such as clupeid bait fish (sardines and herrings), Spanish mackerel (*Scomberomorus maculatus*) and pompano (*Trachinotus carolinus*), include catches made from nearshore Gulf areas that could be considered part of the Sarasota Bay system. Much of even the offshore landings have relationships to Sarasota Bay through the Bay's role as feeding ground and nursery for various life stages of the fish that are eventually caught offshore.

Commercially Important Species

The largest landings, by weight, for Manatee and Sarasota counties in 1986 and 1990 are summarized in *Table 1*. In 1986, the largest single species-landings category was Spanish sardines (*Sardinella aurita* – 4.9 million lbs.), primarily caught from areas outside Sarasota Bay. Black- (striped-) mullet (*Mugil cephalus*) landings (3.3 million lbs.)

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1986 Manatee County		1986 Sarasota County		1990 Manatee County		1990 Sarasota County	
Species	Pounds	Species	Pounds	Species	Pounds	Species	Pounds
Bait Fish	96,000	Bluefish	29,607	Bait Fish	377,407	Amberjack	37,327
Bluefish	31,268	Drum, Red	11,647	Bonito	69,962	Bluefish	19,835
Bonito	82,716	Herring, Thread	24,270	Grouper, Black	89,979	Mackerel, Spanish	48,922
Drum, Red	65,553	Jack, Mixed	42,797	Grouper, Red	692,531	Mullet, Black	286,381
Grouper, Black	156,664	Mackerel, Spanish	26,776	Grouper, Yellowedge	60,478	Mullet, Silver	12,877
Grouper, Red	1,383,369	Mullet, Black	185,141	Herring, Thread	2,878,260	Pompano	59,979
Grouper, Scamp	35,445	Mullet, Silver	23,937	Jack, Crevalle	181,949		
Grouper, Yellowfin	93,067	Pompano	13,054	Mackerel, Spanish	177,146		
Herring, Thread	33,382	Sardine, Spanish	117,150	Mullet, Black	2,805,968		
Jack, Crevalle	507,091	Seatrout, Grey	13,201	Rays	186,253		
Jack, Mixed	179,964	Seatrout, Spotted	10,172	Sardine, Spanish	150,511		
Mackerel, Spanish	97,566	Shark	27,895	Seatrout, Spotted	37,275		
Menhaden	2,134,104			Shad, Common	45,038		
Mullet, Black	3,117,128			Shark	154,168		
Rays	70,623			Sheepshead	57,938		
Sardine, Spanish	4,806,809			Swordfish	38,527		
Seatrout, Spotted	89,625			Misc. Industrial	1,023,606		
Shad, Common	2,051,808						
Shark	38,024						
Sheeps-head	49,200						
Spot	36,592						
TOTAL FINFISH	15,616,837	TOTAL FINFISH	617,190	TOTAL FINFISH	9,380,305	TOTAL FINFISH	529,258

Source: FDNR Marine Fisheries Information System, 1986 Annual Landings Summary and 1990 preliminary summary.

Table 1. Commercial fishery landings for Manatee County and Sarasota County (>30,000 lb. and 10,000 lb. respectively) for 1986 and 1990.

were second. Black mullet are caught and sold as food fish (meat and roe). Black mullet landed in Manatee County are caught in Sarasota Bay and in the Tampa Bay system; the relative contribution of the two systems is unknown. Menhaden (*Brevoortia* sp.) were third in terms of pounds (2.1 million lbs.), but almost all menhaden are taken from lower Tampa Bay. Menhaden landed in Manatee County are frozen for use as bait. Red grouper (1.4 million lbs.) is a high-value food fish caught in offshore Gulf waters.

Overall, Manatee County's total 1986 finfish landings (15.6 million lbs.) were greater than those of all other Florida counties except Gulf County, whose landings (17.4 million lbs.) were dominated by menhaden (12.3 million lbs.) destined for industrial processing into fish meal.

In contrast, Sarasota County's 1986 finfish landings (0.6 million lbs.) exceeded only those of a few small counties. Black mullet (185,000 lbs.) and Spanish sardines (117,000 lbs.) made up almost half the total catch.

The differences between Sarasota County and Manatee County landings probably reflect the distribution of fish houses within the two counties more than the distribution of catch locations. Many fish are caught in Sarasota County but landed at the fishing village of Cortez, on the Manatee County portion of Sarasota Bay.

By 1990, the Manatee and Sarasota landings had changed substantially. Spanish-sardine landings had fallen by more than 96 percent, to just over 150,000 lbs. in 1990. This change was offset by increases of thread-herring *(Opisthonema oglinum)* landings to 2.9 million lbs. Black-mullet landings (3.1 million lbs.) remained stable, but red-grouper landings had dropped by about one-half, to around 0.7 million lbs. in 1990.

Trends in Commercial Landings for Estuarine Species

Black (striped) mullet and spotted seatrout (*Cynoscion nebulosus*) are highly dependent on and primarily caught in Bay and inshore waters; therefore, the landings trends for these two important species probably are indicative of general fishery trends in Sarasota Bay. Annual landings of black mullet *(Figure 1)* have ranged from peaks of around 6 million lbs. in 1957, 1965 and 1969 to as low as around 2 million lbs. in 1976. During the decade and a half from 1957 through 1972, mullet landings averaged over 5 million lbs. Mullet landings generally declined to the point that during the decade from 1980 to 1990, they hovered around and did not rise much above 3 million lbs. per year, despite the fact that a lucrative Far East market for mullet roe was developed during the mid-1980s.

Commercial landings of spotted seatrout have declined even more drastically *(Figure 2)*. Peak two-county landings of 430,000 lbs. were recorded in 1951, and landings may have been even higher in earlier years, when landings records were not maintained. After a sharp drop in the early 1950s – attributed to severe red tides in Sarasota Bay – annual spotted-seatrout landings recovered to about 400,000 lbs. in 1958. In the following decade, landings ranged from 250,000 to

330,000 lbs. A generally consistent decline in spotted-seatrout commercial landings started in the mid- to late 1960s. In the decade of the 1980s, annual commercial landings averaged less than 100,000 lbs.

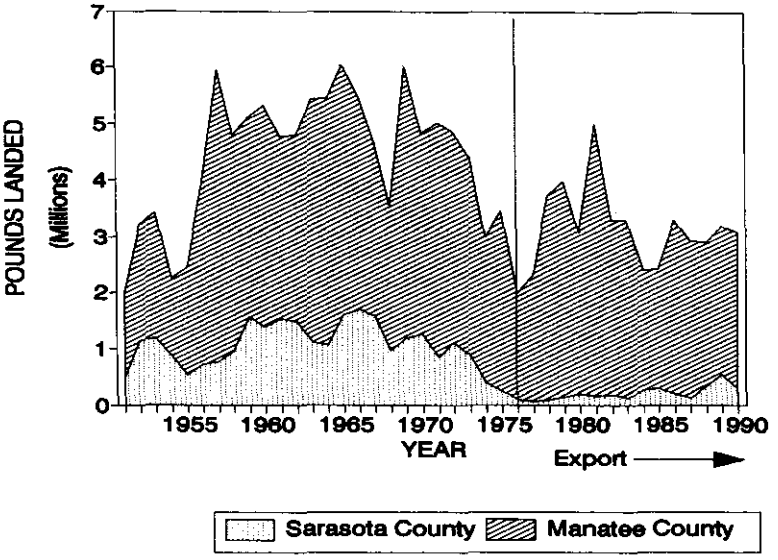
It is obvious that commercial landings for two of the most important fisheries in Sarasota Bay have declined drastically over the last four decades. Landings of black mullet are about one-half of what they once were, and spotted-seatrout landings are about one-third to one-quarter of past levels.

Similar declines in fishery productivity caused by the environmental impacts of population growth have been documented (e.g., Harris *et al.*, 1983), so it is very likely that much of the decline in Sarasota Bay fisheries landings is due to this cause. During the period in which these declines occurred, major changes were occurring in the Sarasota Bay area. Most importantly, population in the two-county area increased by almost tenfold, from around 64,000 in 1950 to about 490,000 in 1990. This rapid population growth resulted in significant environmental changes to the Bay: habitats important to fisheries, such as marshes, mangroves, natural shorelines, tributaries and seagrass beds, were lost or greatly impacted as the land around the Bay, and in some cases Sarasota Bay itself, was developed. Such major projects as the dredging of the Intracoastal Waterway and dredging and filling of Bird Key and large parts of Longboat Key occurred in the 1960s. During the same time, the Bay was also subjected to increasing problems of sewage effluent, stormwater runoff and a host of other impacts of increasing population and urbanization.

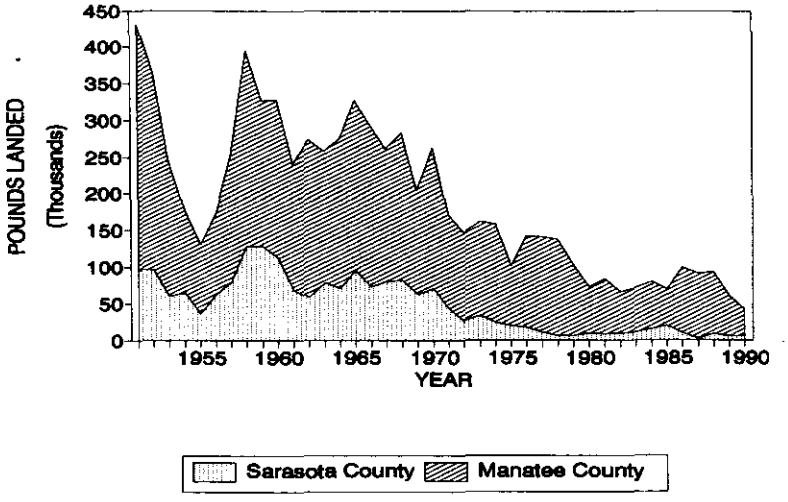
Since mullet are not caught in significant numbers by recreational fishermen, mullet-fishery declines must be attributed primarily to environmental changes and commercial fishing pressure. The fact that the fishery was able to sustain much larger harvests over periods greater than a decade suggests that the declines were not primarily caused by overfishing.

Spotted seatrout, on the other hand, is probably the most important inshore recreational fish species, in terms of numbers landed, on the Florida Gulf coast. Therefore, it is possible that the observed declines in commercial landings of spotted seatrout in the Sarasota Bay area may reflect increasing recreational landings due to population growth and resultant increased numbers of recreational fishermen, as well as environmental changes and commercial fishing. Unfortunately, detailed recreational-fisheries landings information has not been available.

STRIPED (BLACK) MULLET LANDINGS IN THE SARASOTA BAY AREA Figure 1.



SPOTTED SEATROUT COMMERCIAL LANDINGS IN THE SARASOTA BAY AREA Figure 2.



Recreational Fisheries

Prior to the present study, recreational fisheries in Sarasota Bay had never been characterized nor quantified. The Marine Recreational Fishery Statistics Survey (MRFSS) of the National Marine Fisheries Service (NMFS) determines regional or state status and trends, but cannot provide precise information about specific estuaries or bay systems. Therefore, prior to the present study almost no information was available to assess the present status of recreational fisheries in Sarasota Bay. Such an assessment was needed if detection of changes in Sarasota Bay's fisheries and evaluation of the effects of management actions implemented under the Sarasota Bay National Estuary Program CCMP are to be possible in the future.

Relationships Between Sarasota Bay Fisheries and General Environment

General Relationships

Although Sarasota Bay is not extremely large in area, it is very diverse and complex in its fishes and fisheries. A wide variety of fisheries habitats are found in and are important to the Bay.

Because of its geographic location, the Bay's fauna includes temperate, subtropical and tropical species. The Bay is ecologically very connected to the Gulf of Mexico and Tampa Bay, with many important fishes regularly moving to and from these systems. Regional commercial harvest ranges from Bay fisheries for estuarine-dependent species such as striped mullet (*Mugil cephalus*) and spotted seatrout (*Cynoscion nebulosus*) and nearshore fisheries for species such as pompano (*Trachinotus carolinus*) that regularly enter the Bay, to offshore fisheries for species such as grouper and snapper that are found in the Bay as juveniles.

Habitats

Sarasota Bay includes a wide variety of habitats important to fishes and fisheries, ranging from low-salinity estuarine habitat (primarily confined to areas within or near tributaries along the eastern shore of the Bay) to open-Bay habitats such as seagrass beds and hard bottoms, to coastal beach and pass environments.

Seagrass habitats are very important to fisheries in systems such as Sarasota Bay (Harris *et al.*, 1983). One of the NEP goals is to improve water transparency in the Sarasota Bay study area to the maximum allowable by the Gulf of Mexico and local water conditions, and attainment of this goal could be expected to have positive effects on seagrasses and thus improve fisheries.

In some cases, however, efforts to achieve this goal could reduce the availability and productivity of the low-salinity estuarine areas, whose waters typically have higher levels of color and turbidity. A characteristic of Sarasota Bay is its relatively limited area of estuarine, reduced-salinity habitat. This type of estuarine habitat is very productive, and serves as adult habitat for important fish species such as snook (*Centropomus undecimalis*), red drum (*Sciaenops ocellatus*) and striped mullet, and for important crustaceans such as blue crabs (*Callinectes sapidus*) and pink shrimp (*Penaeus duorarum*). The potential negative impacts of low-salinity-habitat loss on important estuarine fisheries must be carefully considered before major actions are taken.

In addition to serving as adult habitat, low-salinity estuarine areas are critical to overall Bay productivity through their function as nursery habitats for juveniles of many important species (Edwards, 1991b). An often-overlooked aspect of fishery management, the availability of suitable nursery habitat, may be the limiting factor to Baywide fisheries production in systems such as Sarasota Bay and Tampa Bay (Edwards, 1989). Due to population increases and development, Sarasota Bay has experienced large decreases in tidal wetlands and other shallow-water habitats that may be critical as nursery habitats for immature stages of important fisheries species. Therefore, identification, characterization and protection of fringing shallow-water habitats should be given high priority in any programs designed to conserve, enhance or otherwise manage the Bay.

Past Surveys

Although Sarasota Bay itself has not been well studied, its total number of fish species can be estimated, based on surveys of adjacent systems (Wang and Raney, 1971; Comp, 1985), to exceed 250 (Edwards, 1987). Only one general ichthyofaunal survey (Bird, 1980) has been performed in the Bay, and this study was limited in scope.

Bird sampled 10 stations in Sarasota Bay on a bimonthly basis for one year. She reported 121 species; pinfish (*Lagodon rhomboides*) were by far the most abundant, accounting for more than half the total number of individuals collected. Bird pointed out an important attribute of the Bay by documenting its role as nursery habitat for several offshore species, including red grouper (*Epinephelus morio*), gag (*Mycteroperca microlepis*), grey snapper (*Lutjanus griseus*) and permit (*Trachinotus falcatus*). With the exception of two unpublished Mote Marine Laboratory ichthyoplankton surveys (Sauers and Serviss, 1985 and a 1983-84 survey), little other information on Sarasota Bay fishes and fisheries was available previously.

Sarasota Bay NEP Fishery Information Needs

Although the roles of estuaries, estuarine habitats and fishery resources have recently begun to be better understood in a general sense (e.g., Comp and Seaman, 1985), such general understanding is not adequate for effective, efficient management of systems such as Sarasota Bay. If programs such as the Sarasota Bay NEP are to sustain or even improve fisheries, fisheries-stock abundances, harvest levels and rates and relationships between fishes and specific habitats within the system under consideration must be determined.

In view of these needs, the general goal of this project was to provide information that can be used to help guide development of actions for inclusion in the Sarasota Bay NEP Comprehensive Conservation and

Management Plan and allow evaluation of such actions.

As discussed above, base-line or characterization information for recreational and commercial fisheries and for fish populations and habitat relationships was almost nonexistent for Sarasota Bay. A very fundamental goal of this project was to provide as much of this characterization information as possible with the available funding. To be useful to efforts to detect changes, the information had to be quantitative as possible. However, accurate and precise quantitative information on marine fishes and fisheries is very difficult and expensive to acquire, and the budget allocated to the fishery-assessment work performed for the Sarasota Bay NEP was limited.

General Description of Sarasota Bay NEP Fishery Resource Assessment Project

In light of the aforementioned considerations and limitations, fish and fisheries of Sarasota Bay were assessed using an approach that included a Baywide ichthyological characterization survey plus cost-effective approaches toward characterizing the recreational fishery.

The ichthyological characterization consisted of a seining survey of shoreline and fringing habitats and a trawling survey of deeper habitats. Recreational fisheries were characterized by a Baywide creel survey conducted primarily by volunteers from the Sarasota Bay community. The creel survey was supplemented by data collected from professional fishing guides, who voluntarily maintained log books of catch and effort information. The project also included scoping tasks designed to assess the potential for obtaining separated commercial landings data for Sarasota Bay as well as the potential for directly assessing Sarasota Bay fish populations in the future. Additionally, historical data previously collected by Mote Marine Laboratory were assembled and provided as part of the project's characterization of Sarasota Bay fish and fisheries.

Overall, the project focused on obtaining characterization information about abundances, distributions, habitat associations and catch/harvest/effort (where appropriate) for species that are important components of recreational or commercial fisheries and species that are ecologically important. The term fish and fisheries are meant to include, in addition to finfish, important crustacean shellfish (blue crabs, stone crabs and pink shrimp), since these species also could be sampled (seine or trawl) or surveyed (creel census or landings) concurrently during the Fisheries Resource Assessment project.

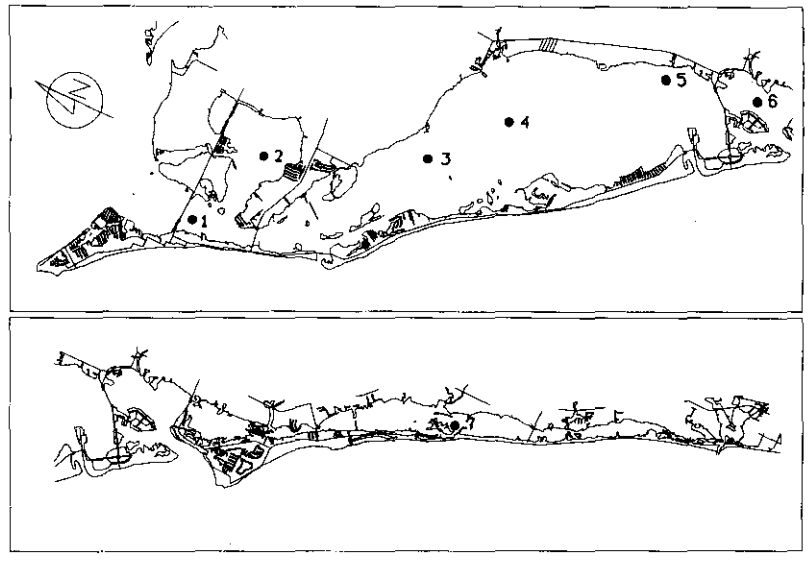


Figure 3. Locations of Sarasota Bay trawl sampling stations.

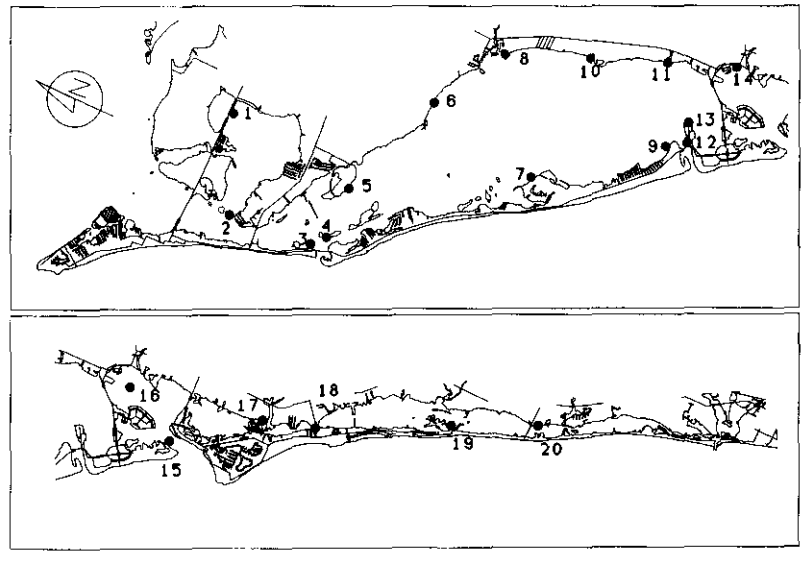


Figure 4. Locations of Sarasota Bay seine sampling stations.

Project Methods and Results

Ichthyological Characterization (Trawl and Seine Ichthyofaunal Survey)

Survey Methods

A total of 27 stations (seven trawl stations and 20 seine stations) located throughout the Sarasota Bay NEP study area *(Figures 3* and *4)* and representing a variety of habitats were sampled during 1990 on a bimonthly basis. Trawl stations were sampled (seven trawls per station) at night using a 3.05-m.-wide otter trawl (Roessler, 1965); seine stations were sampled (one or two hauls per station) during the day with a 15.2 m.-long seine. All fishes and important

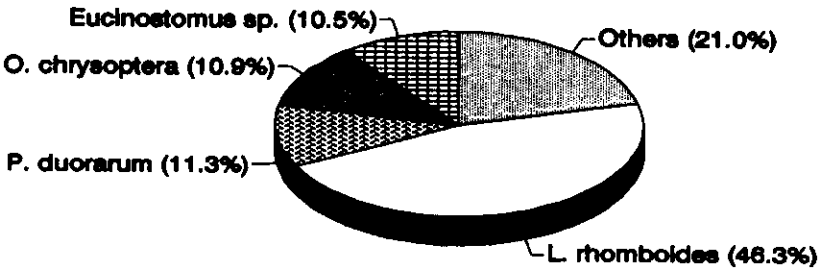


Figure 5. Species composition in terms of total (all replicates and all sampling periods) numbers of individuals for all trawl stations.

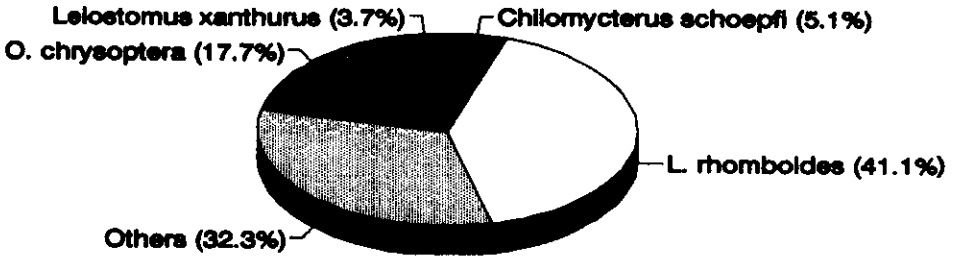


Figure 6. Species composition in terms of total (all replicates and all sampling periods) biomass (wet weight) for all trawl stations.

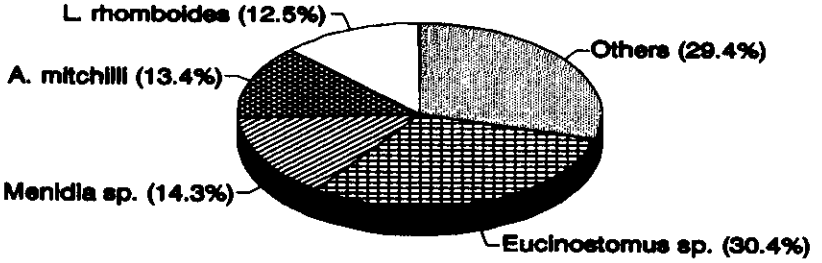


Figure 7. Species composition in terms of total (all replicates and all sampling periods) numbers of individuals for all seine stations.

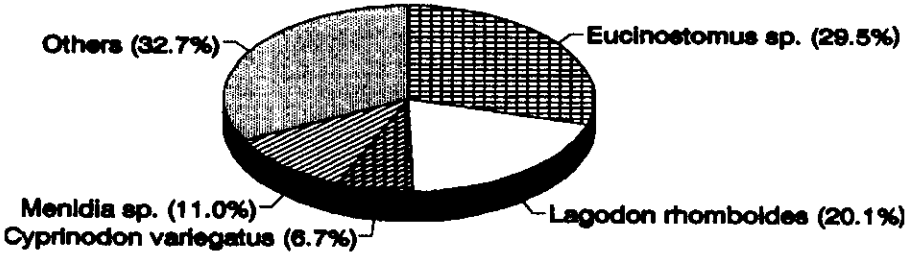


Figure 8. Species composition in terms of total (all replicates and all sampling periods) biomass (wet weight) for all seine stations.

Table 2. Comparison of numerically most abundant fish species, excluding anchovies, collected by trawling in Sarasota Bay (1990–present study; 1979–Bird [1980]), Charlotte Harbor (Wang and Raney, 1971) and Rookery Bay (Yokel, 1975). Values are percentages of total numbers of fish collected in each survey.

	Sarasota Bay		Charlotte Harbor	Rookery Bay
	1990	1979		
Species				
Pinfish	52.2	55.2	37.2	42.0
Pigfish	12.3	11.8	7.2	9.7
Mojarra*	11.9	7.0	7.6	33.5
Silver perch	6.5	9.4	17.7	2.0
Totals	82.9	83.5	69.7	87.2

*Includes E. gula and E. argenteus.

invertebrates collected in the trawls and seines were identified, counted, measured and weighed, and the information was entered into computerized databases.

Survey Results

Dominant Species

A few species dominated the trawl and seine catches in terms of both numbers and biomass (wet weight). At the trawl stations, pinfish dominated the catch, accounting for more than 46 percent of the total numbers and, together with pink shrimp (11 percent), pigfish (11 percent) and mojarras (10 percent), for 79 percent of the total number of individuals collected *(Figure 5)*. In terms of biomass, pinfish (41 percent), pigfish (17 percent), striped burrfish (5 percent) and spot (4 percent) dominated the trawl catch and accounted for all but 32 percent of the total biomass at the trawl stations *(Figure 6)*. At the seine stations, similar dominance by a few species occurred, with mojarras (*Eucinostomas* sp.) replacing pinfish as the numerical dominant *(Figure 7)*, although pinfish contributed greatly to the numbers and biomass *(Figure 8)* collected during the seine survey.

Bird (1980) found similar dominance by the same group of species in her survey of Sarasota Bay, and suggested environmental stress due to pollution as a possible cause for low diversity. Trawling surveys of comparable systems on the southwestern Florida Gulf coast, such as Charlotte Harbor (Wang and Raney, 1971) and Rookery Bay (Yokel, 1974), have found similar dominance by the same suite of species *(Table 2)*; since these other systems are not grossly polluted, it can be concluded that such community structure is not unnatural and does not indicate ecological dysfunction, as suggested by Bird. Therefore, the results of the trawling component of the ichthyological survey indicate that the community structure of Sarasota Bay is relatively normal and has not changed significantly during the last decade.

Some differences among trawl-station total catches were observed *(Figure 9)*. In terms of numbers, total catches at stations T-6 (Big Pass area) and T-7 (Midnight Pass area) were substantially higher than at other stations. The lowest catch was taken at stations T-3, T-4 and T-5 (central-Bay stations), while the number of individuals collected at the northern-Bay stations (T-1 and T-2) was intermediate. Total biomass *(Figure 9)* was similar at all stations except T-6, at which biomass was more than twice as great as at the other stations. The total catch at the seine stations *(Figure 10)* did not seem to show any distinct patterns, except that numerical abundance was highest at station 1.

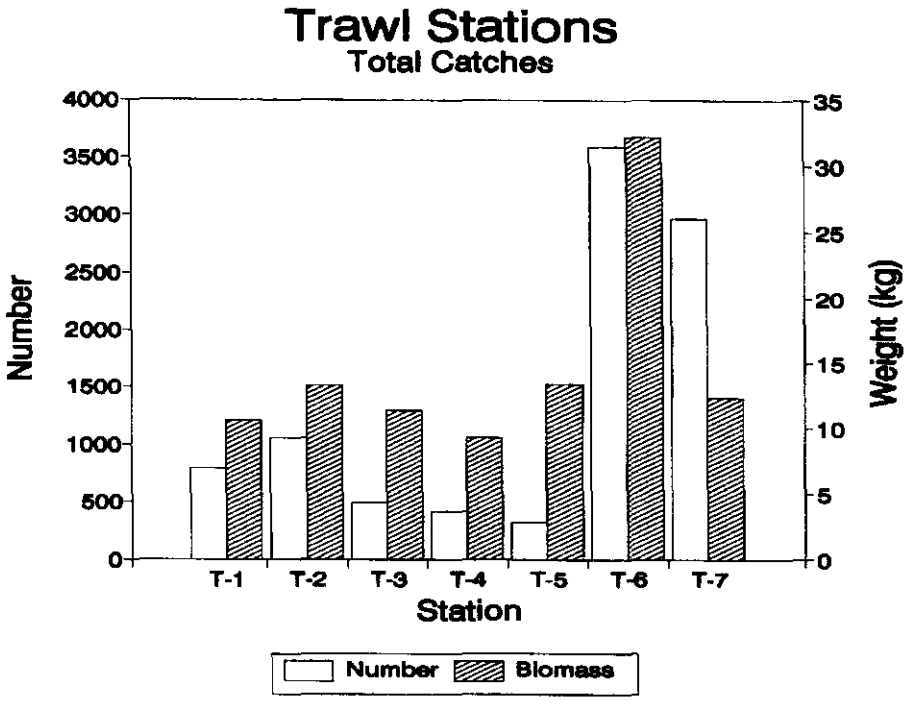


Figure 9. Total (all replicates and all sampling periods) numbers of individuals and biomass for trawl stations.

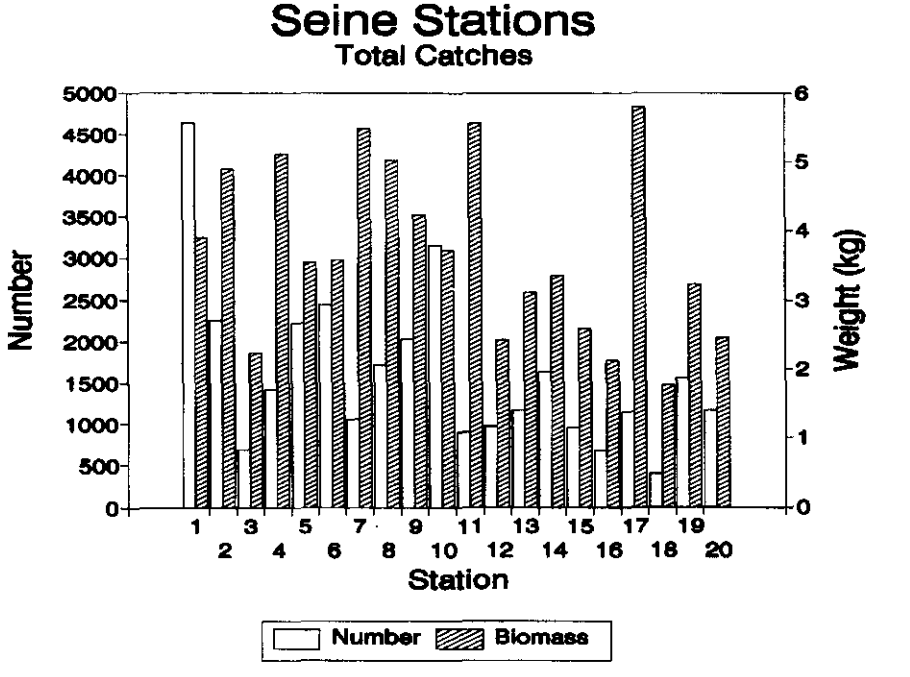
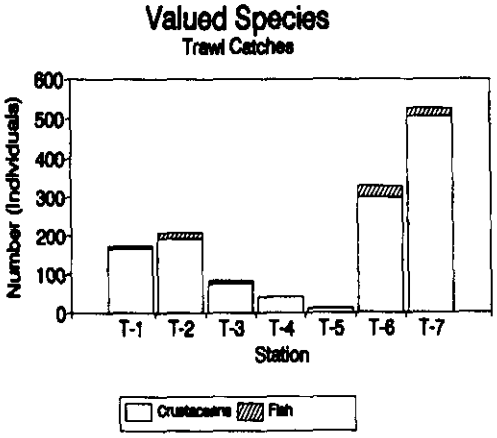


Figure 10. Total (all replicates and all sampling periods) numbers of individuals and biomass for seine stations.

Figure 11. Valued species (crustaceans and fish) and valued fish total catches (sum of all replicates and all sampling periods for each station) at trawl stations.



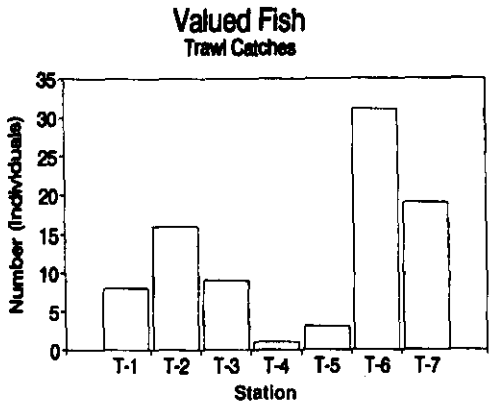
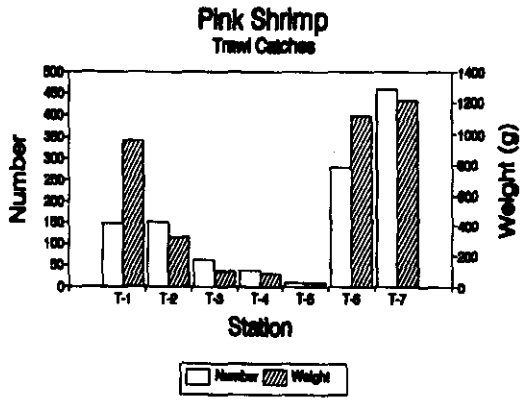
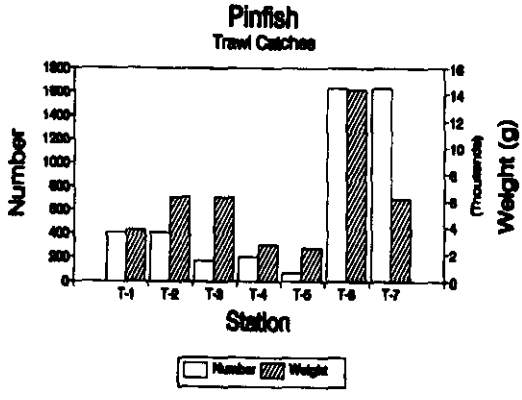


Figure 12. Pink shrimp and pinfish total catches (sum of all replicates and all sampling periods for each station) at trawl stations.





Valued Species

As is typically the case in general trawl and seine surveys, species that are important in commercial and recreational fisheries were not abundant in the trawl and seine catches, so the small numbers of valued fishes collected during the present survey make it difficult to draw any definitive conclusions or to quantitatively characterize the Bay from this perspective. However, substantial differences occurred in the number of individuals of valued species collected at the trawl stations.

Figure 11 shows that valued species were collected in large numbers at station T-6 (Big Pass area) and station T-7 (Midnight Pass area), while numbers were very low at stations T-4 and T-5. A similar pattern *(Figure 11)* held for valued fishes, despite the fact that they accounted for only a small fraction of the catches of valued species. Pink shrimp (*Penaeus duorarum*) was the valued species collected in the largest numbers, with a total of 998 collected in the trawl samples. *Figure 12* shows that the largest number and biomass of shrimp were collected at station T-7 (Midnight Pass area), followed by station T-6 (the station nearest Big Pass). Very small numbers and biomass of pink shrimp were collected at stations T-3, T-4 and T-5. Interestingly, the distribution of pinfish (*Lagodon rhomboides*) followed much the same pattern *(Figure 12)*, with stations T-6 and T-7 very high and stations T-3, T-4 and T-5 very low. It is likely that this pattern is related to benthic vegetation at several stations, and it indicates that at least parts of the Midnight Pass area (the area where the pass formerly existed) are productive with regard to important fishery species.

Figure 13 shows the valued species caught at the seine stations. When the locations of the stations are considered, some patterns seem to emerge. Stations in the northern part of the Bay (stations 1-4) had substantial numbers of valued fish, no mullet, large numbers of pink shrimp and significant numbers of blue crabs. Stations in the main or central portion of the Bay (stations 5-13), with a few exceptions, had much lower numbers of pink shrimp and generally much lower numbers of valued organisms, except for numerous striped mullet at stations 6, 9 and 12. The exceptions were three stations (9, 12 and 13) near New Pass, where shrimp were numerous, and station 10 (just north of Stephens Point on the eastern shore of central Bay), where the abundance of valued species was higher because of relatively large numbers of juvenile blue crabs and juvenile permit. Seine stations south of the Ringling Cause-

way (stations 14-20), with one exception (station 19), had extremely low numbers of valued species, with blue crabs comprising the majority of the valued individuals collected at most stations. Valued species collected at station 19 (Midnight Pass) included good numbers of pink shrimp, blue crabs and fishes. Valued fishes collected at station 19 included juveniles of gray snapper, spotted seatrout, sheepshead and the only snook collected in the entire study. These limited results suggest that the Midnight Pass area is now functioning as a productive nursery habitat for valued fish and crustaceans.

One possible change in valued species was noted from the 1990 survey results. Bird (1980) collected large numbers of juvenile gag (171) and red grouper (37) in the 1979 survey of Sarasota Bay, while only five gag and no red grouper were collected in 1990, despite the fact that several of the stations at which these two important grouper species were collected in 1979 were included in the 1990 survey. However, the differences may be due to different sampling techniques and/or to natural inter-annual variability in recruitment and abundance of these two groupers that use the Bay and other inshore habitats as nurseries (Moe, 1969). On the other hand, if the observed differences reflect real changes, these changes could be expected to have important implications for the commercially and recreationally valuable grouper fisheries in the area.

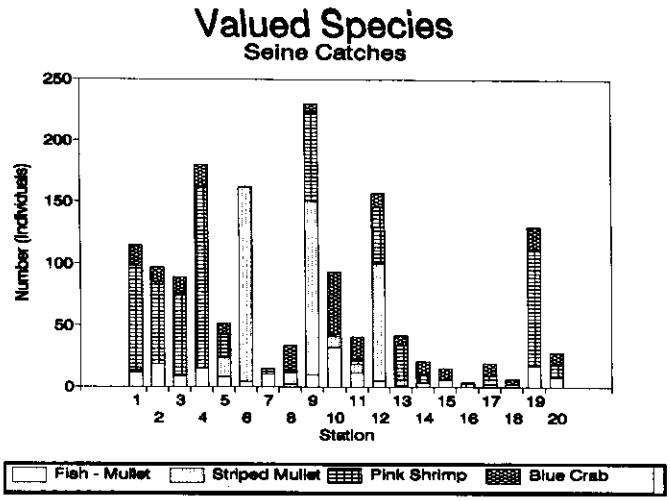


Figure 13. Valued species total catches (sum of all replicates and all sampling periods for each station) at seine stations.

Recreational Fishery Survey

Survey Methods

Nine public boat ramps and nine shore fishing sites were selected from all similar sites in the NEP study area. The boat ramps included almost all the most-used ramps in the area; the shore sites included the most-used shore fishing locations in the study area. Sites were sampled using a stratified random-sampling plan, with each month comprising a "time block" that was stratified into weekdays and weekend days (Hayne, 1991). Monthly target schedules of four sampling days (two weekdays and two weekend days) per site were randomly generated. Each date was randomly assigned a morning or afternoon four-hour work period as follows: for ramps, either 10 a.m.-2 p.m. (designated "AM") or 2-6 p.m. ("PM"); for shore sites, either 8 a.m.-noon ("AM") or 2-6 p.m. ("PM"). The time periods were selected to maximize interception of 1) boaters returning from either morning or all-day trips; and 2) shore anglers fishing during the early- to mid-morning hours and those fishing in the later afternoon.

One hundred-eighteen volunteers were trained as interviewers during the course of the study; a core group of approximately 30 of these volunteers conducted the majority of the 555 completed assignments. Interviewers were trained by the creel-survey coordinator and project supervisors during an intensive training session in interview techniques, fish identification and data recording. The survey coordinator followed up with individual interviewers on a one-on-one basis, checking for correct procedure and knowledge of fish identification. A species-identification guide to fish species inhabiting Sarasota Bay – containing individual species-identification sheets for 65 species of fish (17 cartilaginous fishes and 48 bony fishes) and three species of invertebrates – was prepared and distributed to each interviewer. (The sheets were copied with permission from the publisher, the Food and Agriculture Organization of the United Nations, Rome, Italy.) Interviewers were briefed on key characteristics of major Bay species, using the guidebook and other field books and materials.

A creel-survey form, adapted for the Sarasota Bay region using the National Marine Fisheries Service (NMFS) Marine Recreational Fishery Statistics Survey (MFRSS) form, was used in all interviews. Catch, catch disposition, effort, location, gear and other data were collected with this form. At the assigned intercept sites, interviewers approached and screened anglers and conducted the interviews. Data on fish size were collected and reported as fork length to the nearest 0.5 inches and weight to the nearest 0.25 pound. Large catches (>10) were subsampled (10 fish) for size data.

The shore fishing sites were sampled using the roving-clerk method (Malvestuto, 1983), which measures the instantaneous fishing pressure and fishing success and then extrapolates to total catch and effort for the

Shore Summary					
	Total Effort	Total Harvest	Total Catch	Harvest CPUE	Catch CPUE
Site	(Ang-hr)	(No. fish)	(No. fish)	(Fish/ ang-hr)	(Fish/ ang-hr)
11	20502	11628	30917	.54	1.37
22	17845	15984	31840	.87	2.11
33	18572	12592	22167	.78	1.26
44	20218	41636	47943	1.50	1.90
55	28232	48595	71086	1.66	2.41
66	20557	13945	24417	.69	1.24
77	11716	22147	28895	1.98	2.56
88	6224	2638	5785	.58	1.02
99	10122	4361	13033	.41	1.11
Totals	**153989**	**173525**	**276084**	**1.00**	**1.66**

Table 3. Shore-anglers (shore sites) creel survey catch and effort data summary.

site, but obtains catch per unit effort (CPUE) by estimating the mean success rate of each interviewed angler. The ramp (boat-angling) sites were sampled using the access-point method (Hayne, 1991), which tallies catch and effort from anglers crossing the boat ramp (like individuals passing through a turnstile counter), extrapolates those tallied numbers to total catch and effort and *then* obtains CPUE estimates from the catch and effort totals.

Interview data, adjusted by appropriate probability coefficients, were used to extrapolate from sample data to monthly and yearly estimates of catch, harvest, effort and CPUE for the various sites (Hayne, 1991; Malvestuto, 1983). Catch per unit effort was calculated for fish caught (kept + released + other disposition = catch CPUE) and fish harvested (landings CPUE).

Survey Results - Private Anglers

Angler Success Rates

At the shore sites, annual mean catch CPUE was estimated to be 1.66 fish per angler hour, and landings CPUE was 1.00 fish/angler-hour *(Table 3)*. At the ramp (boat-angler) sites, annual mean catch CPUE was estimated to be 1.32 fish/angler-hour, and landings CPUE was 0.58 fish/angler-hour *(Table 4)*. However, the species composition of the catch and landings of the shore anglers was much different from that of the boat anglers.

Boat-anglers (shore sites) creel survey catch and effort data summary.						
Site	Site Multiplier	Total Effort (Ang-hr)	Total Harvest (No. fish)	Total Catch (No. fish)	Harvest CPUE (Fish/ang-hr)	Catch CPUE (Fish/ang-hr)
10	1.53	30980	18447	40510	.60	1.31
20	1.22	23406	17712	39712	.76	1.70
30	1.79	18415	5731	18223	.31	.99
40	1.19	22753	13232	26865	.58	1.18
60	1.51	32582	25659	43443	.79	1.33
70	1.41	25566	5088	16478	.20	.64
80	1.32	10410	10073	32039	.97	3.08
90	1.00	5829	2038	7364	.35	1.26
100*	1.00	6796	1328	13029	.20	1.92
TOTALS		**169941**	**97981**	**224633**	**.58**	**1.32**
*Site 100 data apply to four months only (9/90-12/90)						

Table 4. Boat-anglers (ramp sites) creel survey catch and effort data summary.

Catch Composition

The species composition of the combined shore-angler and boat-angler catch and landings (harvest) are shown in *Table 5*. Spotted seatrout (20 percent), pinfish (12 percent), sand seatrout (11 percent), sheepshead (8 percent), pigfish (8 percent), silver perch (4 percent) and Gulf kingfish (4 percent) accounted for two-thirds (67 percent) of the combined (shore and ramp) catch. These same species were also the top seven species of the separated shore and ramp catches, although their relative positions were different for shore and ramp stations.

At the shore stations alone *(Figure 14)*, two species of smaller and generally less-desirable fish, pinfish (27 percent) and pigfish (14 percent), contributed most to the catch and similarly (25 percent and 13 percent, respectively) to the landings. Other species important in the shore catch included spotted seatrout (5 percent), Gulf kingfish (4 percent) and sand seatrout (4 percent). Additional species that contributed significantly to the shore landings included sheepshead (7 percent), sand seatrout (7 percent), Gulf kingfish (6 percent) and silver perch (6 percent).

The catch and landings of boat anglers *(Figure 15)* included more fish that are generally desired and sought by recreational anglers. Spotted seatrout (26 percent), sand seatrout (14 percent) and sheepshead (10 percent) contributed most to the catch and similarly (16 percent, 25 percent and 17 percent, respectively) to the landings. The greater landings of sand seatrout as compared to spotted seatrout can be attributed largely to the lack of legal size limits for sand seatrout, whereas a 14-inch (TL) limit applies to spotted seatrout, resulting in a very large proportion (70 percent) of the spotted seatrout being released after being caught by boat fishermen. Other species that contributed significantly to the ramp landings included silver perch (8 percent), Gulf kingfish (7 percent) and pinfish (3 percent).

Disposition of Catch

A high percentage of total (shore and boat) catch of several species were released alive *(Table 5)*. These include spotted seatrout (70 percent released alive), gray snapper (55 percent), red drum (87 percent), red grouper (87 percent), gag (89 percent) and snook (87 percent), probably reflecting legal size limits, creel limits and closed seasons. Species for which a high proportion of the catch was kept for eating purposes include sand seatrout (88 percent kept for

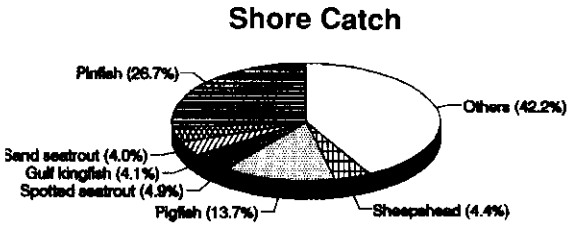
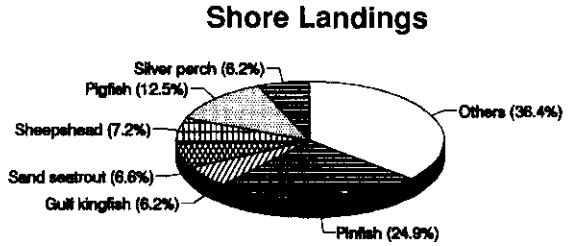


Figure 14. Shore-angler (shore sites) total catch distribution by species in terms of total number of fish caught (landed [= harvested] + released) and total number landed.



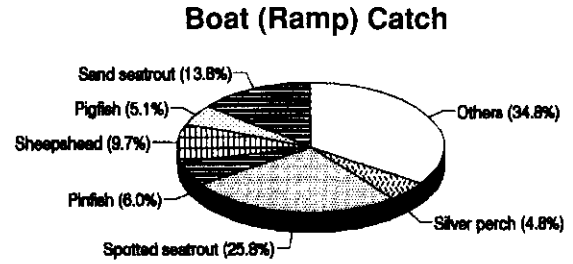
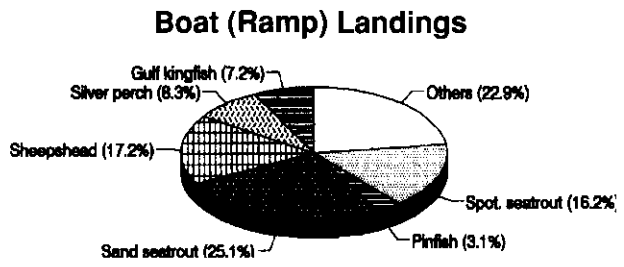


Figure 15. Boat-angler (ramp sites) total catch distribution by species in terms of total number of fish caught (landed [= harvested] + released) and total number landed.



Shore							Ramp						Total	
	Released		Harvest		Total		Released		Harvest		Total			
Species	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Spotted seatrout	192	74.7	65	25.3	257	4.9	2242	70.2	952	29.8	3194	25.8	3451	19.5
Pinfish	693	49.0	720	51.0	1413	28.1	556	75.2	183	24.8	739	6.0	2152	12.2
Sand seatrout	19	9.1	190	90.9	209	5.8	234	13.7	1475	86.3	1709	13.8	1918	10.9
Sheepshead	25	10.8	207	89.2	232	6.8	192	15.9	1013	84.1	1205	9.7	1437	8.1
Pigfish	364	50.3	360	49.7	724	22.8	423	66.5	213	33.5	636	5.1	1360	7.7
Silver perch	15	7.7	179	92.3	194	7.9	104	17.6	487	82.4	591	4.8	785	4.4
Gulf kingfish	38	17.4	180	82.6	218	9.7	36	7.8	424	92.2	460	3.7	678	3.8
Ladyfish	86	84.3	16	15.7	102	5.0	473	91.1	46	8.9	519	4.2	621	3.5
Gray snapper	47	48.0	51	52.0	98	5.1	251	55.9	198	44.1	449	3.6	547	3.1
Hardhead catfish	60	90.9	6	9.1	66	3.6	378	93.8	25	6.2	403	3.3	469	2.7
Red drum	67	85.9	11	14.1	78	4.4	248	87.3	36	12.7	284	2.3	362	2.0
Spanish mackerel	54	29.3	130	70.7	184	10.9	20	12.3	143	87.7	163	1.3	347	2.0
Inshore lizardfish	79	79.0	21	21.0	100	6.6	204	96.2	8	3.8	212	1.7	312	1.8
Black sea bass	41	69.5	18	30.5	59	4.2	173	76.5	53	23.5	226	1.8	285	1.6
Crevalle jack	140	79.5	36	20.5	176	13.0	68	65.4	36	34.6	104	0.8	280	1.6
Striped mullet	18	14.1	110	85.9	128	10.9	0	0.0	144	100	144	1.2	272	1.5
Red grouper	46	92.0	4	8.0	50	4.8	149	85.6	25	14.4	174	1.4	224	1.3
Spottail pinfish	56	43.1	74	56.9	130	13.0	61	82.4	13	17.6	74	0.6	204	1.2
Gulf flounder	23	31.5	50	68.5	73	8.4	31	27.0	84	73.0	115	0.9	188	1.1
Gag	32	97.0	1	3.0	33	4.2	115	87.1	17	12.9	132	1.1	165	0.9
Sand perch	18	60.0	12	40.0	30	3.9	60	69.0	27	31.0	87	0.7	117	0.7
Striped mojarra	10	23.3	33	76.7	43	5.9	46	93.9	3	6.1	49	0.4	92	0.5
Pompano	3	17.6	14	82.4	17	2.5	37	53.6	32	46.4	69	0.6	86	0.5
Bluefish	1	12.5	7	87.5	8	1.2	44	57.9	32	42.1	76	0.6	84	0.5
Southern flounder	12	42.9	16	57.1	28	4.2	20	37.0	34	63.0	54	0.4	82	0.5
Others*	257	40.5	378	59.5	635	12.0	330	64.6	181	35.4	511	4.1	1146	6.49

* Includes all species contributing less than 0.5% of the total (shore + boat) catch.

Table 5. Species composition of recreational fishery (shore and ramp sites) catch and harvest.

eating), sheepshead (82 percent), silver perch (53 percent), Gulf kingfish (89 percent), Spanish mackerel (75 percent), Gulf flounder (70 percent), southern flounder (61 percent) and black drum (64 percent). Overall, nearly half (49.8 percent) the catch was released, 39 percent was kept for eating, and most of the balance consists of fish that anglers fed to pelicans and other birds.

Distribution of Shore-Angler Catch and Effort among Sites

Estimated annual catch and harvest at the shore sites *(Table 3)* were highest at site 55 (Bradenton Beach piers) and site 44 (Manatee Beach Pier/Palma Sola Causeway). Estimated (weighted) annual harvest was highest at sites 44 and 55, and lowest at sites 88 and 99. Estimated annual effort was highest at site 55 and was very low at southern Sarasota Bay sites (77, 88 and 99).

Catch CPUE was high at sites 55 and 77, and was lowest at site 88. Landings CPUE was high (1.5-2.0 fish/hr) at sites 44, 55 and 77, and much lower (0.4-0.9 fish/hr) at the rest of the sites. Overall, the sites that included fishing piers (sites 22, 44 and 55) appear to provide the best opportunities for shore anglers.

Distribution of Boat-Angler Catch and Effort among Sites

Estimated annual catch, harvest and effort *(Table 4)* were all highest for anglers launching from Site 60 (City Island Park), followed by Site 10 (10th St., Sarasota). However, catch CPUE and landings CPUE were by far the highest at Site 80 (Turtle Beach). This fact is significant in that the Turtle Beach ramp provides access to Bay waters around the Midnight Pass area, and the high CPUEs suggest that fishing is good in the area. Site 30 (Kingfish ramp) and Site 70 (Nokomis/789 Bridge) had the lowest catch and landings CPUEs.

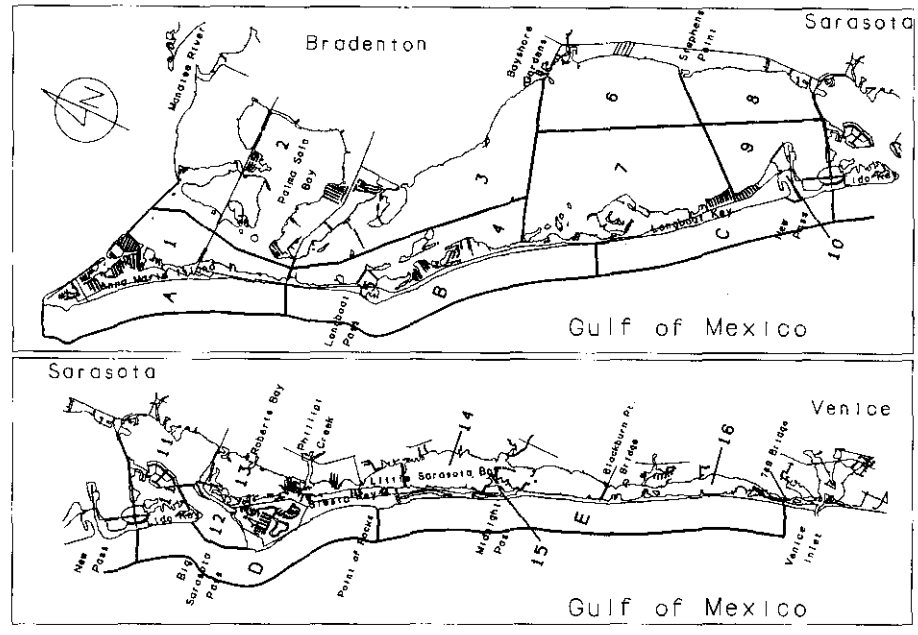


Figure 16. Recreational fishery survey zonation.

Distribution of Boat Angler Catch among Zones (Bay Segments)

The Sarasota Bay NEP segmentation plan (Estevez and Palmer, 1990) was slightly modified to include zones (as opposed to segments) that could be easily identified by anglers in boats *(Figure 16)*. The distribution of boat-angler catch relative by Bay zones is shown in *Figure 17*. The distribution of boat-angler seatrout (spotted and sand seatrout) catch is also shown in *Figure 17*. Zone 9 (western Bay near New Pass) was by far the most important with regard to total and seatrout catch. Zones 1 (western Anna Maria Sound), 4 (southern Anna Maria/ northern Longboat), 8 (eastern Bay from Stephens Point to Ringling Causeway) and 11 (eastern and western Bay from Ringling Causeway to Siesta Drive) also had high total catches. Reach D (nearshore Gulf from central Lido to Point of Rocks) had by far the greatest catch of all the reaches. Because of the overall importance of seatrout in the recreational fishery, seatrout catch followed the same general pattern. The catch distribution probably reflects a combination of ecological and logistical factors. Ecological factors include seasonal movements and concentrations of fishes around passes (zones 1, 4, 9 and 11), and extensive grass flats (zones 1, 4, 9 and 11); logistical factors include location of launching areas and proximity of fishing areas.

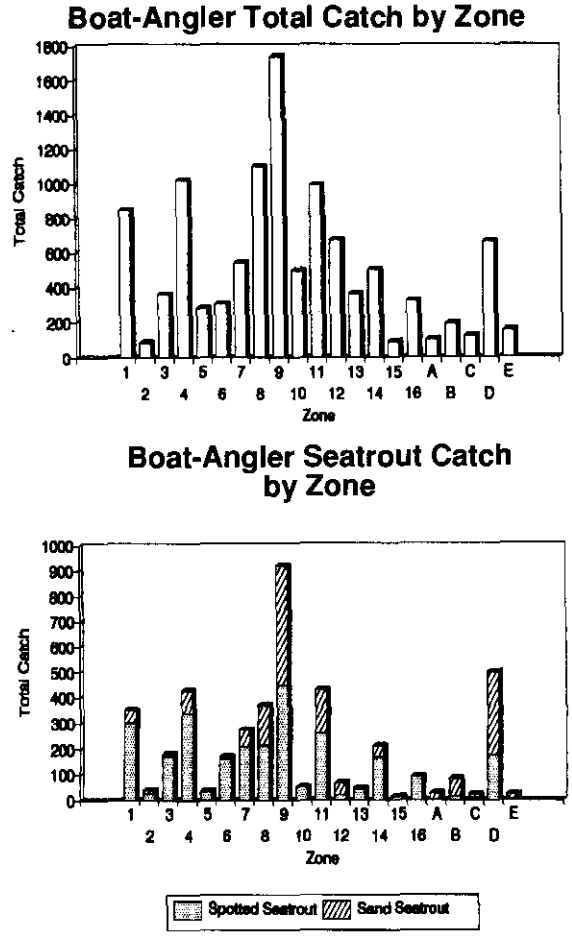


Figure 17.

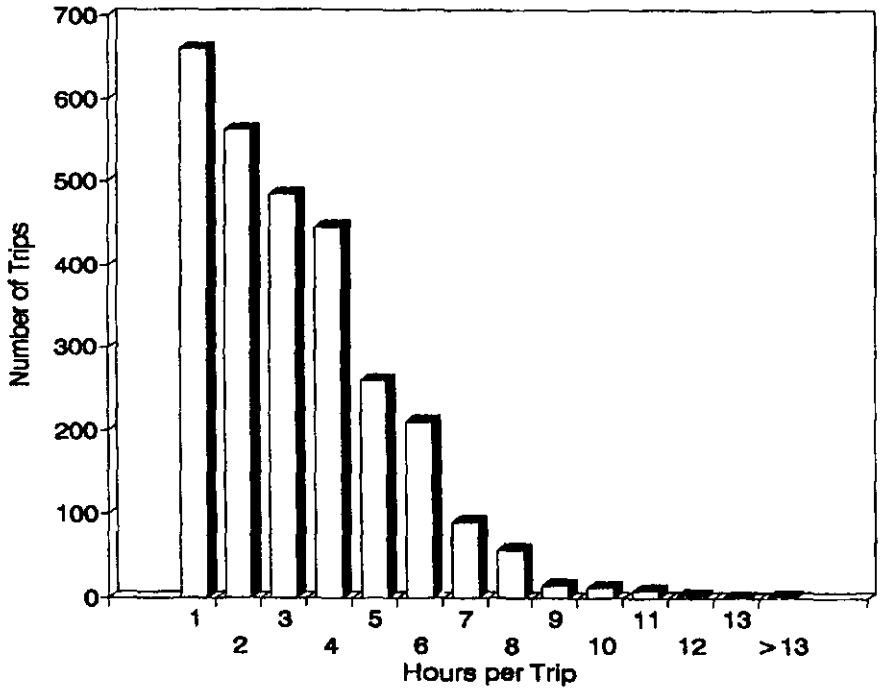


Figure 18. Trip length (rounded to nearest hour) histogram for anglers (shore and boat) interviewed during the recreational fishery survey.

Characterization of Fishery Participants

About 79 percent of the anglers interviewed during the survey were Florida residents; 92 percent of the Floridians were residents of Sarasota or Manatee counties. Of the non-Florida residents, about 10 percent (2.0 percent of all anglers) were from outside the U.S. The anglers spent an average of 3.1 hours per trip; the median trip length was 3.5-4.0 hours *(Figure 18).* The anglers reported having fished an average of 10 days in the previous two months, with the median falling between five and six days (i.e., more than half of all anglers reported fishing on five days or more during the previous two months). Catch (combined shore and boat) was distributed unevenly among angler interviews *(Figure 19),* with the top 10 percent of the angler interviews accounting for about 50 percent of the total catch, and the bottom 50 percent accounting for just over 10 percent of the total catch.

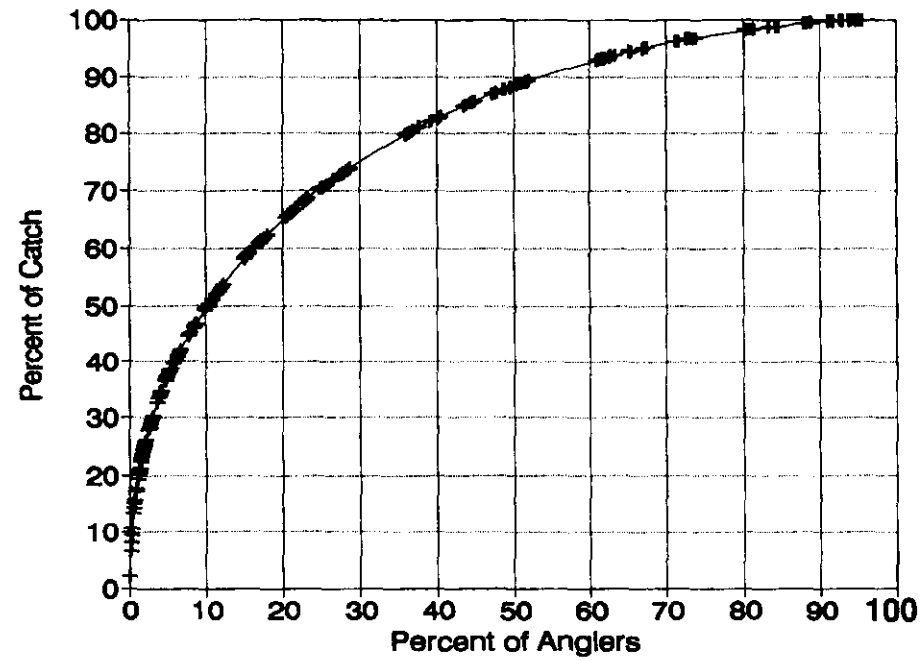


Figure 19. Cumulative catch distribution of total (landed plus released) catch among all (shore and boat) recreational anglers.

Target Species

Targets indicated by recreational anglers are shown in *Figure 20.* Spotted seatrout was by far the most-sought species (31.2 percent of all target indications), followed by sheepshead (11.7 percent), sand seatrout (10.7 percent) and red drum (8.2 percent).

Guided-Angler Surveys

To provide supplemental information by which Sarasota Bay recreational fisheries could be characterized, the assistance of local fishing guides was enlisted; guides were asked to maintain logbook information about trips made in the Sarasota Bay study area. One guide, Captain Jonnie Walker, provided log books he had kept during 13 years of fishing on Sarasota Bay. The guide data were entered into computerized databases and analyzed to provide status and trends information.

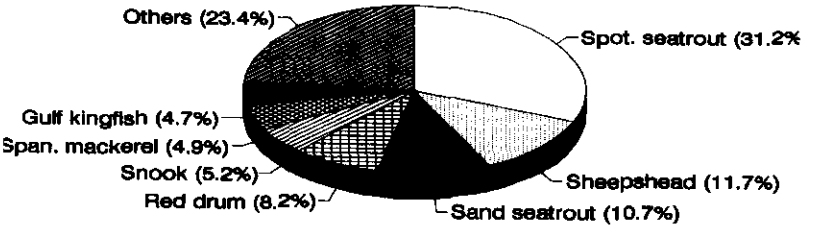
Guided-Angler Success Rates and Catch Composition

Catch per unit effort of guided anglers, based on logs reflecting 2,048 man-hours of angler effort, was estimated to be 1.97 fish caught per man-hour and 0.85 fish landed (harvested) per man-hour. The species composition of the catch and landings of guided anglers *(Figure 21)* was much different from that of private anglers, being comprised much more of desirable species. Spotted seatrout was by far the most important species, accounting for half (49.6 percent) the total number of fish caught and half (50.3 percent) the fish landed by guided anglers, despite the fact that 56.2 percent of all spotted seatrout were released. In addition to spotted seatrout, substantial landings of bluefish (10.4 percent of total landings), sand seatrout (9.8 percent), Spanish mackerel (9.7 percent) and sheepshead (5.7 percent) were reported.

Target Species

Species targeted by guides included spotted seatrout, red drum, Spanish mackerel, pompano, snook and sheepshead. Spotted seatrout was by far the most-sought species, being the primary target in 71 percent of the cases where targets were indicated. Red drum was the primary target in 15 percent of the cases where primary target was indicated, and was either the first second or third target in 17 percent of the cases where targets were indicated. Therefore, since red drum accounted for only 1.5 percent of the total catch, a significant disparity exists between the degree to which red drum were targeted and the extent to which they were caught. Similarly, snook accounted for only 0.2 percent of the total catch despite the fact that they were indicated as the target species in 3 percent of the cases in which targets were noted on the log sheets.

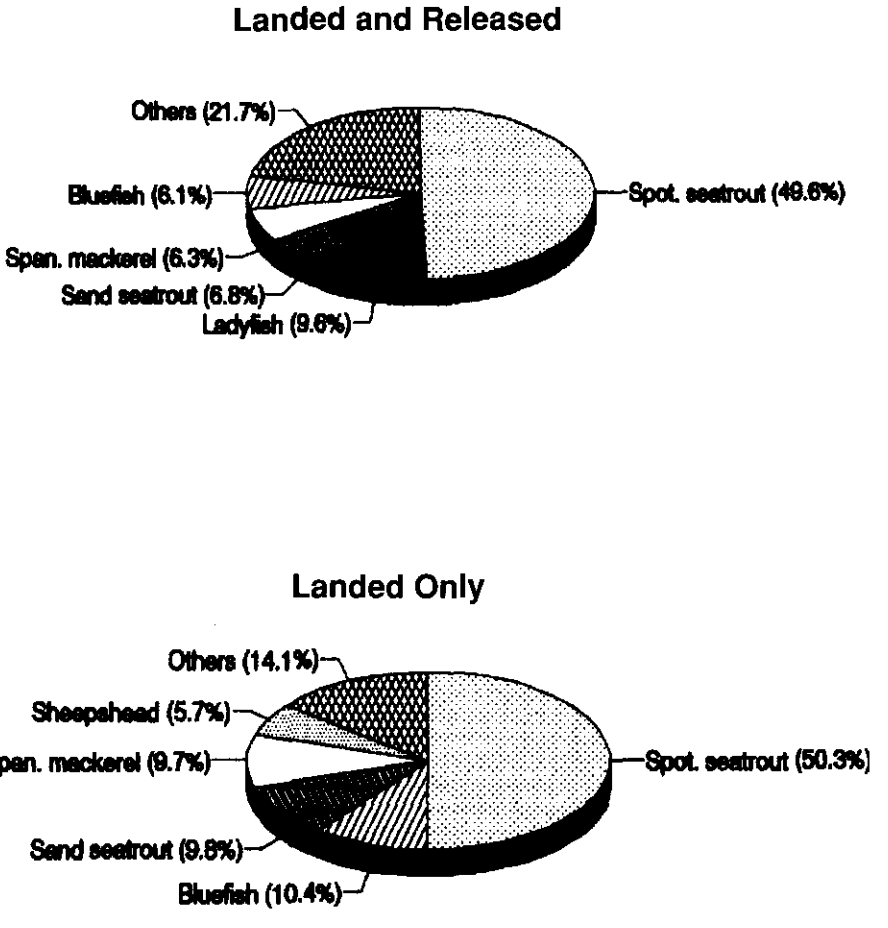
Figure 20. Target species of recreational fishermen (shore and boat).



Success Rates and Catch-Composition Comparisons between Guided and Private Anglers

CPUE of anglers fishing in Sarasota Bay with guides was 1.97 fish caught per man-hour, while the CPUE of private anglers in boats (ramp survey) was estimated at 2.45 fish/man-hour. In terms of fish landed, the guided CPUE was 0.85 fish/man-hour and the private-boat angler CPUE was 1.06. However, the guided catch and landings consisted of a much larger proportion of target and valued species than that of private anglers; for example, about half the guided catch and landings consisted of spotted seatrout *(Figure 21)*, whereas only 26 percent of the private catch and only 16 percent of the harvest of anglers fishing from private boats was spotted seatrout *(Figure 15)*. This probably reflects the fact that higher levels of skill and experience are needed to consistently catch large numbers of spotted seatrout. Sand seatrout were much more important to private-boat anglers, and accounted for 14 percent of their catch and 26 percent of their harvest, as opposed to only 7 percent and 10 percent for guided anglers. Spanish mackerel and bluefish together accounted for more than 12 percent of the guided anglers' catch and over 20 percent of their harvest, but accounted for only 2 percent of the private-boat anglers' catch and 3 percent of their harvest. Overall, the private-boat anglers caught and harvested a greater proportion of less-glamorous species such as pinfish, pigfish and silver perch. Therefore, the catch and effort data of the two groups are not directly comparable.

Figure 21. Guided-angler catch distribution (major species).



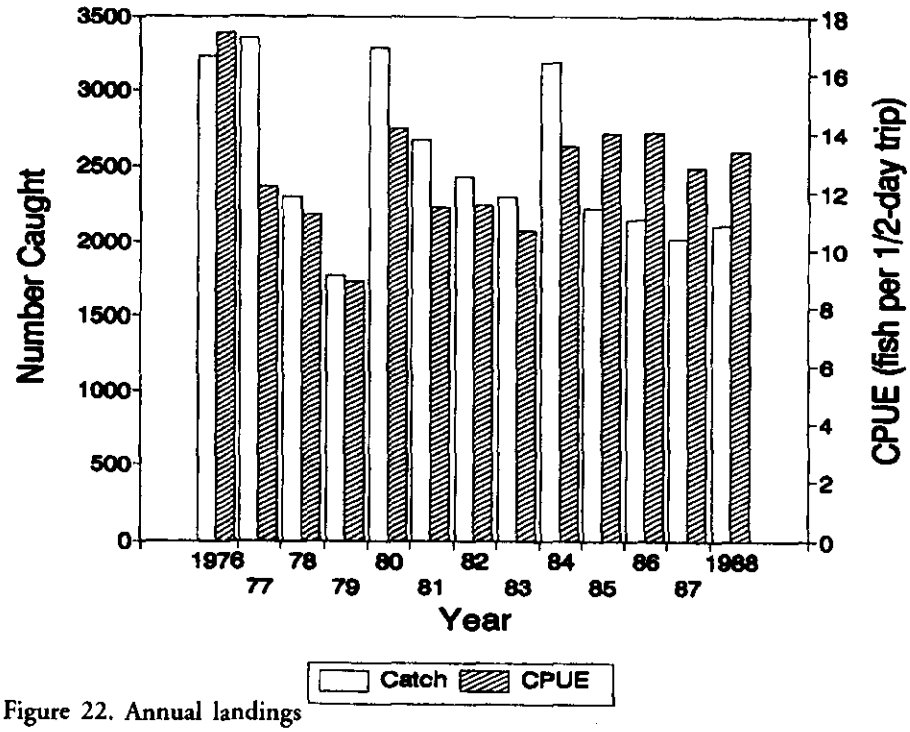


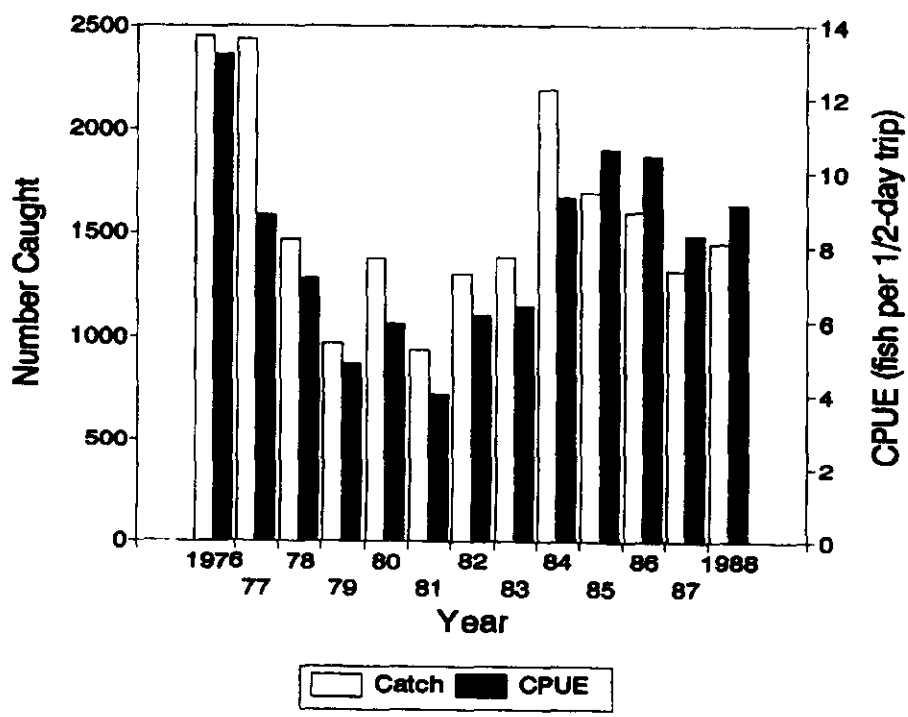
Figure 22. Annual landings and CPUE (number of fish landed per half-day trip) of Capt. Walker.

Figure 23. Spotted-seatrout annual catch (landings) and catch per unit effort (CPUE) of Capt. Walker.

Long-Term Data Analyses

The long-term (13-year) logbook data of Capt. Walker do not provide much evidence of fishery changes during the period 1976-1988. Total annual landings and landings CPUE show no distinct trend *(Figure 22).* Capt. Walker's annual landings and landings for spotted seatrout *(Figure 23)* suggest that cycles of abundance may have occurred during the period, but no evidence exists of consistent decline during the period 1976-88. However, in 1990 Capt. Walker's spotted-seatrout CPUE (landed fish) fell to sightly more than 5.2 spotted seatrout per half-day trip. This decline may partially reflect the fact that the legal size limit for spotted seatrout was increased from 12 to 14 inches on November 1, 1989, but since Capt. Walker's 1990 total (catch) CPUE (landed plus released) for spotted seatrout was only 11.2 fish/half-day trip, his 1990 landings CPUE would not have been as high as in past years even if the 14-inch size limit had not been in effect. Therefore, to the extent that the changes in CPUE are not primarily due to changes in Capt. Walker's fishing practices (e.g., methods and targets), some suggestion is evident that a decline in spotted seatrout abundance or availability may have occurred over the period 1984-90. Whether this decline is part of a cycle of apparent decline followed by increase, as seemed to be the case during 1976-84, remains to be seen. However, the putative cyclical declines during the period make it unlikely that the most recent changes reflect long-term environmental degradation of the Bay. Captain Walker's annual spotted-seatrout CPUE positively correlates ($r = 0.63$, $p < 0.05$) with Sarasota County commercial landings of spotted seatrout during the period (1976-87) for which both types of data are available. This correlation suggests that CPUE data obtained from logbook records such as Capt. Walker's do reflect fish abundance or availability and therefore provide useful information about fishery status.

The conclusion that the data from Capt. Walker's logs do not provide clear evidence of fishery declines should not be taken to indicate that no declines have occurred (in terms of abundances, availability, production or harvest) in Sarasota Bay fisheries. No information for the period prior to 1976 is available, and it is likely that abundance, availability, production or harvest was much higher in the past. Most declines in productivity are likely to have occurred prior to 1976, probably largely as a result of environmental alterations. Commercial landings of spotted seatrout *(Figure 2)*, particularly Sarasota Country landings, had already declined significantly by 1976. Most dredging and filling that accounted for the bulk of the loss of important fishery habitat such as seagrass beds, shallows and intertidal wetlands in Sarasota Bay occurred decades ago, with major projects such as Bird Key, Country Club Shores and the Intracoastal Waterway.



Extrapolated Estimates of Baywide Catch and Effort

Total Catch and Effort

Because funding for this project was limited, it could not include certain features that would have been necessary if estimates of total Baywide catch and effort were to have been obtained directly. Such estimates would require a survey with 24-hour sampling and ways (e.g., on-water surveys or aerial surveys) to obtain data from boats launched from other access points, such as private docks, marinas or shorelines throughout Sarasota Bay.

Although direct information about total effort could not be provided by the present study, estimates of recreational-fishery total catch, total landings and total effort were developed indirectly and are provided because they represent the best-available information, and because such information is important to the Sarasota Bay National Estuary Program as a baseline against which future fishery harvest can be compared and used as an indicator of the Bay's condition. These estimates were based on reasonable constraints to extrapolation of measured estimates of total boat-angler effort, catch and harvest, and their development is detailed in the project technical report. Considering daily periods not included in the survey (e.g., nights, early morning and mid-day) and considering anglers fishing from shore sites not covered in the survey or from boats not launched from any of the ramp sites, it was indirectly estimated that total annual Baywide shore-angler catch, harvest and effort could be reasonably approximated as being six to 14 times as great as that directly estimated *(Table 3)*, and that total annual Baywide boat-angler catch, landings and effort can be reasonably approximated as being two to four times as great as that directly estimated *(Table 4)*. The species composition of the indirectly estimated catch and harvest can be considered to be about the same as that measured in the survey.

Spotted Seatrout

Using the maximum multiplier (4.0) for extrapolating from ramp-site total harvest (97,981 fish *[Table 4])* to total Baywide harvest by boat anglers and the proportion (16.2 percent) of reported seatrout landings *(Table 5)* yields a total estimate of spotted-seatrout landings by boat anglers of 63,492 fish. Similarly, using the minimum (based on the fact that most seatrout were caught at piers or passes, and all Sarasota Bay piers and passes were already included in the shore sites) multiplier (6.0) for extrapolating from shore-site total harvest (173,525 fish *[Table 3])* to total Baywide harvest by shore anglers and the proportion (2.25 percent) of reported seatrout landings *(Table 5)* yields an estimate of Baywide landings of 23,426 spotted seatrout by shore anglers. Therefore, the estimated total (Baywide) number of spotted seatrout caught annually by all anglers would be 86,918. Applying the NMFS estimated average weight of spotted seatrout of 1.15 lb. (NMFS, 1991) provides an estimated recreational total landings of 99,956 lbs. Even if the less-reasonable maximum multiplier (14) were applied to estimate spotted seatrout harvested by shore anglers, total (shore and boat) harvest would amount to only 118,152 lbs.

Spotted-Seatrout Fishery Status

As pointed out in the introduction to this report, commercial landings of spotted seatrout in the Sarasota Bay area have declined from 430,000 lbs. in 1951 to around 100,000 lbs. or less annually in the 1980s *(Figure 2)*. Also pointed out in the introduction was the problem of lack of information on the extent to which the decline in commercial landings has been offset by increasing recreational fishery landings during this period, in which the combined population of Sarasota and Manatee counties increased tenfold. The above indirect estimates of total Baywide catch and effort can address the question of whether a real decline in spotted seatrout has occurred in Sarasota Bay or whether the harvest merely has been re-allocated.

In 1990, combined Manatee and Sarasota county commercial landings of spotted seatrout were only 42,000 lbs.; in 1989, they were about 60,000 lbs. Some of the recent decline in landings may be due to closure of the fishery for red drum, which are often caught with spotted seatrout (Mark Taylor, personal communication), but at least some of that decrease could be expected to accrue to the recreational fishery. Therefore, present total (commercial plus recreational) annual landings can be estimated to be less than 200,000 lbs. If this estimate is even close to being correct, then clearly substantial declines in the spotted-seatrout harvest have occurred during the last four decades. Total landings in 1951 may have been nearly 500,000 lbs. (430,000 lbs. of commercial landings plus unknown recreational landings). During the period 1958-70, annual commercial landings averaged close to 300,000 lbs. Allowing for a substantial recreational harvest similar to that of the present, the total annual yield was probably

near 400,000 lbs. for more than a decade. Present annual yield of less than 200,000 lbs. indicates that current spotted-seatrout fishery production is about half what it was three decades ago, and may be substantially less than half what it was four or more decades ago.

The fact that commercial landings have been very low for about a decade and presently are about equal to or less than recreational landings suggests that the declines cannot be attributed solely to commercial fishing. At worst, commercial and recreational fishing, since they are about equal in magnitude, would have to be considered to contribute equally to any declines that could be attributed to overfishing. The fact that the fishery sustained annual yields (commercial landings) near 300,000 lbs. for over a decade (1958-70) indicates that recent total annual harvest of around 200,000 lbs. should not result in recruitment overfishing – a situation in which a stock is fished to below a point at which the reproductive (recruitment) capacity of the stock decreases. However, these statistics do not totally preclude the possibility of a growth overfishing situation (one in which total yield is decreased because fish are being caught before they grow to the larger size at which they were harvested formerly) and other unknown effects of harvest by the commercial and recreational fisheries.

Although it is not possible to preclude the possibility that fishery harvest may have contributed and may continue to contribute to declines in landings of spotted seatrout, the magnitudes of the declines are likely to be more a result of environmental changes, such as loss of seagrasses and fringing shallows and wetlands. It should not be surprising to find that Sarasota Bay fisheries for species such as spotted seatrout have declined concommitantly with losses of important fishery habitats, as has been found in other systems (Harris *et al.*, 1983). Based on scientific understanding of the relationships between habitat and fisheries (e.g., Seaman, 1985), losses of Sarasota Bay habitats, including seagrasses (20-30 percent loss [Mangrove Systems Inc., 1988]), wetlands (39 percent loss [Estevez, Tidal Wetlands chapter, this volume.]) and natural shorelines (78 percent loss [Sarasota Bay NEP, 1990])can be expected to have greatly diminished spotted seatrout and other fish populations in the Bay.

If the above extrapolations and conclusions are correct and generally reflect fisheries status in the Bay, they could be viewed as providing a measure of encouragement. If total harvest (commercial plus recreational) had been found instead to have remained constant (due to increased recreational harvest offsetting declining commercial harvest), little opportunity would exist to improve the situation. As the regional population continued to grow, increased numbers of fishermen would share a constant yield, with the result that fishing success (CPUE) would consistently decline for both recreational and commercial anglers. On the other hand, if the extrapolations are correct in estimating that stocks/populations have decreased, ameliorative and restorative actions possible under the NEP, such as water-quality improvement and habitat restoration, could result in substantial recovery of Sarasota Bay's fishery carrying capacity and productivity. If such actions are accomplished, Sarasota Bay fisheries can be improved, even in the face of continued population growth.

Comparisons of Sarasota Bay Catch Rates with those from Other Systems

Total Catch and Landings Rates

Very few comparable recreational-creel surveys have been conducted, so only limited information is available for comparative characterization of Sarasota Bay recreational fisheries. However, one series of creel surveys conducted in Texas bays from 1974-83 (McEachron and Green, 1984) provides a good standard for comparison. During the 1974-83 period, the combined mean harvest rate (landings CPUE) for all species harvested by sport-boat anglers from the Texas bays ranged from 0.83 to 0.41 fish/man-hour. The Sarasota Bay sport-boat landings CPUE of 0.58 fish/man-hour is similar to the rates reported for Texas bays; however, the degree to which harvest rates reflect differences in preferences and thus differences in selection of species for harvest is not easily determinable.

Seatrout Catch and Landings Rates

A few species-by-species comparisons can be made between Sarasota Bay's boat-angler harvest rates and those of other systems. Sarasota Bay harvest rates for individual species can be estimated by multiplying the total harvest rate (landings CPUE) by the fraction of the total harvest for which the species accounts *(Table 5)*. For example, spotted seatrout accounted for 16.2 percent of the total boat-angler landings (harvest) and the harvest rate (landings CPUE) was 0.58 fish/man-hour, yielding an estimated spotted-seatrout harvest rate of 0.094 fish/

man-hour. McEachron and Green (1984) found that spotted-seatrout harvest rates by sport-boat anglers in the Texas bays (aggregated for all bays) ranged from 0.42 to 0.18 fish/man-hour, whereas harvest rates for spotted seatrout in Sarasota Bay were estimated to be 0.09 fish/man-hour but undoubtedly would have been higher if the 14-inch size limit were not in effect. However, even if all spotted seatrout caught in Sarasota Bay had been harvested, the harvest rate would have been only about 0.26 fish/man-hour. Therefore, it must be concluded that spotted-seatrout harvest rates in Sarasota Bay are lower than those reported by McEachron and Green (1984) for Texas bays. The present Sarasota Bay catch rates can be put into perspective by comparing them with a long-term data base collected for the Everglades National Park (Davis, 1980). Spotted-seatrout catch rates in different areas of Everglades National Park (ENP) ranged from 0.43 to 0.92 fish per angler-hour during 1959-63, from 0.34 to 0.71 during 1963-67 and from 0.33 to 0.57 during 1972-77.

Similarly, harvest rates for sand seatrout in Texas were found to be 0.04 to 0.23 fish/man-hour; for Sarasota Bay the rate was 0.15 fish/man-hour. In Texas bays the top eight species accounted for all but around 0.01 to 0.04 fish/man-hour (other species) of the total landings CPUE, whereas in Sarasota Bay the top eight species accounted for a smaller proportion of the CPUE, with other species accounting for about 0.18 fish/man-hour. To some degree, this difference may be due to the higher diversity of the Sarasota Bay fish fauna, which includes semi-tropical and temperate species. On the other hand, the difference may also reflect a greater willingness (or necessity) on the part of Sarasota Bay anglers to harvest a wider variety of species.

Trends

It is important to point out that the highest catch rates in the Texas surveys (McEachron and Green, 1984) were found in the first year (1974-75) of the study; thereafter, catch rates declined. In the last year (1982) of the Texas bays study, total catch rate was estimated at 0.53 fish/man-hour and spotted-seatrout and sand-seatrout catch rates were 0.22 and 0.10 fish/man-hour. These rates are similar to the Sarasota Bay rates (total harvest rate = 0.58, spotted-seatrout harvest rate = 0.09, and sand-seatrout harvest rate = 0.15 fish/man-hour). However, the fact that Sarasota Bay harvest rates are similar to or perhaps slightly lower than those determined for systems for which substantial declines have been documented does not speak positively of the status of Sarasota Bay fisheries. If early (1959-63) ENP Florida Bay spotted-seatrout catch rates (0.84 to 0.92 fish per angler-hour) (Davis, 1980) are taken as a reasonable estimate of catch rates from systems that had not yet been subjected to high exploitation or environmental degradation (the so-called "good old days"), it can be concluded that harvest rate in the Sarasota Bay recreational fishery for spotted seatrout has fallen almost an order of magnitude.

Management Options and Recommendations

Characterization Options

Contemplated Sarasota Bay National Estuary Program actions relative to fishery resources can be separated into three categories of action: characterization actions, monitoring actions and management actions.

Since most of the decisions about future actions related to Sarasota Bay's fishery resources are likely to be determined as much by funding as by scientific considerations, it is not possible to recommend a discrete program of fishery resource actions. Some recommendations can be considered independently, but most must be considered together as part of a coordinated effort, and their value must be evaluated in terms of their ability to contribute together to the goals of the Sarasota Bay NEP. Some recommended actions that could contribute greatly if integrated into a coordinated effort, may contribute little if performed alone.

Fishery Characterization

The fishery assessment performed in the present project provides some baseline information for characterization of fish and fisheries of Sarasota Bay. However, full and sufficient characterization would require much larger and longer projects. The extent to which Sarasota Bay is characterized with regard to fish and fisheries depends on the amount of resources the NEP is able and willing to commit to this aspect of the Bay. Assuming some continuing commitment of resources, recommendations for consideration by the Sarasota Bay NEP are discussed below. Advantages and disadvantages for each action are presented in an effort to guide future prioritization of NEP resource allocation.

Commercial Landings

The FDNR Trip Ticket system for collecting commercial-landings data still does not mandate that fishermen report the location at which the landed catch was made; provision of location information is still voluntary. Until location reporting becomes an integral part of the system, commercial-landings data will have limited characterization value. The Sarasota Bay NEP should consider encouraging FDNR to take steps necessary to make this change and to mobilize the political support needed to introduce necessary legislation at the state level. Until such steps are taken and discrete landings information is available, Sarasota Bay fisheries will not be adequately characterized.

Baywide Recreational Catch, Landings and Effort

As pointed out above, the present project, because of funding limitations, was not able to directly measure catch and effort information for the entire Bay, and instead could only provide broadly extrapolated estimates. Although the present study provided valuable CPUE characterization information, without complete catch and effort information the causes of future changes in CPUE cannot be determined. Until the recreational fishery is completely surveyed, Sarasota Bay fisheries will not be fully characterized, and no accurate baseline will be available against which future fishery status can be compared.

Stock/Population Abundance Characterization for Important Species

As an alternative to complete commercial and recreational fishery characterization, stock/population abundance of important species could be determined accurately enough for management and status-assessment purposes with standard fishery-assessment methods. Species for which such assessment should be considered include striped mullet, spotted seatrout and sand seatrout. The Florida Marine Research Institute (FMRI) of FDNR has been performing assessments for Tampa Bay, and the Sarasota Bay NEP should consider strongly encouraging FDNR-FMRI to perform or collaborate in such assessments for Sarasota Bay. Since FDNR was included on the Sarasota Bay NEP Management Committee, but presently is not one of the agencies represented on the Policy Committee, special efforts will be needed to attract a high level of FDNR participation in the Sarasota Bay Program. This probably would be best developed through the Sarasota Bay NEP Policy and Management Committees with the endorsement of the Technical Advisory Committee and Fishery Resources TAC Subcommittee.

Fishery-Independent Juvenile Fish Surveys

Another way characterization could be made feasible is by focusing on assessing year-class strengths of juvenile fishes that will be recruited into Sarasota Bay fisheries. FDNR-FMRI will be using this approach to monitor estuarine fisheries in systems around Florida. This is one of the most attractive approaches toward characterizing and monitoring Sarasota Bay fishes and fisheries; the most practical way for this method to become part of the Sarasota Bay NEP is through participation of FDNR-FMRI. This participation would be best developed through the Sarasota Bay NEP Policy and Management Committees with the endorsement of the Technical Advisory Committee.

Socioeconomic Characterization of Commercial and Recreational Fisheries

Commercial and recreational fisheries are important to the Sarasota Bay area for a number of reasons. The economic value of commercial fisheries is generally appreciated by the public and government officials. Information about value of Sarasota Bay commercial fisheries is available from the commercial-landings data, which also includes dockside prices, but accurate estimation of the impact of commercial fisheries would require a thorough economic analysis. The value of recreational fisheries is often less appreciated and understood. Bell *et al.* (1982) estimated the economic impact of Florida recreational fisheries to be about six times that of commercial fisheries. The ratio for Sarasota Bay is unknown. In addition to economic values, commercial and recreational are sociologically important. Commercial fishing in Sarasota Bay has social roots going back several generations, and recreational fishing is an important component of the regional lifestyle. Thorough characterization of Sarasota Bay fisheries would require that social and economic aspects of fisheries be characterized.

Fishery Habitat and Environmental Relationships Characterization

Ideally, it would be most desirable to determine the quantitative relationship between fish communities and ecological factors such as habitat types and water quality; practically, however, such informa-

tion is very difficult and very expensive to obtain on a system-wide basis. Additionally, basic scientific understanding of such relationships is limited at best. Therefore, it is unlikely that a complete understanding of Sarasota Bay fish community structure and ecological relationships would ever be achieved.

On the other hand, the limited information obtained in the present study could be greatly improved upon by an enhanced "traditional" fishery assessment, using trawling and seining performed on a spatially and temporally more-intense basis by including many more stations around the Bay and by sampling them more frequently (at least monthly). However, it must be pointed out that even such an increase in intensity and effort can provide information that is semi-quantitative at best, in that it may be useful for characterizing major features in terms of numerical attributes.

Critical Habitats

One good way to focus fisheries characterization (as compared to Baywide characterization) is by performing assessments of key habitats known to be very important around the Bay.

One example of such critical habitats is seagrass beds, although even within the general category of seagrass beds a range of habitat types exists. By focusing on habitats that are extensive and common throughout most of the Bay, resource allocation can be brought into line with that which is feasible under the Sarasota Bay NEP. Additionally, by focusing on specific habitats that could be subject to detailed characterization (e.g., seagrass studies), ecological relationships may be revealed.

If such focusing were to occur, it would be essential that the critical habitats be selected carefully. From a fisheries standpoint, several habitats can be recommended. Deep (e.g., depth >1 m MLW) open-water seagrass (*Thalassia*) beds provide some of the most extensive and important adult fish habitat in the Bay and would be a prime candidate for focused fisheries characterization. Shallow fringing seagrass beds (*Halodule* or mixed *Halodule/Thalassia*) are also very important as both adult and nursery habitat. Shallow-creek, bayou and other backwater fringing habitat are the primary nursery habitat for juvenile stages of many important species, such as snook, red drum and striped mullet (Edwards, 1991b), and the availability of this type of habitat may limit fisheries production in such systems as Sarasota Bay (Edwards, 1989). Therefore, this type of nursery habitat should be near the top of any prioritized lists of habitats to be characterized with regard to fishes and fisheries.

Ecological Characterization of Selected Bay Segments

Sufficient resources for a Baywide fish/fishery characterization may not be available, even if efforts are focused on selected habitats. One way to further reduce the cost of characterization would be to limit detailed characterization to selected segments or zones of the Bay in which impacts or changes have occurred or can be anticipated.

Monitoring Options

Although characterization usually has direct value in providing basic understanding, it often has greater value as a base line against which changes can be measured. However, to have this latter value it must be repeated; if it is repeated more than once, it can be considered to be monitoring. Therefore, characterization and monitoring usually are closely related. This is true more for biological and ecological aspects, such as fisheries, than for physical aspects, such as circulation. In the latter case, it may be sufficient to characterize the system once unless major physical changes occur (e.g., major dredging projects, pass closure, etc.), whereas in the former case the initial characterization is meaningful only relative to future status.

Fishery status is a very concrete, integrative manifestation of the condition of a bay or estuary. It is concrete because it directly affects fishermen and other user groups in very real ways that they can directly perceive (e.g., whether or not they catch as many fish as they used to), as opposed to factors such as water chemistry and quality, which the general public cannot directly assess. Fishery status is integrative because it is affected ultimately by a diversity of factors ranging from ecological factors such as habitat availability or water quality (including nutrients and toxics) to sociological factors such as resource use and management. It can be conjectured that if a program such as the Sarasota Bay NEP is to be judged as positive and successful, it must be positive and successful with respect to fisheries.

For such success to be assessed, fishery status must be monitored. Therefore, it is highly recommended that the Sarasota Bay NEP include, at the earliest stage possible, planning for and implementation of fisheries monitoring.

It should be kept in mind that one of the main rationales for including Sarasota Bay in

the National Estuary Program was that it was an estuary that, like many other systems, is more affected by chronic effects of development and over-use than by the acute effects of pollution, although recent studies (see water- and sediment-quality chapter) have found that some pollution problems may present in and around tributaries. For estuaries suffering from widespread and acute pollution, documentation of pollution abatement may be sufficient evidence of significant positive impact of a NEP project. But for estuaries that suffer from effects of development and over-use, success of a NEP project must be determined by evaluating the status of important aspects like fisheries.

Most of the preceding discussion of characterization actions applies to monitoring actions as well. Most of the recommended characterization actions could be recommended as monitoring actions. As with further characterization, the final selection of monitoring actions will be largely influenced by availability of resources and funding.

Management Options

In addition to further fisheries characterization and monitoring, the Sarasota Bay National Estuary Program should consider involvement in direct actions with regard to fisheries. In view of the many alterations and impacts that have already occurred, and of continued regional population growth, it is unlikely that general environmental management and improvement of Sarasota Bay will be adequate to maintain optimal fisheries productivity.

Fisheries management is entering a new era, in which fish stocks/populations and their habitats will have to begin to be managed differently in each estuary or bay system. Fisheries-management problems and opportunities for conservation and enhancement in Sarasota Bay are in many ways the same as those faced by other systems and other areas. Thus the National Estuary Program, through proactive, direct involvement in fisheries-management issues, can contribute to the future not only of Sarasota Bay, but also of many other estuaries, bays and communities.

Approaches

The Sarasota Bay NEP could adopt one of three general approaches with regard to fisheries management:

1) General environmental management alone. The Sarasota Bay Program could choose to take no direct fishery-management actions, and instead concentrate on general environmental improvement and management and hope that benefits accrue to fisheries. This appears to be the choice of most other NEP programs, and for many of those programs this choice may be justified. However, this choice is reasonable only in cases where the estuarine system has been so greatly degraded by pollution that pollution abatement can be expected to allow fisheries to greatly recover from a depressed state.

Fortunately, Sarasota Bay does not suffer from acute pollution that can be identified as having depressed fisheries. Instead, Sarasota Bay was selected for inclusion in the National Estuary Program because it is representative of a class of estuaries that suffer much more from the effects of over-use and over-development than from the effects of pollution. General environmental improvement and management would be important to Sarasota Bay fisheries by preventing continued environmental degradation and resultant continued fisheries declines. General environmental improvement attained through actions such as habitat creation/restoration of marshes, wetlands, shorelines, Bay bottom communities, etc. can have positive effects on the Bay's fishery capacity. However, the quantity of improvement possible in the Bay is limited. For example, it is likely that only a small portion of the estimated 78-percent loss of shorelines (Roat and Alderson, 1990) will be ever be recovered; limited areas are available for wetlands recreation, so only a very small fraction of the 42-percent loss of wetlands (Estevez, 1992) can ever be offset, and much of the undetermined loss of seagrass beds can never be regained, because the loss was due to dredging and filling.

Therefore, it is unlikely that a general environmental approach can result in restoration of very much of the Bay's lost fishery productivity, although it may be very important in ensuring that losses do not continue. In view of the almost certainty of continued regional population growth and increasing use of Bay resources, unless fishery productivity is significantly restored Sarasota Bay fisheries will continue to decline, in the sense that users will have a declining share of a fixed resource.

2) Fisheries-oriented environmental management. The Sarasota Bay Program could choose to take environmental-management actions specifically targeted toward improving, increasing and protecting fisheries habitat. Many of the general environmental actions, such as habitat restoration, could be of greater value to fisheries if they were designed specifically to

provide high levels of fishery productivity. Natural habitats such as marshes, mangroves, shallows, shorelines, seagrass beds, etc. each vary greatly with regard to fishery value and productivity. When such habitats are created or restored, attempts could be made to design them in ways that maximize their fishery value.

Existing habitats could be modified in ways that enhance their fishery value. Examples of this approach include artificial habitat modules for seawalls, as are presently being developed and evaluated in Sarasota Bay NEP early action demonstration projects; rip-rap and other enhancement of shorelines; artificial juvenile-habitat reefs in shallows, dredge holes and bare bottom areas; and restoration of low-salinity juvenile fish habitat in tributaries through management of freshwater inflow (dynamic habitat) as well as creation or improvement of static (physical) habitat (Edwards, 1991b). In addition to habitat and environmental enhancement, habitat protection would be an important part of this approach. Specific habitats that are of high value to Sarasota Bay fisheries should be identified and then carefully protected.

3) Fisheries management. The Sarasota Bay Program could become directly involved in fisheries-management actions designed to address the special problems and needs of Sarasota Bay and other systems subject to high levels of population, urbanization and resource use. In Florida, the Marine Fisheries Commission (MFC) is responsible for developing statewide regulations and measures for managing saltwater fisheries, but is beginning to realize that regional or even system-specific approaches are needed for optimal fishery management. The MFC has already indicated that it could be interested in working with the Sarasota Bay NEP to develop refined management measures that could be implemented for Sarasota Bay on a pilot-project basis.

Numerous special management measures could be considered for testing in Sarasota Bay, including size and creel limits; seasons; quotas; gear limitations (e.g., barbless hooks, net limitations, etc.); sanctuary, managed, limited-access or closed areas; and special licensing. Stocking programs for such species as snook, red drum and seatrout could be considered. The Sarasota Bay Program could also become involved in education and public awareness about fisheries issues such as catch-and-release, minimized harvest, and alternative-species targeting and harvesting.

In the long run, considering the fact that Sarasota Bay has a finite capacity for fishery production but a continually growing regional population, direct involvement in fishery habitat and management issues is essential if the NEP hopes to attain its goal of restoring and sustaining fishery resources in Sarasota Bay.

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Shellfish

Bivalved Shellfish of Sarasota Bay

by L. K. Dixon
Mote Marine Laboratory

Executive Summary

Stationary bivalved shellfish were selected for a contamination assessment of Sarasota Bay, as an organism that integrates the exposure concentrations of contaminants over a finite period of time (weeks to months). Filter feeding, bivalves are exposed to large volumes of water, and feed on suspended particulates that typically contain the bulk of chemical contaminants. The resultant tissue concentrations are used as a measure of the present-day chronic contamination exposure, as opposed to the instantaneous or historical conditions deduced from water-column and sediment samples.

The study emphasized two recreationally important and edible shellfish, oysters (*Crassostrea virginica*) and hard clams or quahogs (*Mercenaria* spp.), which offered either a fairly ubiquitous distribution within the study area, or for which a substantial national database existed for contaminant levels. Field and laboratory work was designed to survey the populations of the two species and to determine contamination levels in the edible tissues, including pathogenic bacteria, metals, pesticides and petroleum-based polynuclear aromatic hydrocarbons (PAH).

The study originally was structured to evaluate contaminants during both dry and wet seasons, but low rainfall amounts for the year prevented the collection of what might be presumed to be "worst-case" summer wet-season conditions, when contaminant loadings and bacterial populations are maximized. No formal health-risk or stock assessment was conducted.

Of the 169 stations surveyed for clams, one-quarter had no clams reported during either sampling; yields at the remaining three-quarters of the stations were very low. Stations where no clams were found were concentrated along the eastern shore of Sarasota Bay and near Midnight Pass. The lowered abundances on the eastern shore have been reported from relatively pristine areas elsewhere on the west coast of Florida and may be linked to physical factors. The lack of live clams near Midnight Pass is attributed

primarily to episodes of low salinity. Conditions have been favorable for juvenile clams to settle and grow in the past, but this study cannot establish whether the dead clams observed in the area settled before or after the closure of Midnight Pass. The larger "chowder" clam predominates in all areas, due to predation, rapid growth rates and potentially poor or erratic recruitment.

Oysters are also common in the area, and are most abundant in the bays and tributaries south of Big Pass. Here, larger watersheds and relatively smaller volume of receiving waters maintain more favorable lowered-salinity regimes than in the northern portion of the study area, and consequently exclude predacious molluscs in particular. On the whole, however, oysters are restricted by predation to an intertidal habitat where reduced feeding times produce smaller, less commercially desirable organisms.

Fecal coliforms in *water* at over half of the stations slightly exceeded the National Shellfish Sanitation Program (NSSP) criteria; no *tissue* exceeded the NSSP criteria for fecal-coliform or total plate counts. Bacterial counts at sampling times did not indicate highly polluted conditions, and suggest that the major groups of vibrios and aeromonas are a part of the normal ecosystem, and not of human fecal origin.

Oyster tissue metal concentrations were more useful for detecting station differences than were *Mercenaria* tissues due to broader ranges of contaminants encountered. No geographic variation for mercury occurred in either species, which implies that mercury is not associated with any major point sources in the study area.

Individual stations noted for comparatively high metal content included Hudson Bayou, Bowlees Creek, Phillippi Creek and South Creek. In relation to Florida Gulf Coast values, Sarasota Bay oysters are well above-average for lead; the Hudson Bayou concentration exceeded the highest average lead value reported for either Florida or the nation.

No station averages of tissue concentrations exceeded Food and Drug Administration (FDA) action levels for mercury. Tissue levels of copper and zinc indicated that oysters in Phillippi Creek, Hudson Bayou and possibly South Creek may suffer from impairments such as altered shell thickness and abnormal larvae. Sediment concentrations indicate that more extensive impacts could be expected in some areas.

While chlorinated pesticides were evident in many tissue samples, most concentrations were low. No station with detectable pesticides in the spring reported the same compounds during the fall sampling, indicating that sources of pesticides to the study area were intermittent. No pesticide exceeded the FDA action levels, but oysters from Phillippi Creek, Blackburn Bridge and Hudson Bayou were comparatively high in concentrations of specific pesticides. Trace amounts of the labile organophosphate chlorpyrifos (dursban) were detected in both clam and oyster samples, indicating some influx of pesticides currently in use.

Analyses of shellfish tissues detected no quantifiable levels of PAH, although trace amounts were found at some stations. The compounds present indicate that the PAH were derived primarily from pyrogenic or combustion sources. The stations were distributed broadly, and the low concentrations of PAH detected in Sarasota Bay shellfish indicated no chronic petroleum or pyrogenic contamination. Again, sediment concentrations of these compounds indicated that biological impacts may be expected in some locations.

Feasibility of aquaculture or other commercial efforts within the study area was deemed low for the following reasons: 1) the frequent occurrence of toxic phytoplankton blooms ("red tides"), which have closed shellfish beds 37 percent of the time during the last 13 years; 2) the high degree of adverse urban and recreational-boating impacts on water quality; 3) the relatively small area of approved waters; 4) the poor shipping characteristics of dominant local *Mercenaria* species; 5) the lack of subtidal oyster habitat and larger individuals in approved areas; and 6) the difficulty of obtaining leases of subtidal state lands.

Resource enhancements at this time can include both seeding of clams and cultch placement for oyster spat to increase the populations, but will not likely result in any direct increase in recreation potential. Harvestable individuals would likely remain low or unacessible unless 1) salinity regimes were radically restored (oysters); 2) non-point-source (NPS) loadings were reduced; 3) regions nearer tributaries were reclassified for harvest; and 4) shore access improved. Reclassification of any areas for additional harvests will not occur without substantial reductions in non-point-source loadings of bacteria and other contaminants.

Valid ecological inducements exist for enhancements to bivalve populations, however. As filter feeders, both clams and oysters have the theoretical potential to improve the water clarity of Sarasota Bay, particularly if water-clarity impairments are linked to phytoplankton levels. Other benefits of enhancing shellfish populations would include increased biomass of the estuary, support of other species, additional habitat complexity, increased shoreline stability and reduced sediment resuspension through wave damping.

Research needs noted during this project included the quantification of the airborne loads of metals and PAH in relation to surface runoff, relevant for assessing whether conventional non-point-source controls can achieve significant reductions in contaminants. Little is known of the population dynamics of bivalves, including recruitment, predation pressures and harvesting pressure, which should be quantified to manage the resource and protect from overharvest. Mapping of oyster resources should be updated. Historical salinity regimes in the southern study area could be identified by morphological characteristics of current and Indian midden oyster shell. If NPS controls improve, a formal, contaminant-specific health-risk assessment and recreational-effort assessment will become necessary, as would a true wet-season tissue sampling. The suite of analytical compounds should also be further expanded to include selected polychlorinated biphenyl (PCB) isomers, as traces were detected in some samples.

Bivalved Shellfish of Sarasota Bay

Background

On a nationwide basis, the bulk of water-quality problems that limit shellfishing are attributed to bacterial and viral contamination, followed by the presence of biotoxins such as those in red tides. Toxic compounds (pesticides, PCBs and metals) in water or sediments generally account for fewer "use impairments" (National Academy of Sciences, 1991). Current classification of waters by the Florida Dept. of Natural Resources (FDNR) is designed to protect against these hazards, with approximately 3,000 acres within the study area designated as "conditionally approved" *(Figure 1).*

Shellfishing in Sarasota Bay is limited to an area off the southeastern end of Longboat Key.

An additional area in Palma Sola Bay, although "conditionally approved," has been closed since 1981.

The area in which shellfish are considered safe for harvest and human consumption by FDNR, however, is considerably smaller than the Class II waters ("suitable for shellfish harvesting and propagation") of the region identified by the Florida Administrative Code.

Sources of fecal coliforms that can cause waters to be classified as harvest-limited include urban or non-point-source runoff, sewage-treatment plants, failed septic systems, industrial wastes, boating activities, agricultural runoff from grazing lands and fecal material from wildlife, including bird rookeries (Broutman and Leonard, 1988). Stormwater runoff or non-point-source impacts are recognized as one of the major water-quality problems within Sarasota Bay (Florida Dept. of Environmental Regulation, 1988). Within the Bay study area, 47 percent of the watershed is currently listed as "developed," i.e., either residential, commercial, institutional, industrial, transportation or power or sewage-treatment-plant land uses. Estimates are that at build-out 82 percent will be similarly classified, with concomitant increases in non-point-source loadings of some parameters (Camp Dresser & McKee, 1992).

Of the classification categories, "conditionally approved" and "restricted" require the most state resources to maintain. Lack of resources often dictates that areas remain unclassified, and also has resulted in management decisions to downgrade the classification of areas. While FDNR plans a reclassification for this area, expanded opened waters will require a further commitment to continued sanitary monitoring. Statewide, overall trends are for the continued downgrading of classifications, primarily due to increasing recognition of non-point-source impacts (Broutman and Leonard, 1988).

Declines in Florida landings of bivalved shellfish have been matched by national declines; both have been attributed to overharvesting and a continuing expansion of areas affected by non-point-source pollution (National Oceanic and Atmospheric Administration, 1991). Locally, the commercial fisheries for oysters and clams collapsed in 1967 and 1971, respectively, and clam fisheries in Florida have historically been erratic (Arnold, unpublished manuscript).

The collapse of shellfish fisheries in Florida has often been associated with catastrophic events such as red tides or hurricanes (Steidinger *et al.*, 1973; Godcharles and Japp, 1973). Locally, overharvesting does not appear to be a problem, due to the absence of commercial fisheries and the low numbers of recreational clammers observed. Recreational harvesting is largely unquantified, however, although thought to be important both in the study area and nationally (Stanley and Dewitt, 1983). Reduced shoreline access produced by a high level of coastal development in the Sarasota Bay study area undoubtedly restricts recreational clamming (Stevely *et al.*, in press). Quantitative data on recreational harvesting of bivalves is not available.

There are no active shellfishing-production leases of submerged lands on the southwest coast (John Stevely, personal communication). Feasibility of aquaculture or other commercial efforts within the study area is deemed low for the following reasons:

Kellie Dixon

Ms. Dixon has a background in analytical chemistry, which she has applied for more than 15 years to studies of state, regional and local sediments, water and biota. Most recently, she has been active in describing the pollutant content of the regional sediments and biota with an emphasis on the trace metals commonly associated with urban stormwater. She is currently evaluating the quality of stormwater runoff for a number of local municipalities. She has worked extensively with the salinity and water-quality structure of many of the estuaries and tidal rivers of Florida (including Sarasota Bay). She has designed a number of data-intensive projects employing unattended data-collection platforms for evaluating thermal and water-clarity impacts.

1) difficulty of obtaining leases of subtidal state lands; 2) high degree of adverse urban and recreational-boating impacts on water quality; 3) relatively small area of approved waters; 4) poor shipping characteristics of the dominant local *Mercenaria* species; and 5) lack of subtidal oyster habitat in approved areas; and 6) small-sized individuals occurring in intertidal habitats. Ecological or recreationally oriented, rather than commercially oriented, enhancements may be the most effective.

In addition, red tides of a dinoflagellate, *Gymnodinium breve*, produce potent neurotoxins (Steidinger, 1983, 1990) that frequently force closure of the approved shellfishing beds in Sarasota Bay. The bivalves may be only marginally affected except in extreme instances (Tiffany and Heyl, 1978; Roberts *et al.*, 1979), but filter feeding concentrates the toxic phytoplankton (Cummings and Stevens, 1970; Music *et al.*, 1973), and human consumption can produce neurotoxic shellfish poisoning (Baden, 1973).

The west-central region of Florida's coast receives the bulk of the red-tide outbreaks, perhaps attributable to patterns of currents in the Gulf of Mexico. As a direct result, Sarasota Bay shellfish beds have been closed for 37 percent of the time during the past 13 years (1978-91), primarily during the fall and winter harvesting months. Extended closures of beds could also permit the fast-growing *Mercenaria* to grow beyond optimal commercial size.

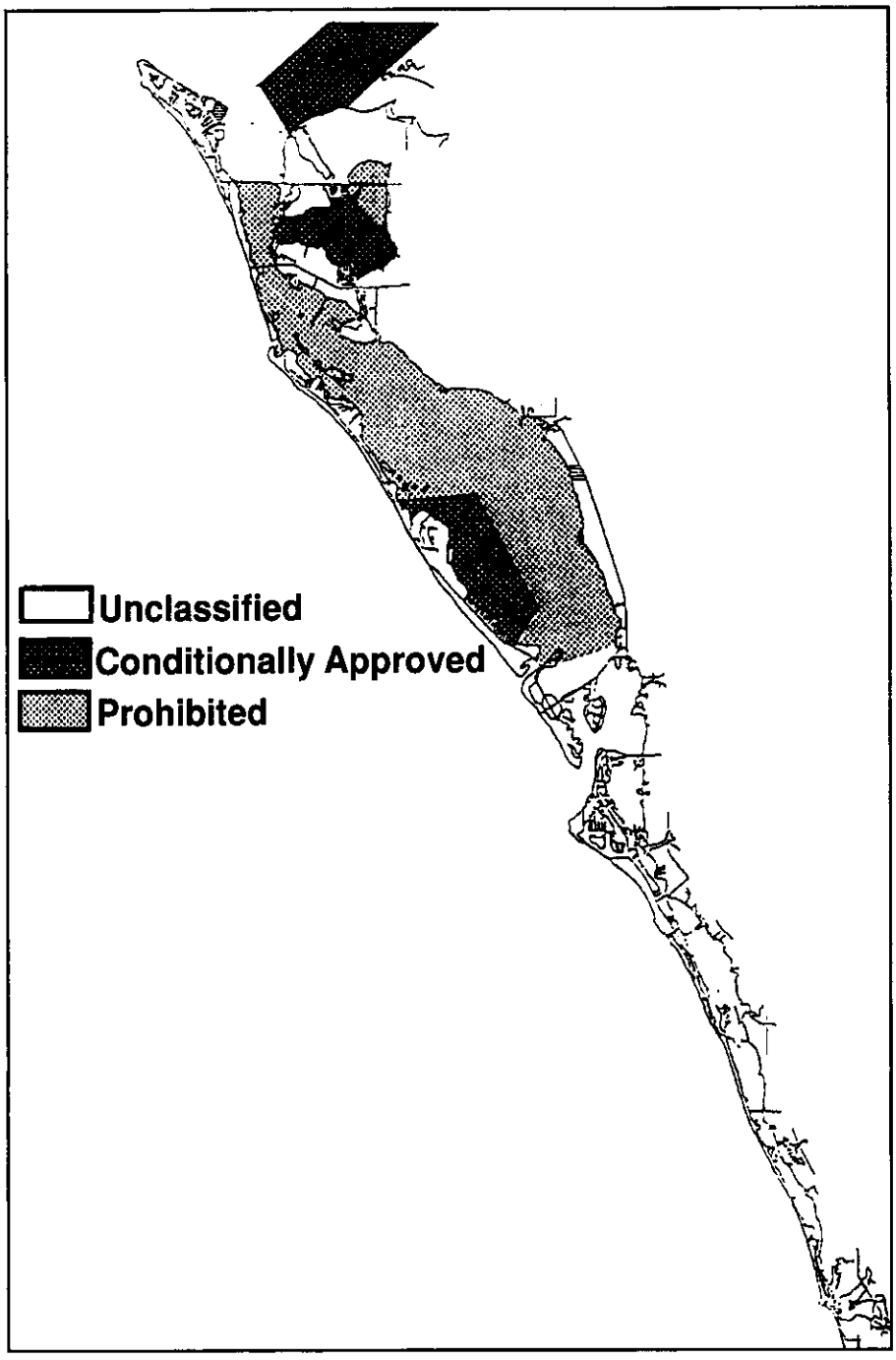


Figure 1. Classification of shellfish harvesting waters within Sarasota Bay. Palma Sola Bay temporarily closed since 1981.

Study Design/ Methods and Rationale

To evaluate the contaminant status of an area, water-column concentrations are notoriously variable and pose many difficulties in interpretation. Organisms that remain in an area, however, provide an integrating effect and, through depuration, generally reflect only the most recent weeks or months (NOAA, 1989).

Biomonitors, if they tolerate a wide range of pollutants, should also reflect contaminant bioavailabilities and in some instances can magnify pollution gradients, making them more readily detectable. Bivalves are particularly well-suited for this role due to their feeding strategy, in which they filter large volumes of water and associated particulates. The particulates concentrated include not only preferred phytoplankton food sources, but also bacteria and viruses, toxic dinoflagellates (red tide) and inorganic and detrital particles. The same particulates also typically contain the bulk of the anthropogenic contaminants, specifically toxic metals and organic compounds.

Population Surveys

Population surveys and tissue analyses were performed on two bivalved shellfish, *Mercenaria* spp. and *Crassostrea virginica*, selected for abundance, broad geographic distribution (to permit Bay-wide comparisons), recreational interest and size of existing data base. The hard clam surveyed was described as *Mercenaria* spp., since the dominant local species, *M. campechiensis*, is known to hybridize readily with *M. mercenaria*.

Lack of knowledge on seasonal fluctuations of *Mercenaria,* apparent site-specific mortalities (Estevez and Bruzek, 1986), possible erratic recruitment controlled by predation rather than by environmental factors (Mulholland, 1984) and a potentially unstable population, coupled with the potential year-round availability of clams for harvest, made two seasonally based population surveys desirable for *Mercenaria* during the study year. The surveys of *Mercenaria* employed a timed-effort approach to mimic recreational shellfishing and avoid impact to grassbeds. Clams found were measured and released. The efficacy of the technique for smaller clams, in particular, was verified with raked quadrats in unvegetated areas and probing in areas with vegetation. The 169 stations were distributed as evenly as possible among the shallow (less than three feet below MLLW) areas of Sarasota Bay.

Surveys of oysters consisted primarily of identifying areas of viable and senescent reef (Hines and Belknap, 1986), based on both previous mapping (Mangrove Systems, 1988) and observations during this study. Reef condition and any physical destruction were noted, as was dominant oyster length, the presence of legal-sized individuals and oyster predators.

Tissue Contaminants

Stations for tissue collections were selected for broad geographic distribution and, for oysters, endeavored to include the major tributaries to the Sarasota Bay system. Twenty stations were selected, 10 for *Mercenaria* and 10 for *Crassostrea.* Following each of the two population surveys, two composite tissue samples were collected from each of 20 locations. Collections took place in April and again in November-December 1990. Clams collected from Bishops Point were the only tissues collected from within "conditionally approved" waters. Water-column samples were also collected for bacteriological analyses. A total of 80 tissue samples and 40 water samples were analyzed for the entire study.

The original study design called for collection and analysis of tissues during the dry season, followed by two collections and tissue analyses at some priority subset of stations during a significant storm event in the wet season. Tissue levels of pollutants during the dry season, while not worst-case, were to allow for Bay-wide comparisons of possible problem areas. Data obtained from tissues collected in the wet season were to represent a "worst-case" scenario, under conditions of maximum runoff and presumably highest pollutant loadings. Low rainfall amounts received during the year forced the redesign of the study, to focus on potential seasonal differences between each of the 20 tissue stations. The two samplings were referred to as a spring and a fall collection to avoid the implication that substantial rainfall occurred.

In the marine environment, one of the most important routes for the human contraction of infectious diseases is through water contact and the consumption of raw shellfish (Southern California Assn. of Governments, 1988). The pathogens of most concern are associated with human fecal wastes. A number of microbial analyses were selected to provide information on sources of contaminants and severity of contamination. Sample matrices included both shellfish tissues and water-column samples.

Aerobic plate counts quantified the entire heterotrophic bacterial population. Total and fecal coliform and fecal streptococci were used as sewage tracers. A total of seven pathogenic vibrio species were selected for quantification, together with *Aeromonas hydrophila* and *A. sobria,* which are potential human pathogens. The vibrios and aeromonas are indigenous to marine waters, unrelated to the presence of sewage and have been identified in both approved and prohibited waters (Blake and Rodrick, 1983) with no correlation to fecal-coliform levels. *E. coli* are also potential enterotoxic pathogens, and were also selected for enumeration.

Uptake routes of contaminants for bivalves include both from solution and from ingested food particles. Bioaccumulation of chemical contaminants reflects the net results of exposure, uptake and excretion, as well as any degree to which tissue concentrations are "diluted" by increasing size of the organism (Rainbow, 1990). In addition, size or age, seasonal variation in either physiological processes or contaminant loads, sex and reproductive status, temperature and salinity and vertical position on the shoreline (Phillips, 1990; National Academy of Sciences, 1980; Paes-Osuna and Marmolejo-Rivas, 1990) can also influence tissue levels.

Bioavailability, the degree to which contaminants are available to biota, also plays a role. Particularly for metals subject to uptake from solution, the factors that affect speciation and free ions present (ionic strength, salinity, pH, EH, sulfides, presence of dissolved organics and other chelating agents, suspended sediment) will influence metal bioavailability (McClusky *et al.*, 1986; Ahsanullah and Florence, 1984; Elder, 1988).

Toxicity varies with compound, life stage and size of the particular organism, with embryos and larvae notably more sensitive to contamination (Viarengo, 1989). Toxicity effects can be evidenced through either biochemical or whole-animal responses (growth, morphology or activity). Half-lives, or the time period required for half the body burden of contaminant to be excreted, are typically longer for metals than for organochlorines or hydrocarbons (Phillips and Segar, 1986).

A number of effects have been linked to metals; oysters, clams and other bivalves have been reported to exhibit reduced growth and larval toxicity, formation of abnormal larvae for several bivalve species (Marten *et al.*, 1981; MacInnes and Calabrese, 1978), reduced fecundity, reduced filtration rates or burrowing behavior (Bayne *et al.*, 1985; McGreer, 1979) and impaired settlement and survival (McGreer, 1982). Metal-detoxification strategies, particularly for oysters, frequently allow high concentrations of certain metals to be accumulated as the metals (copper and zinc, in particular) are sequestered within the organism by metal-binding proteins or in granular form (Mason, 1988).

Sarasota Bay is fortunate in that it has, in comparison to other estuaries within the National Estuary Program, comparatively few industrial point-source discharges. One of the major problems identified in the nomination document, however, was stormwater runoff. Pollutants characteristic of stormwater include metals, toxic organic compounds and petroleum products. Marinas and boating operations can contribute metals to the environment, as well.

Metals selected for tissue-contaminant analyses were arsenic, cadmium, copper, lead, mercury and zinc. These elements were selected due to the national databases available on shellfish tissue levels, presence in urban runoff and toxicity information available (for both bivalves and humans).

Chlorinated pesticides are persistent, lipid-soluble, synthetic chemicals that are toxic to a wide variety of aquatic organisms, as well as humans, and in some instances are carcinogenic. Sublethal effects of chlorinated pesticides create stress on bivalves through interference with enzyme pathways (Engle *et al.*, 1972). Eggs and larvae are more susceptible than juveniles and adults (NOAA, 1990a). Chlorinated pesticides have been replaced with less persistent, yet often more toxic, organophosphate and carbamate pesticides. These pesticides generally do not persist in the marine environment for years; however, they do persist for weeks to months, and may have a short-term impact following local applications and stormwater runoff. Dursban, or chlorpyrifos, for instance, is identified as a potential hazard for benthic species (Schimmel *et al.*, 1983).

Pesticides selected for contamination assessment included representatives from three classes of chemicals (carbamate, organophosphate and chlorinated pesticides). These indicators were the organophosphates chlorpyrifos (dursban), used for domestic and industrial insect control, and dibrom (naled), used as a mosquito adulticide, and the carbamate bendiocarb (ficam), used on turf and ornamental plants (Agricultural Chemicals Handbook, 1989). In addition to these pesticides currently in use around the Bay, residues of persistent chlorinated hydrocarbon pesticides (e.g., DDT and derivatives, chlordane, BHC) were monitored.

Although no major oil spills have been observed in Sarasota Bay, it likely receives a chronic influx of petroleum (consisting of roughly 40 percent PAH), both from tributaries bringing stormwater runoff from an urban watershed and through spillage from a number of marinas. Of greatest concern are the polynuclear aromatic hydrocarbons (PAH), which include both toxic and carcinogenic substances (NAS, 1985). Summaries of PAH input to aquatic environments attribute 73 percent to petroleum spills, 21 percent to atmospheric

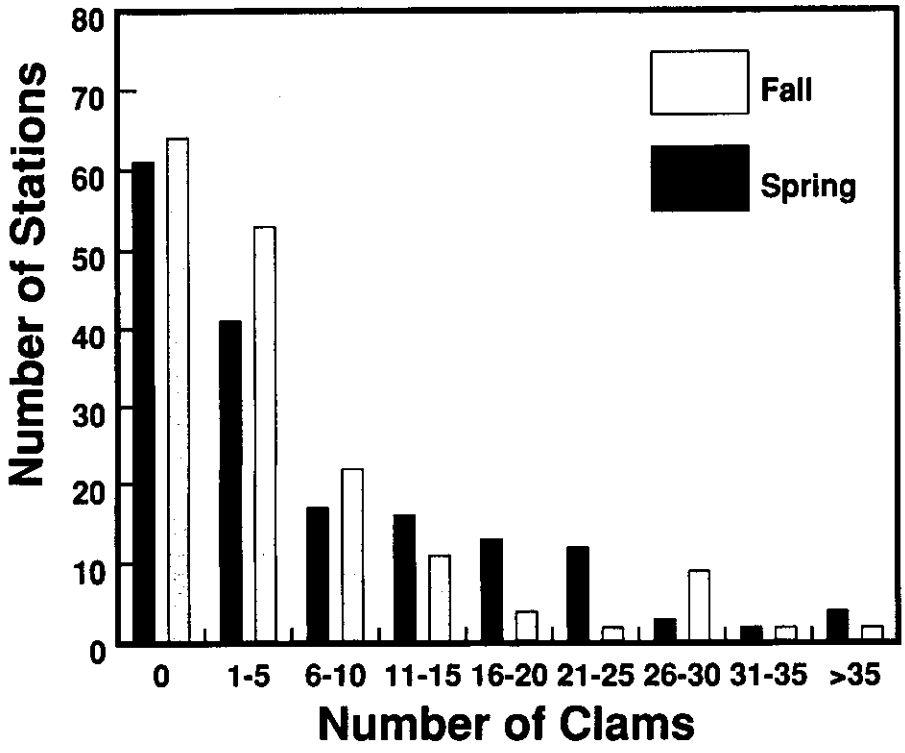


Figure 2. Clam abundance during the spring and fall seasons, number of organisms per timed effort.

deposition (generally of combustion products) and three percent to wastewaters and surface runoff, with one percent from biogenic sources (Eisler, 1987).

Sources of PAH may be from either petroleum or combustion (petrogenic or pyrogenic); both sources may be from human activities, such as oil spills and combustion of fossil fuels, or from natural occurrences, such as oil seeps and forest fires (Farrington, 1980; NAS, 1985). The predominant source can be distinguished by the mix and types of compounds present. Petroleum-derived PAH contain more of the smaller compounds (two and three rings) with alkyl substitution on the rings (Farrington, 1980). Combustion sources are characterized by unsubstituted three- to five-ring compounds as many substitution groups are removed in the combustion process. Combustion sources predominantly include fluoranthene and pyrene (NAS, 1985).

The lower molecular weight PAH (two to three rings) are generally acutely toxic but noncarcinogenic, while the four- to seven-ring, higher-molecular-weight compounds are less toxic but carcinogenic, mutagenic or teratogenic (Eisler, 1987). The low-molecular-weight toxic compounds include anthracenes, fluorenes, naphthalenes and phenanthrenes, while the carcinogenic compounds include benzo(a)pyrene (Kennish, 1991).

As a whole, PAH are not biomagnified within the food chain, due to rapid degradation, depuration and the low absorption in higher organisms (Jakim and Lake, 1978). Seasonal increases in PAH tissue concentrations coincide with periods of lipid storage for spawning (Marcus and Stokes, 1985). Pyrogenic PAH are apparently tightly bound (Farrington, 1985) or incorporated in sediment particles and not readily available for biological accumulation, while petrogenic PAH occur in dissolved and colloidal suspensions, more readily available for biological uptake.

Analytical techniques for all contaminant analyses were detailed in both the project EPA-Approved Quality Assurance Plan and the Draft Final Report.

Results

Population Surveys

Little seasonal variation was apparent in the abundance *(Figure 2)* or size of clams. The distribution of *Mercenaria* varied with sediment and vegetation type, being most numerous in sandy mud and in sparse *Halodule* beds. Clams were most abundant on the western shore of Sarasota Bay (largely in the "conditionally approved" area), western Anna Maria Sound and New Pass, where up to 35 individuals could be found in a 30-minute effort. Clam abundance was not significantly correlated with the quarterly water-quality data collected under the National Estuary monitoring program.

Approximately one-third of the stations sampled had no clams during any one survey, and roughly three-quarters of the stations reported fewer than five animals during the field work *(Figure 2)*. No clams were found during either survey at one-quarter of the stations.

In the Midnight Pass area *(Figure 3)*, numerous mature and intact, but dead, clams showed evidence of some abrupt change in environmental factors other than

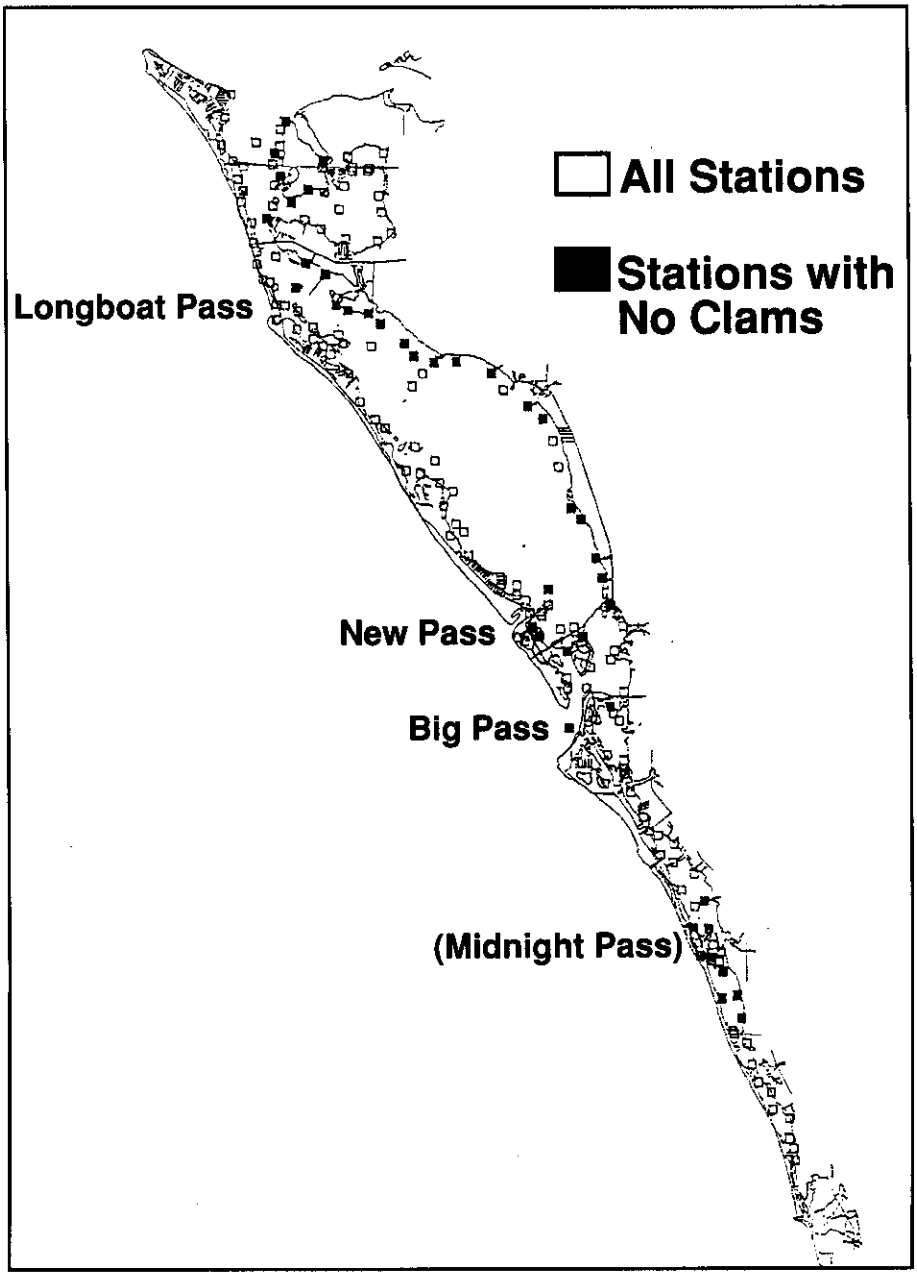


Figure 3. Stations where no clams were found during either population survey.

predation. Prolonged periods of reduced salinities during the wet season are a likely explanation for the death of these organisms. Low current velocities experienced by any area near the tidal null zone may also have contributed by providing insufficient food. The presence of the mature (although dead) individuals, however, indicates that conditions were favorable for settlement and growth during past times. It could not be determined, however, whether the initial settlement of the dead individuals pre- or post-dated the closure of Midnight Pass.

The large number of stations on the east side of Sarasota Bay with no clams found *(Figure 3)* is not easily explained. It is reported that this pattern of more clams on the west side of bays is common on the Florida west coast, however (Don Hesselman, personal communication), and could be associated with bathymetry, associated wave energies, sediment type or predation.

Predacious molluscs were observed primarily in the northern portion of the study area. The less valuable, larger "chowder" clam predominates, due to predation, rapid growth rates and potentially poor or erratic recruitment. The smaller, although still large, mean clam lengths (<100 mm) were found at stations roughly in the area of passes *(Figure 4)* – Longboat Pass, New and Big Passes – and in the far south portion of the study area near Venice Jetties. These may represent more recent sets of cohorts. Smaller-sized clams also were noted in shell or coarse substrate, while larger individuals were found in sand.

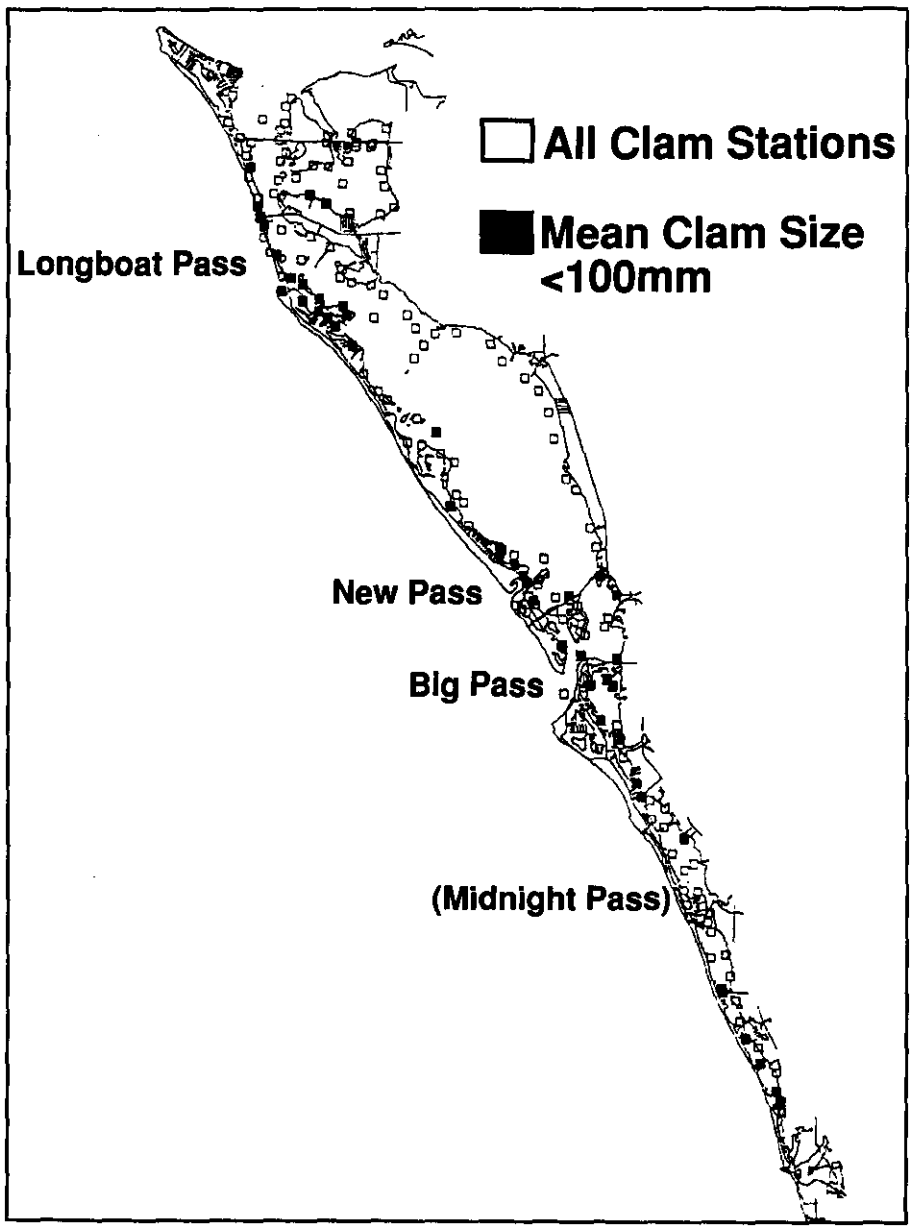
The rapid growth habits of *Mercenaria* and intense predation on juveniles undoubtedly bias populations towards larger individuals. Assuming that the individuals less than 50 mm in size are less than two years old (Jones *et al.*, 1990), it is apparent that recruitment rates are relatively slow. The quantitative effect of harvest pressure on these and on *Mercenaria* populations elsewhere is relatively unknown.

The extent of recreational clamming was not a portion of this study, but clammers were observed or reported during the survey in four areas: New Pass, Pansy Lagoon, the Selby Gardens area and the north end of Palma Sola Bay. Bay access is relatively easy at these locations, but all sites are in prohibited shellfishing areas. Much of the harvested organisms may be used for bait in finfishing.

Oysters are also common in the area, and were most abundant in the more enclosed bays south of Big Pass. Phillippi, North, Catfish and South Creeks flow into shallow Roberts Bay, Little Sarasota Bay and Blackburn Bay, and this freshwater is undoubtedly responsible for the lowered salinity and nutrient input favorable for oyster survival. In addition, the watershed contributing to the southern portion of the study area is roughly double that which drains to Sarasota Bay.

Figure 5 illustrates the areas where oyster bars or reefs were observed. It is clear in the figure that oysters were more abundant in the southern portion of the study area. The high levels of predators (*Melongena*) noted throughout the study area, however, restrict oysters to an intertidal habitat in many regions. As a result, the oysters that feed less than subtidal populations are smaller and less commercially and recreationally desireable.

Figure 4. Stations with mean clam size less than 100 mm.



Bacteriological Contaminants

Fecal coliforms in *water* never exceeded 64 per 100 ml, with more than half the stations slightly exceeding the National Shellfish Sanitation Program (NSSP) criteria of 14 per 100 ml. No *tissues* exceeded NSSP criteria of 230 fecal coliform or 50,000,000 total plate count per 100 g tissue. The maximum tissue concentrations were 100 fecal coliform per 100 g tissue and 51,000 organisms per 100 g for total plate counts.

During the two sampling periods in 1990, all bacterial counts in both tissue and water-column samples remained exceptionally low in Sarasota Bay, perhaps as a result of the relatively low rainfall that occurred during this sampling year. (Rainfall deficits were more than 15 inches below normal for calendar year 1990 in the Manasota Basin, and 22 inches below average for the eight-year period of record at the City Island gaging station.) Additionally, as sampling was delayed in anticipation of increased rainfall amounts, the study was not conducted during the warmest portion of the year, when ambient bacterial counts are expected to be at a maximum.

Although fecal-coliform standards for waters (14 per 100 ml) were slightly exceeded at many stations, only one, Bishops Point, was within a "conditionally approved" area. Counts at this station were 32 and 16 per 100 ml during spring and fall, respectively. The fecal-coliform water standard is apparently a conservative value, since none of the tissues was in excess of the 230 per 100 g standard for tissue. Only the waters at the South Creek station were below the standard during both sampling events.

Bacterial counts at sampling times did not indicate highly polluted conditions, nor for that matter the presence of high numbers of vibrios unrelated to pollution. Of the vibrios, the most frequently identified were *V. alginolyticus, V. parahaemolyticus* and *Aeromona hydrophila*, with *V. vulnificus* occurring only in the spring and at selected stations in the water column and oyster tissue samples. Results suggest that the major groups of vibrios and aeromonas are a part of the normal ecosystem, and not of human fecal origin.

The low levels of vibrios are also a likely result of sampling during the spring and fall rather than during the warmer months, when bacterial populations are typically more numerous. While specific dose-response information is lacking for vibrio infections, the vibrio counts determined during this study are approximately four orders of magnitude less than either total vibrios or *V. vulnificus* alone as documented at a Gulf Coast oyster-processing plant (Ruple *et al.*, 1989).

The erratic counts of total coliform bacteria may indicate that some non-human inputs may be significant at some locations, but the low levels of fecal coliform and fecal streptococci found prevented the use of fecal coliform-to-fecal strep ratios to gain information on sources of fecal matter.

Metals

No consistent seasonal variation in tissue metal concentrations was observed, although this result may differ in years with more rainfall. Comparisons between species support other literature in that Sarasota Bay oysters are noted for high concentrations of copper and zinc. Copper and zinc oyster maxima were 20 or more times higher in oyster tissues than in the maximum clam tissue concentrations, and is attributed to

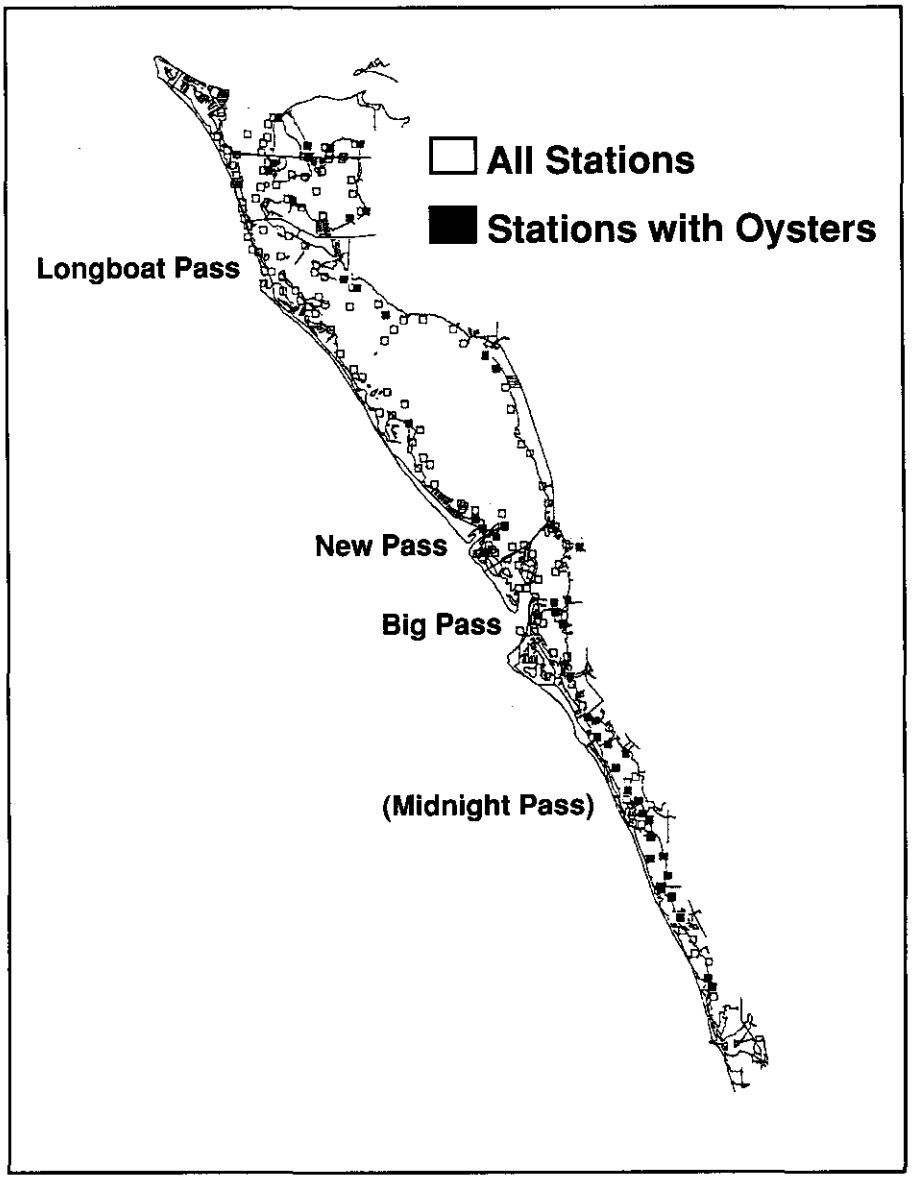
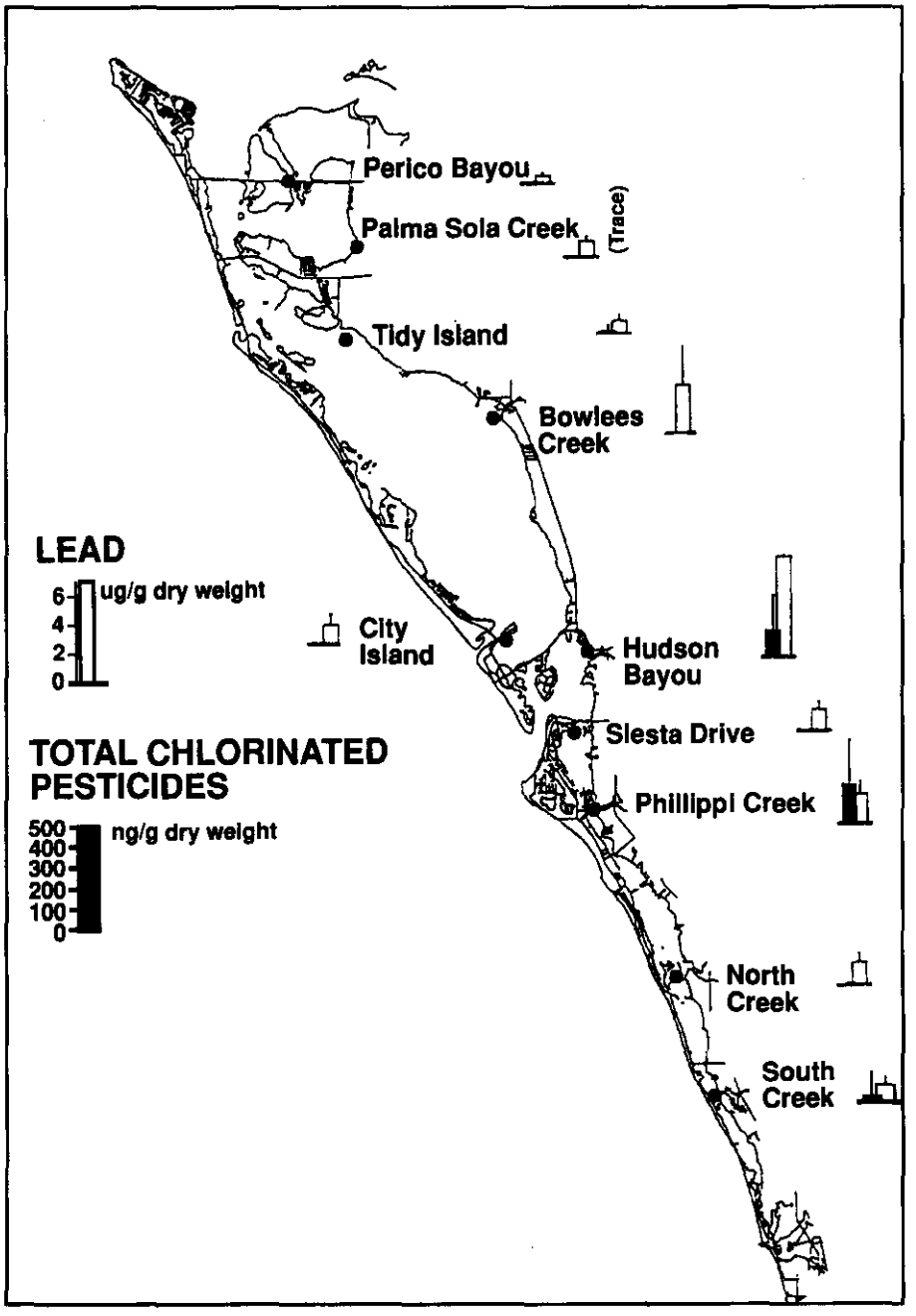


Figure 5. Areas of oyster reefs, clumps or bars within Sarasota Bay.

species-specific physiological strategies for metal detoxification. Lead concentrations were slightly higher in clam tissues than in oysters.

Significant variations occurred between stations for all metals and for each species, with the exception of mercury. Since the ability of shellfish to bioaccumulate mercury has been extensively documented, it can be inferred that mercury is not associated with any major point sources or loadings from the basins represented by stations within this study. Oysters typically displayed a larger range between stations than did *Mercenaria*, with geographic variation most pronounced for copper, lead and zinc, and least noted for arsenic and cadmium.

Figure 6. Geographic distribution of lead and total chlorinated pesticides in oyster tissue. Mean and standard deviation of all samples for the station.



Oyster tissues in Sarasota Bay were evaluated by comparison with the oyster tissue data base developed by the National Oceanic and Atmospheric Administration's National Status and Trends Program (NS&T) (NOAA, 1989). Data from the NOAA program include dry-weight tissue metal values for oysters collected in 1986-88 from 20 stations along Florida's Gulf Coast.

In relation to Florida Gulf Coast values, Sarasota Bay oysters are lower than average in cadmium and mercury, average for arsenic, slightly above-average for copper and zinc and well above-average for lead. The Sarasota Bay/Hudson Bayou concentration of 6.9 ug/g exceeded the highest average lead value reported (5.4 ug/g) for either Florida or the nation *(Figure 6)*. Metal concentrations in clam tissues were similar to other urban areas.

Individual stations are noted for their comparatively high concentrations of arsenic (South Creek and Siesta Bridge), copper (Hudson Bayou), lead (Hudson Bayou and Bowlees Creek) and zinc (Phillippi Creek, Hudson Bayou and South Creek). In comparison, oysters from Palma Sola Creek and Perico Bayou were low in overall metal concentration.

For clam tissues, those gathered from the Phillippi Creek estuary were highest in lead, mercury and zinc, while those from near Selby Gardens were highest in cadmium and copper. Arsenic concentrations in clams were highest in tissues collected off Bishops Point. Clams from the northeast side of the Manatee Avenue Bridge were the lowest in metals.

Overall, tissue metal concentrations were most notable in Hudson Bayou, Phillippi Creek and South Creek. Tissue concentrations of zinc and lead do not correlate particularly well with predicted loads from the various basins, which may reflect varying bioavailability of metals, or unknown point sources.

No station averages of tissue concentrations exceeded Food and Drug Administration (FDA) action levels for mercury, while only the clams at the Selby Gardens station exceeded the unofficial NSSP recommendations for cadmium. Almost all the clam stations, however, and some of the oyster sites exceeded the more-restrictive Canadian action levels for lead.

There is a comparative lack of data sets in which biological effects data (mortality, physiological processes, reproductive impairment or other sublethal effects) are presented together with tissue concentrations, most being evaluated as a function of water-column or sediment concentrations. Long *et al.* (1991) have compiled this information

for oysters. Tissue levels of copper and zinc indicated that oysters in Phillippi Creek, Hudson Bayou and possibly South Creek may suffer from impairments such as altered shell thickness and abnormal larvae. Sediment contaminant concentrations indicate that ecological impacts may be greater than can be defined from tissue concentrations alone (Water and Sediment chapter).

Toxic Organics

Oysters and clams from the majority of the sites sampled throughout Sarasota Bay in Spring and Fall 1990 did not contain substantial amounts of pesticides, yet low levels of chlorinated pesticides were evident. Most concentrations were near detection limits. Of the station averages of the pesticides detected, the highest concentrations were usually contained in oysters, but these organisms were also more directly exposed, as stations were preferentially near the mouths of tributaries.

For the study as a whole, eight of the 18 pesticides under analysis were found in shellfish. No station with detectable pesticides in the spring reported those same compounds during the fall sampling, indicating that sources of pesticides to the study area were intermittent rather than continuous. Sources could be associated with the resuspension of older contaminated sediments, as during dredging operations, or with the new applications of approved carbamates or organophosphates.

No pesticide exceeded the applicable FDA action levels. A greater variety of pesticides was detected in the fall samples than in those collected in spring. Dieldrin was the most prevalent compound during the study (occurring in the most number of samples), followed by beta-BHC, gamma-BHC and p,p'-DDE.

The oysters collected in the spring from Phillippi Creek, however, did contain DDE in concentrations equal to seven percent of the FDA action level of 5,000 ng/g. This level was considered high in relation to the 1986-88 NS&T data for the southwest Florida coast (NOAA, 1989). *Mercenaria* from Blackburn Bridge contained approximately 12 percent of the FDA action level for chlordane. One sample of oyster tissue from Hudson Bayou contained five percent of the total DDT (the sum of all DDT, DDE and DDD) allowed by FDA during the fall sampling.

Notable concentrations of p,p'-DDE were found in oysters collected from the mouth of Phillippi Creek during the spring and from Hudson Bayou in the fall, with lower concentrations of dieldrin, chlordane, BHC and the organophosphate pesticide chlorpyrifos. Phillippi Creek represents the largest watershed basin within the study area, and the loadings may well be high. The Hudson Bayou watershed, while small, is highly developed, with both residential and commercial areas, and was also exceptional for metal contaminants in oysters.

During the fall, trace amounts of the labile organophosphate chlorpyrifos (dursban) were detected in three clam samples and one oyster sample, indicating some influx of pesticides currently in use. Only one clam sample (from the Manatee Avenue site), however, contained quantifiable amounts of chlorpyrifos, averaging 5 ng/g.

The concentrations of total chlorinated contaminants (pesticides from the EPA 608 series) in shellfish tissue averaged over the two seasonal sampling episodes are illustrated *in Figure 6* for oyster tissue samples. Oysters exhibited greater concentrations of pesticides, and residues were detected at five of the 10 sites sampled, with the greatest amounts found at Phillippi Creek and Hudson Bayou. This ranking was primarily the product of concentrations of single compounds, p,p'-DDE for both locations. Pesticide contamination was detected in five of the 10 clam sampling sites, with the greatest amount found at the Long Bar site (due to the heptachlor levels found). Blackburn Bridge clams were the next most-contaminated overall, again due to a single compound (alpha-chlordane).

The concentrations of p,p'-DDE in Phillippi Creek oysters during the spring sampling represent anomalously high amounts relative to other shellfish samples throughout the southwest Florida coast (NOAA, 1989), but are still well below the 5,000 ng/g FDA action level for fish. The fact that p,p'-DDE was not found in oyster samples from the same site during the subsequent collection, however, indicates no continuing contamination problem. Sediment contaminant concentrations, however, indicate that ecological impacts from pesticides and PAH may be greater than can be defined from tissue concentrations alone (Water and Sediment chapter).

The predominance of DDE is indicative of long-term contamination from DDT pesticides applied to the watershed more than 20 years ago. Periodic disruption and erosion of contaminated soil or resuspension of contaminated sediments would produce the observed inconsistent pattern of minute amounts of DDT metabolites. Due to low precipitation throughout 1990, and correspondingly lower inputs of stormwater to the

Sarasota Bay system, the tissue analyses presented here probably do not represent a maximum contaminant scenario. During a wetter season or immediately following a major rainfall, a greater influx of current-use pesticides in stormwater runoff and proportionally greater tissue concentrations would be possible.

Analyses of shellfish tissues detected no quantifiable levels of PAH (greater than 50 ng/g dry weight), although trace amounts (15-50 ng/g) were found at some stations. The stations were broadly distributed, and the low concentrations of PAH detected in Sarasota Bay shellfish indicate no chronic petroleum or pyrogenic contamination and subsequent bioaccumulation.

Sarasota Bay shellfish PAH compounds were derived primarily from pyrogenic sources rather than from direct input from petroleum products. Primary sources would include atmospheric deposition of PAH-containing particles from automobile and boat engine exhaust, coal and oil combustion, industrial processes and forest fires, as well as used crankcase oil washed into the estuary with stormwater runoff. Since many of the PAH in estuaries come from stormwater runoff, a better understanding of the impact from runoff could be gained from monitoring the PAH composition of stormwater at select runoff sites and at select shellfish beds following a major rainstorm.

Because of dry conditions throughout 1990, the environmental conditions represent a minimum-case scenario for stormwater-derived contaminants. In general, the results are indicative of estuarine environments with no consistent, widespread influx of petroleum contamination.

Management Recommendations and Research Needs

The coliform standard and resulting classification of waters appears to be effective in limiting human exposure to toxic contaminants as well. The most-contaminated sites in the study area were in areas currently unclassified or prohibited to shellfish harvesting, in areas adjacent to tributary mouths. The lack of a wet season, and therefore potentially worst-case data during this study, however, should be recognized.

As shellfish in Sarasota Bay generally do not appear to be grossly polluted, recommendations for bacterial (fecal organisms only) and toxic compound control and reduction is based on reducing non-point-source loadings of particulates. Some specific watersheds (Hudson Bayou and Phillippi Creek) could obviously benefit from these techniques more than others. An evaluation of the airborne loads of metals and PAH in relation to surface runoff is needed to indicate whether conventional non-point-source controls (retention, detention, other surface-water management strategies) would achieve significant reductions. Continued restrictions on dredging practices and solids control during these activities should protect shellfish from intermittent exposures to older contaminated sediments. Improved application practices of pesticides could reduce the amounts of recent material reaching the estuary.

Development of biologically based sediment criteria would afford the best protection to the bivalved species, but species-specific thresholds must be developed. These thresholds must extend beyond conventional acute and chronic toxicity assessments, and help to define the ecological impacts of these toxic compounds. The criteria might be applied Bay-wide, or may be restricted to areas designated for shellfish harvesting, recruitment areas or seed beds. Incidentally, human consumers might also receive additional protection if sediment concentrations and shellfish tissue concentrations were monitored and controlled.

As vibrios are apparently endemic to the estuarine environment, controlling human exposure to these pathogens will continue to focus on education of at-risk individuals, primarily those with blood, liver or immunological disorders. Existing Sea Grant informational pamphlets are quite informative. Approaches may be considered to area physicians and/or health specialists. Information pamphlets could be incorporated into the existing recreational fishing-license or boat-registration programs. The comparatively low levels of vibrios found reduces the priority of this effort somewhat.

More extreme measures could include the development of a recreational shellfishing licensing program for distribution of information and generation of revenue, making information available at public access points and restricting the harvest of *Mercenaria* during warm months when *Vibrio* counts are expected to be high. The first of these measures is certain to be unpopular and does not seem justified in view of the low *Vibrio* counts observed. An ecological aspect of vibriosis that deserves attention is the etiology of vibriosis on juvenile shellfish. Infestations can rapidly devastate an aquaculture facility and may play a role in limiting "wild" stocks.

While harvest pressure for human consumption appears low within the study area, any enhancement in this resource may

generate additional interest and pressure. Currently, harvest pressure in approved areas does not reduce the population below that in other areas of the Bay, or prevent (through the removal of reproductive adults) the occurrence of smaller individuals. (If recruitment is higher in this region from environmental factors, this generalization may not hold for other regions of the Bay if they are reclassified in the future.)

Some recreational harvesting in unapproved areas, for bait or consumption, was observed during the surveys. An examination of densities of clams as a function of public access points, however, demonstrated no consistent pattern that would indicate populations are reduced as a function of harvesting by shore-based shellfish gatherers. Those areas with no clams reported appeared instead to reflect regional environmental conditions, and no obvious justification exists for reducing access to protect populations.

Overall, information is lacking on population dynamics, including recruitment, predation pressures and harvesting pressure, which should be quantified to manage the resource and protect from overharvest. Recruitment rates are reported to be highly erratic, and may be a function of environmental variables (of either the water column or the sediments/substrate) coupled with physiological requirements. Currents also undoubtedly play a role in larval distribution. The degree of predation and harvest pressure the various ages of a stable population can support is also difficult to assess, but of interest in managing this resource.

Recommended activities related to the oyster resource would be to update the spatial mapping. Much of the information included in the Sarasota County Habitat Trend Analysis (Mangrove Systems, 1988) on oyster reefs appears outdated, and the Manatee County portion of the study area is unmapped.

Any NPS controls implemented for particulate and toxics removal would also improve detention of stormwaters and increase the dry-season base flow. The restoration of altered flows would be very beneficial to oyster populations in the southern portion of the study area. During historical times, freshwater flows to the Bay were generally less variable, as larger wetland and pervious areas provided for runoff attenuation and the controlled delivery of higher base flows to the estuary. Increasing impervious areas has increased the speed with which runoff occurs, and freshwater pulses occur on a short-term basis. As a result, less water remains on the uplands to provide for dry-season or base flows, and more saline conditions dominate between storm events.

The Phillippi Creek area was apparently impassable due to oyster bars prior to the construction of the Intracoastal Waterway. Opening this channel has most likely decreased flushing times, increased salinities within the Bay and permitted increased invasion of oyster predators such as *Melongena.* Removal of existing bars, even if senescent, should be discouraged from the standpoint of preventing further flow or flushing alterations. In addition, reef removal would reduce the available preferred substrate for oyster-spat settlement. Additional support for flow restoration could be found from a determination of the paleoenvironment in the study area by the use of morphological characteristics of present day and Indian midden oyster shells. Although more technically complex, creation of off-channel oyster bars that could divert freshwater flows into areas less well-flushed might also serve to increase the duration and extent of low-salinity habitat.

If NPS controls improve, with a potential expansion of the approved shellfish-harvesting area, a formal health-risk assessment and recreational effort assessment will become more pertinent. In addition, a wet-season tissue sampling would become essential to quantify what could be worst-case tissue contaminants. The suite of analytical compounds could be further expanded to include selected PCB isomers, since some of these highly toxic compounds were observed in sediment samples.

Resource enhancements at this time could include both seeding of clams and cultch placement for oyster spat to increase the populations, but these activities should be coupled with small-scale investigation to determine optimum locations, timing or rates of success. The enhancements will be difficult to evaluate economically, and, due to limited approved waters and limited oyster habitat, they will not likely result in any direct increase in recreation potential. For oysters in particular, harvestable individuals would likely remain low unless 1) salinity regimes were radically restored; 2) subtidal growth habits were encouraged; 3) non-point-source loadings were reduced; 4) regions near tributaries were reclassified for harvest; and 5) sufficient monitoring were supported to guarantee sanitary quality.

Valid ecological inducements for these enhancements exist, however. As filter feeders, both clams and oysters have the theoretical potential to improve the water clarity of Sarasota Bay, particularly if water-

clarity impairments are linked to chlorophyll or phytoplankton levels. The size preferences of shellfish should be compared to dominant phytoplankton species in the region for predicting improvements.

Other benefits of enhancing shellfish populations would include increased biomass and productivity of the estuary, and the support of other species that prey on larval bivalves. Expanding oyster reefs could also provide additional habitat complexity particularly suited to invertebrate fauna and juvenile fish, increased shoreline stability and reduced sediment resuspension through wave damping.

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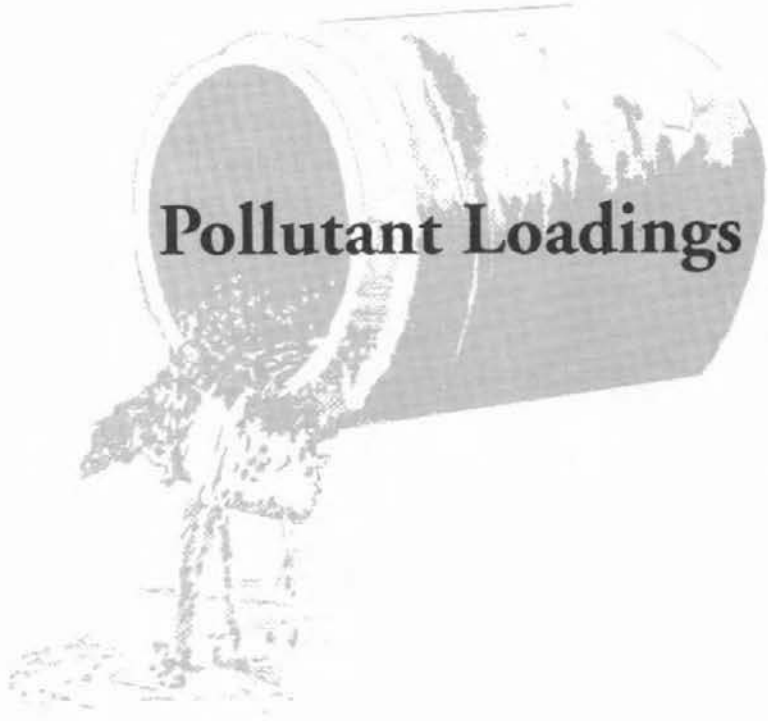
Pollutant Loadings



Point- and Nonpoint-Source Pollutant-Loading Assessment

by Michael G. Heyl
Camp Dresser & McKee Inc.

Executive Summary

As part of the Sarasota Bay National Estuary Program, Camp Dresser & McKee Inc. (CDM) conducted an assessment of point and nonpoint sources to quantify the loadings of nutrient and metals contributed to Sarasota Bay, identify the sources and areas contributing the largest share of the total load and analyze alternative measures for reducing these pollutant loadings.

Total phosphorus (TP), total nitrogen (TN), lead and zinc were selected for analysis because they represent the major point- and nonpoint-source contaminants, and their characteristics and association with different land uses are well documented in the literature. Loadings of these pollutants were estimated for existing conditions and three future land-use scenarios: five-year, 20-year and buildout.

Generally, the results indicate that surface runoff is the largest source of total pollutant loadings to Sarasota Bay. The exception is that rainfall contributes the largest share of zinc loads. Under existing conditions, surface runoff accounts for about 45 percent of the TP and TN loads, more than 90 percent of the lead load and 25 percent of the zinc load. Under the buildout scenario, pollutant loads attributed to surface runoff are projected to rise to more than 50 percent of the TP and TN loads, 93 percent of the lead loads and 33 percent of the zinc loads.

Point sources contribute a relatively small percentage of the total pollutant loadings, primarily because the majority of the wastewater-treatment plants (WWTPs) in the study area do not discharge effluent directly to surface waters. Instead, the effluent from most WWTPs is either reused for irrigation, discharged to percolation ponds or disposed of via deepwell injection. Less than 25 percent of the total WWTP flow is discharged directly to surface waters, and only after receiving advanced treatment.

Strategies identified for protecting the water quality of Sarasota Bay focus primarily on nonpoint-source and point-source pollution controls. Since nonpoint-source pollution is responsible for the largest percentage of existing loadings to Sarasota Bay and will contribute the greatest increase in future loadings, the most critical management strategy to protect water quality in the Bay is to control surface runoff from new and existing development. While the estimates of existing and future loadings indicate that point sources and septic tanks are not major contributors of pollutants to Sarasota Bay, improvements can be made. It is important to ensure that appropriate treatment and disposal will continue to be provided to handle the future increased flows in a manner consistent with water-quality protection.

Twenty-three management alternatives to ameliorate pollutant loadings to Sarasota Bay were identified and evaluated. Continuing the state-mandated requirement of providing stormwater-treatment facilities for all future development (Alternative A) will control loading increases to some extent, resulting in increases of seven percent for TP and 14 percent for TN loads. By contrast, if the required stormwater-treatment facilities are combined with cluster development, restricted imperviousness on commercial and industrial areas and implementation of Sarasota County's wastewater plan, annual nutrient loadings for the buildout scenario can actually be reduced by nine percent over existing loads.

Because a method has not yet been established for evaluating the effectiveness of pollutant-load reductions in achieving Sarasota Bay National Estuary Program goals, no target reductions have been established, and therefore no basis exists for recommending one loading reduction over another. Further field and modeling studies are required to evaluate the potential benefits that may result from varying load reductions and to support a valid cost/benefit evaluation of the management alternatives.

Point- and Nonpoint-Source Loading Assessment of Sarasota Bay

Michael G. Heyl
Mr. Heyl is a principal scientist with the consulting firm Camp Dresser and McKee, Inc. in Sarasota, where he has been involved in modeling the source, magnitude and impacts of pollutant loadings to rivers and estuaries. He is the past chairman of the Point/Non-Point Source subcommittee of the Sarasota Bay Program's Technical Advisory Committee. Previously, he was an environmental scientist with the Manatee County Public Works Dept., directing several watershed yield studies and freshwater-release requirement investigations of the Manatee River. Mr. Heyl is a former research scientist of Mote Marine Laboratory, where he studied estuarine and water resources issues. He holds a Master's Degree in Chemistry from the University of South Florida.

Purpose and Scope

The purpose of the assessment was to quantify the loadings of nutrient and metals contributed to Sarasota Bay by point and nonpoint sources, so as to identify the sources and areas contributing the largest share of the total load and analyze alternative measures for reducing these pollutant loadings. The assessment was conducted in three phases:

- Phase I – Existing data were used to estimate pollutant-loading levels for existing conditions and future land-use scenarios.
- Phase II – Field studies were conducted to estimate pollutant loads from golf courses and canal communities within the study area.
- Phase III – The Phase I pollutant-loading levels were refined, and alternative management strategies for reducing pollutant loadings were modeled and evaluated.

Characterizing all pollutant loadings and all pollutant sources was beyond the scope of this study. Instead, the scope of the assessment was limited to four pollutant parameters: total phosphorus (TP), total nitrogen (TN), lead and zinc. These parameters are representative surrogates for the major point- and nonpoint-source contaminants, and ample literature exists documenting their pollutant characteristics and relationships to different land uses.

The sources evaluated included stormwater runoff, baseflow, point-source discharges, septic tanks and rainfall.

Study-Area Characteristics

Characteristics of the study area considered essential to the pollutant-loading analysis were watershed boundaries, existing and future land use, soil characteristics, water quality and pollutant sources.

Watershed Delineation

The study area (*Figure 1*) extends from Anna Maria Island and Perico Island south to Casey Key. In addition to Sarasota Bay, the area includes the smaller Roberts Bay, Little Sarasota Bay, Dryman Bay and Blackburn Bay. Approximately 150 square miles of land area and 52 square miles of water surface comprise the study area. Twenty watersheds were delineated *(Table 1)*.

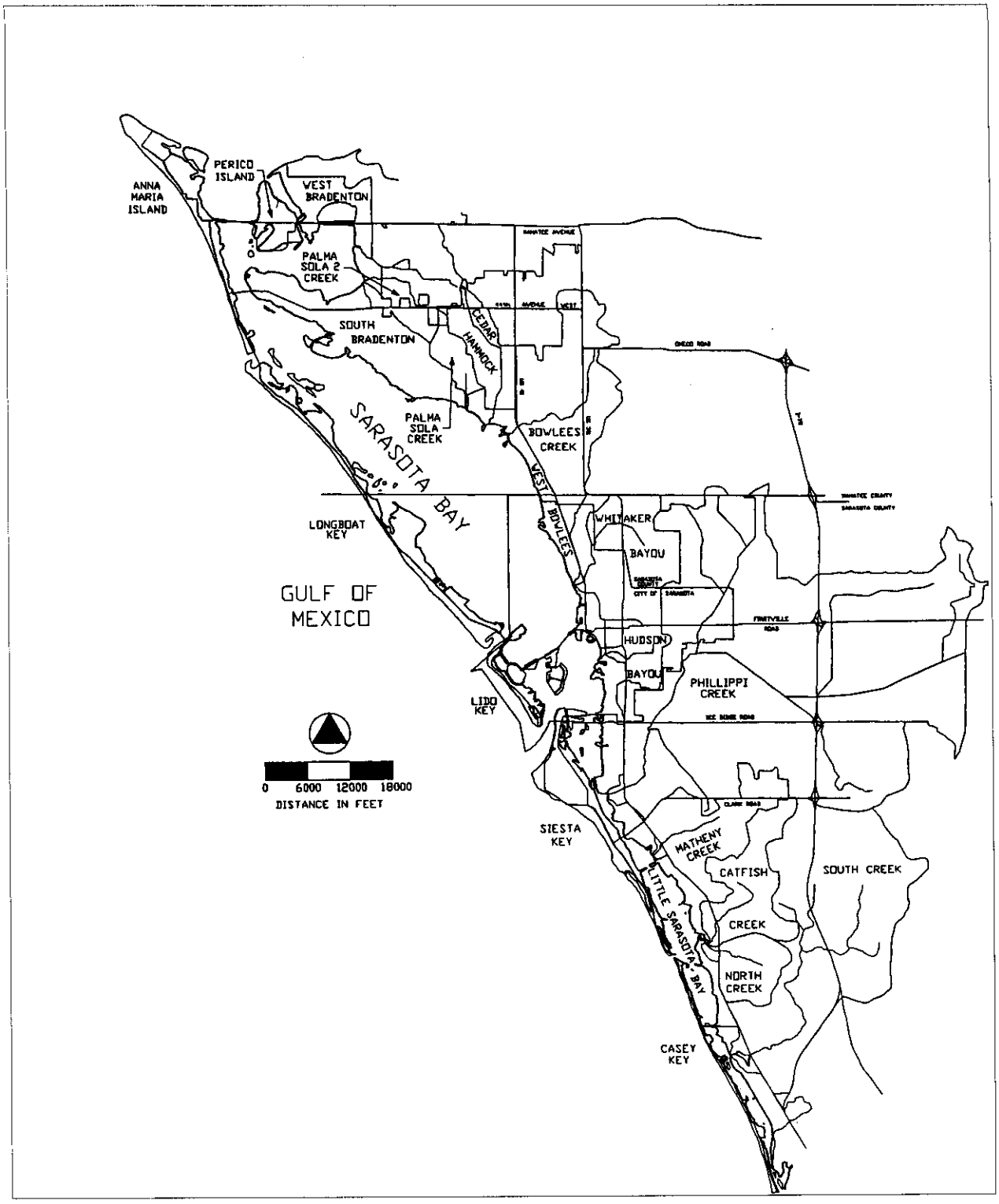
Existing Land Use

Existing land use in the study area was established based on aerial photographs and corresponding zoning maps provided by Real Estate Data, Inc. Sarasota County has the largest contributory area to the Bay, accounting for 65 percent of the total land area. Manatee County, the City of Sarasota and the barrier islands make up 21, eight and six percent of the total land area, respectively.

Table 2 presents the existing land use for the study area by jurisdiction. Slightly more than half the study area consists of urban development (residential, commercial, industrial and institutional); the rest is open or undeveloped. Of the urban development, about 81 percent is residential, primarily medium- and high-density single-family residential. For the open or undeveloped areas, about 18 percent is either cropland or citrus; the rest is primarily rangeland/woodland, open/recreation and forested uplands.

Within Sarasota County, approximately 42 percent of the land area consists of urban development; the remaining 58 percent is open or undeveloped. Sarasota County's urban development is most prevalent in the land areas closest to the Bay. About 87 percent of the urban development is residential, primarily split among low-, medium- and high-density single-family residential land uses (*Table 2*).

Within Manatee County, approximately 64 percent of the land area consists of urban development; the remaining 36 percent is open or undeveloped. Roughly 72 percent of the urban area is residential, primarily divided among medium- and high-density single-family- and multi-family-building land uses. About 87 percent of the City of Sarasota is urban development; the other 13 percent is open or undeveloped. Residential



development accounts for 70 percent of the total urban land use, primarily divided among medium- and high-density single-family- and multi-family-building land uses. Most of the open or undeveloped land, located in the far eastern part of the city, consists of golf courses and parks that will not be developed for other uses in the future.

As a group, the barrier islands have 66 percent of their land area in urban development and 34 percent open or undeveloped. Most open or undeveloped areas are located on Longboat Key and Perico Island, where open/recreation land use predominates. Siesta Key and Anna Maria Island are predominantly urbanized, with 94 percent of the urban area residential.

Figure 1. Sarasota Bay NEP Study Area.

Watershed	Drainage Area (acres)	Jurisdiction
Philippi Creek	36,417	City of Sarasota Sarasota County Manatee County
Hudson Bayou	1,595	City of Sarasota
Bowlees Creek	6,489	City of Sarasota Sarasota County Manatee County
West Bowlees	1,559	City of Sarasota Sarasota County Manatee County
Whitaker Bayou	5,015	City of Sarasota Sarasota County
Direct to Bay	4,241	City of Sarasota Sarasota County
Matheny Creek	3,800	Sarasota County
Catfish Creek	3,360	Sarasota County
North Creek	1,920	Sarasota County
South Creek	12,995	Sarasota County
Palma Sola Creek	900	Manatee County
Palma Sola 2	1,120	Manatee County
West Bradenton	4,395	Manatee County
South Bradenton	4,635	Manatee County
Cedar Hammock	1,930	Manatee County
Siesta Key	1,385	Barrier Islands
Anna Maria Island	919	Barrier Islands
Perico Island	860	Barrier Islands
Longboat Key	1,697	Barrier Islands
Other Islands	900	Barrier Islands

Table 1. Watersheds in Sarasota Bay NEP Study Area.

Future Land Use

Three land-use scenarios were developed: (five-year future, 20-year and buildout future), two of which are discussed. The five-year scenario was based on the Developments of Regional Impact (DRI) data provided by Sarasota and Manatee counties. The Comprehensive Plans for both counties and the barrier-island communities were used to develop the buildout scenario. Both scenarios excluded the City of Sarasota, because the city is currently approaching buildout and future development will be limited.

In the five-year scenario, all projected development will be in Sarasota County, where an estimated 1,686 acres of open or undeveloped land are expected to be developed. Overall, 248 acres of open/recreational, 1,350 acres of rangeland/woodland and 88 acres of citrus will be developed to create 1,319 acres of medium-density single-family residential, 120 acres of industrial, 20 acres of institutional and 227 acres of commercial area.

In the buildout scenario, almost 31,000 acres of open or undeveloped land within the two counties are projected to be converted to urban land uses. Of the 31,000 acres, about 85 percent will be developed for residential uses and 15 percent will be converted to commercial or industrial use.

Soil Characteristics

According to Soils Conservation Service (SCS) soil surveys for Manatee and Sarasota counties, the soils in the study area are generally classified as B/D, indicating that they tend to be poorly drained in unimproved areas and moderately drained where drainage improvements have been implemented.

Water-Quality Characteristics

Based on reports from the Florida Dept. of Environmental Regulation (FDER), Sarasota Bay is generally characterized as having "fair" water quality; its tributaries are characterized as having "poor" to "fair" water quality. Tributaries with "fair" water-quality ratings include Phillippi, Matheny and Catfish creeks; Whitaker Bayou has a "poor" water-quality rating. In most cases, the poor to fair ratings are due to elevated nutrient levels, which are generally attributed to urban runoff and discharge from wastewater-treatment plants.

Land Use	Area (acres)				
	City of Sarasota	Sarasota County	Manatee County	Barrier Islands	Total
Cropland	0	3,756	1,912	130	5,798
Forested Uplands	168	673	1,052	44	1,937
Rangeland/Woodlands	126	15,544	1,253	19	16,942
Open/Recreation	650	11,688	2,222	1,373	15,933
Wetland	0	1,449	415	403	2,267
Citrus	4	2,278	209	0	2,491
Low-Density Single Family Residential	368	7,375	292	388	8,423
Medium-Density Single Family Res.	1,320	6,827	2,012	1,641	11,800
High-Density Single Family Residential	2,164	5,163	3,422	741	11,490
Multi-Family Building	946	1,983	2,677	754	6,360
Mobile Home	0	1,065	862	37	1,964
Commercial/Services	926	1,485	654	169	3,234
Institutional	529	647	365	0	1,541
Industrial	521	1,106	1,989	40	3,656
Transportation	17	203	633	15	868
Water Body	75	1,028	228	2	1,333
Sewage Treatment and Power Plants	30	30	30	5	95
Total	7,844	62,301	20,226	5,761	96,132

Table 2. Existing Land Use by Jurisdiction.

Several studies of water-quality trends in Sarasota Bay since the mid-1960s have identified declining salinity and nutrient levels over time. Changes in land use appear to be one plausible reason for these trends. The transformation of certain types of agricultural land to urban residential land use increases surface runoff, resulting in greater freshwater dilution in the Bay.

Sources of Pollutants

Five sources of pollutants to Sarasota Bay have been considered in this study:

•Surface Runoff

When it rains, the volume of rainfall that cannot infiltrate into the soil runs off the land surface into numerous tributaries, and ultimately to Sarasota Bay. As the runoff travels over the land, it picks up accumulated pollutants, such as nutrients (nitrogen and phosphorus) that have been applied as fertilizers and metals (lead and zinc) that have been deposited on streets by automobiles.

Because 60 percent of the study area is currently characterized by improved land uses (e.g., agricultural, residential, industrial, commercial), surface runoff is likely a significant contribution to the total pollution loading to the Bay. Cropland, citrus, commercial, industrial and the more dense residential land uses can be expected to contribute high concentrations of nitrogen and phosphorus to tributaries. With the exception of cropland and citrus, these same land uses will also contribute relatively high metals concentrations.

• Baseflow

The baseflow loading accounts for pollution conveyed by groundwater. The fraction of total watershed loading that is due to baseflow becomes smaller as the watershed develops, because more of the rainfall is converted to surface runoff and less infiltrates into the soil. The concentration of pollutants in the groundwater is based on the natural composition of the soil.

• Point-Source Discharges

Point-source discharges in the study area include municipal- and private-utility wastewater-treatment plants (WWTPs). Nutrients in the effluent discharges from WWTPs can be a water-quality concern. Seventeen WWTPs are over 0.1 million gallons per day (mgd) in the study area, for a total flow of roughly 27 mgd. However, only four of these WWTPs (total combined flow of 6.5 mgd) discharge directly to surface waters, and all these provide advanced wastewater treatment (AWT) prior to discharge. The other 13 WWTPs reuse the effluent for irrigation and/or discharge to percolation ponds or deep wells. Because of the limited direct discharge from WWTPs, point sources would be expected to contribute only a small portion of the total pollution loads to Sarasota Bay.

• Septic Tanks

Septic tanks (also referred to as onsite disposal systems) are used in some cases to treat waste from individual homes, multi-family buildings and commercial and

industrial areas. Basically, a septic tank achieves primary treatment (i.e., settling) and discharges the effluent to a drainfield. Further pollutant transformation and removal occurs as the effluent percolates downward through the drainfield to the water table; additional dilution and removal is expected to occur as the effluent mixes with and moves along with the groundwater flow.

Septic tanks are used throughout the Sarasota County mainland and in the barrier islands. All residential development on Casey Key (157 acres) is served by septic tanks. In Sarasota County, the percentage of land served by septic tanks varies by the type of land use, as noted below.

Land-Use	% Served by Septic Tank
Low- and Medium-Density Single-Family Residential	58
High-Density Single-Family Residential	38
Multi-Family Building	13
Mobile Homes	3
Commercial	21
Industrial	23
Institutional	9

- **Rainfall**

Loadings to Sarasota Bay also are contributed by rainfall on the Bay surface. Considering that the water surface is about 52 square miles (34 percent of the total drainage area to the Bay), rainfall could have a significant impact on pollution loading. Average daily rainfall accounts for 133 mgd.

Methodology for Pollutant-Loading Projections

This section presents an overview of the methodology and assumptions used to estimate pollutant loadings from the various sources: nonpoint sources, point sources, septic tanks and rainfall.

Rainfall and Runoff Relationships

Rainfall and streamflow were calculated based on long-term monitoring data from U.S. Geological Survey (USGS) stream gauges and local rain gauges. Based on these data, an average annual rainfall of 54.6 inches and an average annual streamflow volume of 14.8 inches were assumed for the study area.

The majority of the rainfall is cycled back to the atmosphere by evaporation and/or as water vapor released by plants (called transpiration). The rainfall that infiltrates into the soil becomes baseflow, contributing to streamflow via underground movement. The rainfall that cannot infiltrate becomes surface runoff, contributing to streamflow as overland flow. The proportion of rainfall that becomes runoff depends on how impervious the land surface is. A pervious land surface, such as a grassed area, cropland or woodland, allows most of the rainfall to infiltrate into the soil, creating very little runoff. For this study, it was assumed that only 15 percent of the rainfall on pervious areas becomes runoff.

An impervious area, however, prevents infiltration because the rainfall cannot reach the soil. Urban land uses tend to have more impervious areas – sidewalks, paved streets and parking lots, rooftops, etc. – generating greater runoff. The greater the amount of directly connected impervious area (DCIA), the greater the volume of runoff will be. DCIA differs by land-use type. For example, commercial areas tend to have a high percentage of DCIA, roughly 85 percent. In residential areas, DCIA increases with the density of development (i.e., number of dwellings per acre). Thus, low-density single-family residential land use is about 20-percent DCIA, and high-density single-family residential land use is about 40-percent DCIA. *Table 3* presents the percent of DCIA assumed for each urban land use.

Just as the amount of impervious area in a watershed affects the volume of runoff, it will also affect the baseflow volume. For example, if the drainage area were 50-percent impervious due to residential and commercial development, the baseflow volume would be reduced by 50 percent. Thus, the percentage of streamflow contributed by baseflow diminishes as development occurs in the watershed; at the same time, surface runoff increases. The net result is an increase in overall flow.

Nonpoint-Source Pollutant-Loading Factors

Nonpoint-source pollutant loadings are a function of the quantity of flow and the concentration of pollutants in the flow. Thus to estimate the pollutant loadings from surface runoff, estimated pollutant concentrations for each land use are multiplied by the runoff flow. Because runoff volume and pollutant concentrations differ by land use, pollutant loadings will also differ by land use.

For the four pollutants included in these analyses (TP, TN, lead and zinc), event mean concentrations (EMCs) for each land use were estimated based on data developed through the EPA Nationwide Urban Runoff Program (NURP). An EMC is defined as the

Land Use	DCIA (%)	Event Mean Concentration Values (mg/l) Total P	Total N	Total Lead	Total Zinc
Cropland	1	1.13	3.74	0.000	0.000
Forested Uplands	1	0.16	1.02	0.000	0.000
Rangeland/Woodlands	1	0.16	1.02	0.000	0.000
Open/Recreation	1	0.16	1.02	0.000	0.000
Wetland	100	0.03	0.25	0.000	0.000
Citrus	1	0.41	0.92	0.000	0.000
Low-Density Single Family Residential	20	0.39	1.87	0.049	0.054
Medium-Density Single Family Res.	30	0.39	1.87	0.049	0.054
High-Density Single Family Residential	40	0.33	1.65	0.076	0.060
Multi-Family Building	50	0.33	1.65	0.076	0.060
Mobile Home	60	0.33	1.65	0.076	0.060
Commercial/Services	85	0.15	1.18	0.235	0.120
Institutional	40	0.15	1.18	0.235	0.120
Industrial	70	0.15	1.18	0.235	0.120
Transportation	90	0.15	1.18	0.235	0.120
Water Body	100	0.15	0.82	0.006	0.146
Sewage Treatment and Power Plants	40	0.15	1.18	0.235	0.120

Table 3. DCIA and EMC Values Sarasota Bay NEP Study.

average concentration of a pollutant in stormwater runoff (e.g., total mass/total runoff volume). The EMC values by land use are shown in *Table 3.*

For the nutrients TP and TN, the EMC values are highest for cropland, citrus and low- and medium-density single-family residential land uses, due to fertilization of agricultural lands and residential lawns. Commercial, industrial and unimproved areas have the lowest EMC values for nutrients, less than half the agricultural and residential values. For lead and zinc, the unimproved and agricultural land uses have very low EMCs (essentially zero for planning purposes), whereas residential, commercial, industrial and other urban land uses generate high loadings of metals.

EMC values alone cannot be used to determine the relative loading impacts of different land uses. Pollutant loading depends on the EMC value and the volume of surface runoff for a particular land use. Because commercial and industrial land uses have a much greater percentage of impervious area than residential land use, they tend to produce greater loadings in terms of lbs./ac./yr., even though they are characterized by lower EMC values.

For example, the average annual surface-runoff loads for commercial and medium-density single-family residential land uses are relatively similar: 1.6 lbs. per acre per year (lb./ac./yr.) for commercial and 2.2 lb./ac./yr. for residential for TP, even though the EMC is much higher for the residential area. The loadings for TN are 12.3 and 10.1 lb./ac./yr. for commercial and medium-density residential land uses, respectively. The greater volume of surface runoff from the commercial areas compared to the residential areas accounts for the higher pollutant loadings.

Baseflow loadings, like surface-runoff loadings, are calculated by determining the flow volume and the flow concentration. Based on analysis of existing dry-season water-quality data, the following values were selected for baseflow concentrations (see figure at right).

- TP: 0.30 mg/l
- TN: 1.00 mg/l
- Lead: 0.003 mg/l
- Zinc: 0.05 mg/l

Studies conducted during Phase II examined the projected loads from golf courses and canal communities within the study area, as summarized below.

Golf-Course-Runoff Loadings

Because the study area includes 23 golf courses whose maintenance requires intensive irrigation and fertilizer and pesticide application to sustain high-quality turf, the potential water-quality impacts from golf-course maintenance were evaluated. A literature review of golf-course maintenance practices was conducted, and field studies of surface-water and groundwater quality were conducted by Mote Marine Laboratory (MML) on a local golf course.

A private golf course in northwest Bradenton was selected for storm-event and monitoring-well sampling. The course is irrigated with reclaimed water from the Manatee County Southwest WWTP.

Based on the limited sampling of eight storm events, the average runoff from all

events was approximately 10 percent of the applied rainfall. The average EMC for TP was 1.3 mg/l and 2.6 mg/l for TN. Using these values, the total maintained golf-course area (2,896 acres) within the study area was modeled as a single land-use watershed for a typical rainfall year. Based on the median EMCs, the results indicate that the annual runoff from all golf courses in the study area contains an estimated 14,610 lbs. of nitrogen (range 1,270-62,580 lbs.) and an estimated 7,530 lbs. of phosphorus (range 10-50,230 lbs.). The wide range is indicative of the variable nature of runoff EMCs and the low number of values available for consideration.

Golf-course-runoff loadings account for only 2.9 percent of the TP load for all sources and 1.1 percent of the TN load for all sources. Results of golf-course groundwater sampling for the Sarasota Bay NEP and other studies reported in the literature indicate that golf-course maintenance practices have minimal impact on groundwater quality.

Canal-Community Loadings

The study area has 128 miles of canal waterfront/shoreline residential development. The potential groundwater loadings of TP and TN to Sarasota Bay from these communities were evaluated. The concern over residential groundwater loadings was based on the fact that waterfront-community lawns tend to be well-maintained and usually present relatively steep land-to-canal gradients. The maintenance practices to sustain a turf lawn require regular fertilization and irrigation; the high fertilization rates and high irrigation rates combined with steep land gradients implied that groundwater loadings could be a significant contribution to the Bay. A representative site was selected and two monitoring wells were installed for quarterly groundwater sampling. Water levels in the monitor wells and in the canal were also recorded quarterly when groundwater samples were collected.

The canal communities within the study area consist of an estimated 2,793 acres of medium-density single-family residential land use. Based on the sampling results, the average annual loading of TP is 863 lbs. and of TN is 17,073 lbs. from all canal communities in the study area. By comparison, a typical medium-density residential area this size not located along a canal generates an estimated 880 lbs. of TP annually and 2,930 lbs. of TN annually as baseflow. Thus, the total canal-system subsurface loading of TP is not significantly different between the canal and non-canal communities, with canal communities contributing only 0.3 percent of the TP loadings to Sarasota Bay. The TN subsurface loads are approximately six times greater for the canal communities, yet they constitute only 1.3 percent of the TN loadings to Sarasota Bay.

Point-Source Loadings

Of the 17 WWTPs with flows greater than 0.1 mgd in the study area, only four discharge effluent directly to a surface water. The remaining effluent-disposal methods include a combination of irrigation, percolation ponds and deep-well injection. Less than 25 percent of the total WWTP flow is discharged to surface waters.

The WWTPs are distributed throughout five watersheds (South Bradenton, Phillippi Creek, Matheny Creek, Whitaker Bayou, Siesta Key), with one small plant in a watershed that drains directly to the Bay. All the WWTPs provide either secondary or advanced treatment.

Anna Maria Island, Longboat Key and the portion of Manatee County within the study area are all served by Manatee County's Southwest Regional WWTP. The plant currently has an average daily flow rate of 12.8 mgd. The effluent is reused for irrigation purposes, primarily at the Manatee Fruit Co. site and several golf courses; in addition, effluent can also be discharged into a deep-well injection system during wet weather. In effect, no effluent from this WWTP is directly discharged to surface waters.

The City of Sarasota is served by the city's WWTP. In 1991, the average daily flow was 6.9 mgd. The plant has recently been upgraded from secondary treatment to advanced wastewater treatment (AWT), and the majority of the effluent is now reused to irrigate pasture land and golf-course property, with only intermittent surface-water discharge. Prior to these improvements, secondary effluent was discharged to Whitaker Bayou. Loadings to Sarasota Bay from the discharge to Whitaker Bayou have decreased considerably since these improvements were implemented. Additional reuse sites, which will further reduce loadings from this point source, are planned.

Siesta Key and parts of Sarasota County are served by a number of small package plants and privately owned wastewater-treatment utilities; the total flow for these plants is approximately 7.4 mgd. Most of the facilities discharge via irrigation, drainfields and percolation ponds, although two of the larger plants discharge directly to surface waters. Effluent from the two WWTPs with direct discharge meets AWT standards.

Watershed	Discharge (mgd)	Concentration (mg/l)			
		TP	TN	Lead	Zinc
Phillippi Creek	1.63	1.03	3.78	0.015	0.076
Matheny Creek	1.52	1.05	3.44	0.019	0.094
Whitaker Bayou	3.47	1.02	3.20	0.019	0.097
Direct to Bay	0.04	1.48	7.38	0.007	0.037
Siesta Key	1.82	1.00	3.00	0.020	0.100
South Bradenton	2.08	0.74	3.69	0.004	0.018

Table 4. 1991 Point-Source Flows and Flow-Weighted Pollutant Concentrations.

The effluent concentrations assumed for the point-source analysis are:

Treatment Level	TP (mg/l)	TN (mg/l)	Lead (mg/l)	Zinc (mg/l)
Secondary	4	20	0.025	0.100
Advanced	1	3	0.025	0.100

Since not all the WWTPs discharge directly to surface waters, different loadings were determined for the different effluent-disposal methods. For example, for deep-well injection, it was assumed that no load would reach the Bay. For percolation ponds and drainfields, a removal rate of 90 percent was assumed for all pollutants; a slightly higher removal rate of 95 percent was assumed for irrigation practices, with the higher efficiency attributed to plant uptake. The point-source flows and concentrations for the watersheds affected by point-source discharges are shown in *Table 4*.

Septic Tank Loadings

CDM conducted a literature review and analysis to evaluate the pollutant loadings contributed by septic-tank systems. Typical concentrations reported in the literature for effluent as it is discharged from the tank are 40-80 mg/L for TN and about 15 mg/L for TP, as compared to 3 mg/L TN and 1 mg/L TP for AWT. Additional nutrient removal takes place as the effluent travels through the soil column to the water table. In most instances, soil is effective in removing TP, such that 90 percent or more is retained in the soil through adsorption. For TN, however, much of the mass in the effluent reaches the water table. After percolation to the water table, the concentrations of TN and TP are reduced to about 30 mg/l and 2 mg/l. As the pollutant load travels along with the surficial aquifer toward a body of water, the concentrations of TP and TN are further reduced by decay and dilution. The longer the travel time to the water body, the greater the pollutant reduction.

For the Sarasota Bay NEP study area, septic tanks account for only a small fraction of the total study-area pollutant loadings, but the impact of septic tanks varies among watersheds. Watersheds that have a relatively high concentration of septic-tank contribution include Phillippi Creek, Matheny Creek and the areas along the west coast of the mainland and the east coast of the barrier islands that drain directly to the Bay. While septic tanks may have significant impact on local water quality, they do not appear to be a major factor in total pollutant loadings to the Bay. Overall, septic tanks account for an estimated 3.3 percent of the TP loading and 9.6 percent of the TN loading to the Bay.

Rainfall Loadings

The annual rainfall total of 54.6 inches distributed over 52 square miles of Sarasota Bay surface area yields an equivalent flow rate of 133 mgd. Pollutant concentrations, based on monitoring data from the Tampa Bay NURP study, were estimated as: TP 0.15 mg/l, TN 0.82 mg/l, lead 0.006 mg/l, zinc 0.146 mg/l. For the average rainfall year, the calculated rainfall loads in pounds per year are 61,700 for TP, 337,400 for TN, 2,500 for lead, 60,100 for zinc. These loads are significant, and reveal that in the case of zinc, rainfall contributes a greater load to Sarasota Bay than any other source.

Pollutant-Loading Projections for Existing Land-Use Conditions

A spreadsheet model was used to calculate the pollutant loadings to Sarasota Bay for existing land-use conditions. Pollutant loadings to the Bay were analyzed by pollutant source, by watershed and by political jurisdictions. For the average annual rainfall conditions, the percentage of the total loading occurring in the wet and dry seasons was determined. Pollutant loadings for a wet year and a dry year were also estimated and compared with those of an average year.

Average Annual Loading Results

Table 5 represents the average annual pollutant-loading results by watershed for

Watershed	Area (acres)	Total Runoff (in)	TP (lb)	TN (lb)	Lead (lb)	Zinc (lb)
Phillippi Creek	36,417	25.24	66,860	362,950	7,410	9,450
South Creek	12,995	18.79	11,050	53,190	250	1,400
Bowlees Creek	6,489	33.61	11,100	64,320	6,970	4,270
Whitaker Bayou	5,015	40.74	20,270	89,870	3,630	3,630
S. Bradenton	4,635	27.87	12,550	56,260	590	1,120
W. Bradenton	4,395	28.94	7,250	35,910	1,490	1,410
Matheny Creek	3,800	35.96	11,390	57,290	2,040	2,100
Catfish Creek	3,360	21.73	3,590	18,640	240	560
Cedar Hamk.	1,930	32.35	4,090	20,830	1,280	970
North Creek	1,920	20.60	2,160	11,170	220	350
Longboat Key	1,697	23.62	2,730	13,000	440	450
Hudson Bayou	1,595	32.58	3,070	16,570	1,940	930
W. Bowlees	1,559	27.93	2,990	14,800	710	590
Siesta Key	1,385	45.94	8,410	30,230	580	1,030
Palma Sola 2	1,120	25.12	1,640	8,340	350	320
Anna Maria	919	28.32	1,740	8,660	450	360
Palma Sola	900	23.47	1,710	7,490	230	220
Other Islands	900	27.94	1,640	8,360	310	290
Perico Island	860	33.12	1,040	4,750	50	100
Direct to Bay	4,241	31.85	8,760	51,120	2,290	1,850
Bay Surface	33,280	54.60	61,730	337,460	2,470	60,080
TOTAL	129,412	34.26	245,770	1,271,210	33,940	91,480

Table 5. Average Annual Loadings by Watershed for Existing Land-Use Conditions.

existing land-use conditions.The four largest watersheds – Phillippi Creek, South Creek, Bowlees Creek and Whitaker Bayou – account for more than half the runoff and total loadings to the Bay, excluding rainfall. Phillippi Creek and Whitaker Bayou contribute a large percentage of the total loadings for both nutrients and metals; in contrast, Bowlees Creek, which is highly industrialized relative to the other watersheds, has a greater relative contribution of metals loadings than nutrient loadings. South Creek, which is primarily open or undeveloped, has a greater relative contribution of nutrient loadings than metals loadings.

Table 6 shows the percentage of the total average annual loadings attributed to each of the major sources. Generally, the results indicate that surface runoff and rainfall are the two largest sources of pollutant loadings to Sarasota Bay. Together, these two sources account for 70 percent of TP, 73 percent of TN, 98 percent of lead and 91 percent of the zinc loadings. Surface runoff is the major source of TP, TN and lead, while rainfall is the major source of zinc. The primary reason these two sources dominate the total loadings is that the two sources account for 84 percent of the total flow that reaches the Bay.

Septic tanks and point-source discharges contribute a relatively small percentage of total loadings. The values in the table show that the combined loadings of septic tanks and point sources are 16-18 percent of the total loadings for the nutrients, and one to three percent for the metals. Septic-tank loadings are limited by the relatively low failure rate of eight percent. In addition, as a result of the substantial travel time from septic tanks to the Bay and its tributaries, a relatively small fraction of septic-tank-effluent loading reaches the Bay. Point-source loadings are limited by the implementation of AWT standards at wastewater-treatment plants, along with a shift from surface-water discharge to reuse of wastewater for irrigation.

Wet-Season and Dry-Season Results

Separate analyses were conducted to determine how the total annual pollutant load was distributed between the wet season (June-September) and the dry season (October-May) of an average year. Results indicate that about 60 percent of the annual loading occurs during the wet season and 40 percent occurs during the dry season, for all four of the analyzed pollutants. Because surface runoff and rainfall are major load contributors, one would expect that the loading distribution would reflect the precipitation distribution between wet and dry season. The runoff distribution is also very similar, with 62 percent of the runoff

attributed to the wet season and 38 percent of the runoff attributed to the dry season.

The distribution of loadings among the various pollutant sources during the wet and dry seasons is also very similar to the average annual distribution. The largest changes occur for point-source loadings. Unlike the other sources of pollution, wastewater sources actually have a greater total flow volume during the eight-month dry season than during the four-month wet season. Consequently, the percentage of the total loading due to point sources is substantially higher during the dry season, and lower during the wet season. Even during the dry season, however, the point-source loadings for TP, TN and zinc are less than the loadings due to surface runoff or rainfall.

Wet-Year and Dry-Year Results

Analyses were also conducted to evaluate loadings during a dry year and a wet year. Based on a comparison with the average year's loadings, the loadings for all pollutants will be 28-31 percent higher during the wet year and 24-27 percent lower during the dry year. These values correspond closely to the differences in rainfall and runoff values among the wet year, dry year and average year. The wet-year and dry-year load distributions by source are also very similar to the average-year distribution. The largest change occurs for point-source discharges, because the total loading is assumed to be the same regardless of the annual precipitation volume. Thus, the percentage of loadings due to point sources are noticeably higher during the dry year and lower during the wet year. Even during the dry year, however, the point source loadings for TP, TN and zinc are less than the loadings due to surface runoff and rainfall.

Pollutant-Loading Projections for Future Land-Use Conditions

Pollutant-loading estimates were developed for the five-year and buildout future-land-use scenarios. In addition, as part of the Phase III study, a 20-year future-land-use scenario was developed to determine how much of the buildout development will occur in the next 20 years and how pollutant loading will be affected.

Five-Year Pollutant-Loading Projections

Future loadings over five years are expected to be similar to existing loadings. The five-year projections revealed a very small increase in total runoff volume, a small decrease in overall TP loadings and a small increase in TN and metals loadings. Phillippi Creek and Whitaker Bayou are still the major contributors of all four pollutants, and Bowlees Creek is a major contributor of metals loadings.

Increased nonpoint-source loadings from increased urbanization are offset by reduced point-source loadings resulting from changes in wastewater-treatment and disposal practices (i.e., a shift from surface-water discharge to reuse and deepwell injection). Baseflow loadings decrease slightly because new development results in less groundwater recharge and a corresponding reduction in baseflow quantity. Septic-tank and rainfall loadings are assumed to be the same as for existing conditions. Surface runoff is still the major source of TN, TP and lead, whereas rainfall is the major source of zinc.

Table 6. Average Annual Loadings by Source for Existing Land-Use Conditions.

	TP		TN		Lead		Zinc	
Source	(lb)	% of total	(lb)	% of total	(lb)	% of total	(lb)	% of total
Surface Runoff	110,870	45.1	588,210	46.3	30,180	90.3	23,260	25.4
Baseflow	33,800	13.8	112,690	8.9	300	0.9	5,620	6.1
Septic Tanks	8,230	3.3	123,520	9.7	0	0.0	0	0.0
Point Sources	31,140	12.7	109,330	8.6	490	1.5	2,520	2.8
Rainfall	61,730	25.1	337,460	26.5	2,470	7.4	60,080	65.7
TOTAL	245,770		1,271,210		33,440		91,480	

	TP		TN		Lead		Zinc	
Source	(lb)	% of total	(lb)	% of total	(lb)	% of total	(lb)	% of total
Surface Runoff	126,340	47.9	671,120	49.0	36,190	91.8	27,860	29.1
Baseflow	31,750	12.0	105,890	7.4	280	0.7	5,310	5.5
Septic Tanks	8,230	3.1	123,520	9.0	0	0.0	0	0.0
Point Sources	35,510	13.5	132,270	9.7	500	1.3	2,540	2.7
Rainfall	61,730	23.4	337,460	24.6	2,470	6.3	60,080	62.7
TOTAL	263,560		1,370,260		39,440		95,790	

Table 7. Average Annual Loadings by Source for 20-Year Future Scenario.

Twenty-Year Pollutant-Loading Projections

Within the 20-year planning horizon, Manatee County is expected to reach about 55 percent of buildout, and Sarasota County about 40 percent of buildout. Longboat Key will be at 68 percent of buildout, and Perico Island is expected to be less than 10 percent of the way to buildout. Anna Maria Island, Siesta Key and the other islands are expected to reach 100-percent buildout within 20 years. The City of Sarasota is already considered at buildout under existing conditions.

Table 7 shows the average annual loadings by source for the 20-year future scenario. Surface runoff increases, resulting in increased TP and TN loads of 14 percent over existing conditions. Lead and zinc loads both increase by 20 percent over existing conditions. Point-source loads of TP and TN also increase (14 percent and 21 percent, respectively) as flows increase with increased development. Overall, the major sources of nutrients and metals are surface runoff and rainfall.

Buildout Pollutant-Loading Projections

In the buildout scenario, loadings for all pollutants increase. The increase in loading for TP, TN and zinc ranges from 11-17 percent, whereas the increase for lead is 40 percent. *Table 8* shows the projected average annual loadings by watershed for the buildout scenario.

In some cases, watersheds that had minor impacts under existing land-use conditions have a substantially larger contribution in the buildout future scenario. For TP, Phillippi Creek and South Bradenton are still the largest watershed contributors, but the loading from South Creek has increased 46 percent, such that the total loading from South Creek is greater than the Whitaker Bayou loading. The Phillippi Creek, South Bradenton, South Creek and Whitaker Bayou watersheds are also the largest contributors of TN in the study area. Phillippi Creek, Whitaker Bayou and Bowlees Creek are still the major contributors of lead and zinc loadings. Like South Creek, Matheny Creek also exhibits substantial loading increases, such that the loading from Matheny Creek is comparable to the Whitaker Bayou loadings for all of the analyzed pollutants.

Table 9 shows the average annual loadings by source for the buildout scenario. As expected, the increase in surface runoff also generates increased surface-runoff loadings, with increases ranging from 32 percent for TP to 45 percent for zinc. The increase in surface runoff due to urban development also results in a decrease in baseflow quantity, so baseflow loading is less for the buildout scenario. Point-source loading is greater than existing conditions for the buildout scenario due to the increase in wastewater flows generated by the buildout population. Rainfall and septic-tank loadings are assumed to be the same for the existing and buildout scenarios, the latter because all future development was assumed to be sewered rather than served by septic tanks. While some new septic tanks will be permitted, particularly in low-density residential areas, the county's wastewater plan includes connection of existing septic tanks to centralized WWTPs. Overall, the major sources of nutrients and metals are surface runoff and rainfall.

Alternative Management Strategies

Strategies for protecting the water quality of Sarasota Bay focus primarily on point-source and nonpoint-source pollution control. Since nonpoint-source pollution is responsible for the largest percentage of existing loadings to Sarasota Bay and will contribute the greatest increase in future loadings, the most critical management strategy to protect water quality in the Bay is to control nonpoint pollution from new and existing development.

While the estimates of existing and future loadings indicated that point sources and septic tanks were not major contributors of pollutants to Sarasota Bay, it is important to ensure that appropriate treatment and disposal will continue to be provided to handle the future increased flows in a manner consistent with water-quality protection.

Point Source Controls

Overall, the current wastewater treatment and disposal practices in the study area are effective at limiting point-source pollution to Sarasota Bay. Most of the treated effluent is not discharged directly to surface waters; instead, effluent is typically reused for irrigation, discharged to drainfields or injected into deep wells. The effluent that is discharged directly to receiving waters is treated to AWT standards. Consequently, a continued policy of AWT, reuse and deepwell injection in the study area may provide sufficient water-quality protection for point-source pollution.

Potential problems could arise, however, if the numerous septic-tanks systems, small utilities and package plants within Sarasota County are not properly maintained. Sarasota County's wastewater-planning guidance document (Vision 20/20) calls for consolidation of the existing package plants and small utilities into a centralized wastewater-treatment system that will achieve AWT standards. In addition, the plan provides for connection of 80 percent of the existing septic tanks to the centralized sewer system. For future effluent disposal, the county is evaluating recharge outside the study area and reuse within the study area.

Analyses of the affect of implementing the county's plan indicate that TP loads for the buildout scenario will be reduced by eight percent and TN loads by 10 percent.

Nonpoint-Source Controls

The best management practices (BMPs) for controlling nonpoint-source pollution include both nonstructural and structural controls. Nonstructural controls limit the percentage of imperviousness of an area to limit the volume of runoff, and consequently

Table 8. Average Annual Loadings by Watershed for Buildout Future Land-Use Conditions.

Watershed	Area (acres)	Total Runoff (in)	TP (lb)	TN (lb)	Lead (lb)	Zinc (lb)
Phillippi Creek	36,417	29.80	81,990	446,470	13,320	13,880
South Creek	12,995	21.83	16,520	78,680	1,190	2,360
Bowlees Creek	6,489	36.31	11,990	70,740	8,070	4,850
Whitaker Bayou	5,015	38.36	16,550	78,640	3,810	3,410
S. Bradenton	4,635	44.44	19,950	98,860	1,960	2,270
W. Bradenton	4,395	30.99	8,010	40,220	1,800	1,650
Matheny Creek	3,800	44.41	15,560	74,830	3,290	3,010
Catfish Creek	3,360	30.17	6,670	33,960	1,260	1,310
Cedar Hamk.	1,930	32.35	4,090	20,830	1,280	970
North Creek	1,920	28.47	4,110	20,220	580	700
Longboat Key	1,697	26.89	3,450	16,370	570	580
Hudson Bayou	1,595	32.58	3,070	16,570	1,440	930
W. Bowlees	1,559	28.74	3,170	15,580	740	620
Siesta Key	1,385	49.76	9,610	33,830	610	1,150
Palma Sola 2	1,120	31.79	2,340	11,880	610	510
Anna Maria	919	29.95	1,890	9,400	500	390
Palma Sola	900	30.68	1,870	9,300	430	360
Other Islands	900	29.29	1,810	9,110	330	320
Perico Island	860	38.33	1,460	7,090	160	210
Direct to Bay	4,241	32.86	9,120	53,150	2,490	1,970
Bay Surface	33,280	54.60	61,730	337,460	2,470	60,080
TOTAL	129,412	37.43	284,960	1,483,190	46,910	101,530

	TP		TN		Lead		Zinc	
Source	(lb)	% of total	(lb)	% of total	(lb)	% of total	(lb)	% of total
Surface Runoff	146,050	51.3	776,460	52.4	43,610	93.0	33,680	33.2
Base-flow	29,200	10.2	97,460	6.6	260	0.6	4,890	4.8
Septic Tanks	8,270	2.9	124,060	8.4	0	0.0	0	0.0
Point Sources	39,710	13.9	147,750	10.0	570	1.2	2,880	2.8
Rainfall	61,730	21.7	337,460	22.8	2,470	5.3	60,080	59.2
TOTAL	284,960		1,483,190		46,910		101,530	

Table 9. Average Annual Loadings by Source for Buildout Future Land Use Conditions.

the runoff pollutant loads. Structural controls, on the other hand, are designed to capture the runoff and remove the pollutants.

The nonstructural controls considered in this study are:

- Density Restrictions. The density of residential development can be restricted to limit the amount of impervious area, and thus the runoff, in a watershed.
- Clustered Development. Development can be concentrated on a portion of a tract, leaving the remainder as permanent open space (pervious area).
- Restrictions for Industrial and Commercial Land Uses. Because industrial and commercial sites have a high degree of impervious area, they also have a high potential for transport of pollutants. Restricting impervious areas can be an effective means of reducing pollutant loads.

There are two basic types of structural BMPs: retention controls and detention controls.

Retention controls (e.g., basins, infiltration trenches, dry wells) capture stormwater runoff and divert it into the soil profile, where pollutant removal can occur by natural processes such as filtration, adsorption and oxidation by soil microorganisms.

Both wet and dry detention basins capture stormwater and detain it for a limited period before release to the watershed conveyance system. Removal of suspended pollutants is achieved by sedimentation. Wet detention basins have a permanent pool of water, promoting the additional removal of dissolved pollutants through physical, biological and chemical processes.

Since 1982, the Florida Dept. of Environmental Regulation has required that all new developments be served by stormwater-treatment facilities; within the study area, this requirement is best met by wet detention basins. Retention controls are not feasible for large-scale application in the Sarasota NEP study area, because the water table is high and the soils are not highly permeable. Wet detention basins are preferable to dry detention basins because of their higher pollutant-removal efficiencies and lower maintenance requirements. When properly designed and constructed, wet detention basins are also attractive community assets.

A wet detention basin with a permanent pool sized for a 14-day hydraulic residence time during the wet season can be expected to remove 50 percent of the TP, 30 percent of the TN, 80 percent of the lead and 50 percent of the zinc in stormwater runoff.

Evaluation of Alternative Management Strategies

Twenty-three alternative management strategies for controlling future pollutant loadings were developed and evaluated. A cumulative pollution-control strategy underlies development of the alternatives. A short list of 14 alternatives that comply with current policy and regulations includes a mix of structural and non-structural nonpoint-source controls, as well as wastewater-control alternatives.

Alternative A assumes that all future residential and commercial development would be in accordance with the current comprehensive plans and served by wet detention BMPs, which would be the baseline or minimum controls to meet FDER require-

ments of providing stormwater-treatment facilities for all future development. Nonstructural land-use restrictions were added to this basic nonpoint-source structural-control strategy to increase the pollution-reduction benefits. Combinations of density restrictions and limitations to the amount of impervious area (e.g., 60 percent) for commercial and industrial sites were combined with wastewater strategies to arrive at the 14 alternatives described as follows:

Alternative A, Comprehensive-Plan Buildout with Wet Detention, assumes that all future development will be served by wet detention BMPs, in conformance with FDER and SWFWMD requirements. Since stormwater-treatment facilities are required by law, this is the baseline alternative for future scenarios, and BMPs are assumed in all other alternatives.

Alternative B, Two-Acre Residential Density Restrictions, assumes that all future development would be restricted to a minimum lot size of two acres (10-percent impervious) and served by a wet detention BMP.

Alternative C, One-Acre Residential Density Restrictions, assumes that all future development would be restricted to a minimum lot size of one acre (20-percent impervious) and served by a wet detention BMP.

Alternative D, 30/70 Cluster Development, assumes that all future residential development would be clustered so that 30 percent of the tract would be medium-density single-family residential and 70 percent would remain permanent open space (equivalent to 10-percent impervious) and served by a wet detention BMP.

Alternative E, 50/50 Cluster Development, assumes that all future residential development would be clustered so that 50 percent of the tract would be high-density single-family residential and 50 percent would remain permanent open space (equivalent to 20-percent impervious) and served by a wet detention BMP.

Alternative F, Two-Acre Residential Density Restrictions, assumes that all future residential development would be restricted to a minimum lot size of two acres (10-percent impervious), future commercial and industrial development would be restricted to 60-percent imperviousness and all future development would be served by wet detention BMPs.

Alternative G, One-Acre Residential Density Restrictions, assumes that all future residential development would be restricted to a minimum lot size of one acre (20-percent impervious), future commercial and industrial development would be restricted to 60-percent imperviousness and all future development would be served by wet detention BMPs.

Alternative H, 30/70 Cluster Development, assumes that all future residential development would be clustered so that 30 percent of the tract would be medium-density single-family residential and 70 percent would remain permanent open space (equivalent to 10-percent impervious), future commercial and industrial development would be restricted to 60-percent imperviousness and all future development would be served by wet detention BMPs.

Alternative I, 50/50 Cluster Development, assumes that all future development would be clustered so that 50 percent of the tract would be high-density single-family residential and 50 percent would remain permanent open space (equivalent to 20-percent impervious), future commercial and industrial development would be restricted to 60-percent imperviousness and all future development would be served by wet detention BMPs.

Another five alternatives were developed by adding a point-source-control requirement, implementation of the Sarasota County wastewater plan, to alternative A (A+WW Plan, etc.) and alternatives F through I. According to the wastewater plan, central wastewater treatment would be provided to serve new development, package plants would be eliminated and the number of septic tanks reduced. The effluent would be reused for urban irrigation or recharged to the groundwater to preclude surface water discharge.

For each alternative management strategy, pollution loadings for the 20-year and buildout future-land-use scenarios were calculated and compared to existing loading levels to determine their relative pollution-reduction capabilities.

Table 10 presents the pollutant loads for these alternatives along with existing loads to facilitate comparison of the relative pollutant loads of each alternative. Existing loads include the benefit from existing BMPs, which currently serve about 13 percent of development. Rainfall loads have been excluded from all alternatives.

The range of alternatives for amelioration of pollutant loadings presented in *Table 10* can be characterized as controlled increases to reduction in existing loadings. Were it not for existing regulations requiring stormwater-treatment facilities for all new development, the passive "no action" approach would result in uncontrolled increases over existing loads ranging up to a

Alternative	TP (lb/yr)	TN (lb/yr)	Lead (lb/yr)	Zinc (lb/yr)
Existing Loads (1991)	184,040	933,750	30,970	31,400
Uncontrolled Buildout	223,230	1,145,730	44,440	41,450
A	196,540	1,064,620	33,670	36,220
B	191,460	1,017,140	38,410	36,840
C	196,180	1,050,270	38,810	37,470
D	189,950	1,006,040	37,640	35,710
E	192,990	1,034,790	38,500	36,950
F	189,320	1,005,120	33,140	35,030
G	194,040	1,038,250	33,540	35,660
H	187,810	994,020	32,370	33,900
I	190,850	1,022,770	33,310	35,140
A + WW Plan	175,700	914,860	33,450	35,080
F + WW Plan	168,480	855,360	32,920	33,890
G + WW Plan	173,200	888,490	33,320	34,520
H + WW Plan	166,970	844,260	32,150	32,760
I + WW Plan	170,000	873,010	33,090	34,000

Table 10. Average Annual Loadings for Buildout Future Land-Use Conditions with Management Alternatives (Rainfall Excluded).

43-percent increase for lead. Compared to buildout with no stormwater controls, significant reductions in pollutant loadings result from implementation of the existing regulations requiring stormwater-treatment facilities (Alternative A). By itself, however, Alternative A still results in a seven- to 14-percent increase in nutrients over existing loads.

By contrast, Alternative H+WW Plan (a combination of the required BMPs, restricted imperviousness on commercial/industrial areas, 30/70 cluster development and improved wastewater treatment) results in annual nutrient loadings nine percent *lower* than the existing loads.

Table 11 presents the conceptual cost estimates for these 14 alternatives. Annualized costs were developed assuming an interest rate of eight percent over a period of 30 years. The conceptual costs of the wastewater plan alone are also provided to show the portion of the costs attributed to the plan.

For the wastewater plan, only the costs for the portion of wastewater facilities within the NEP study area were included, as derived from Sarasota County's regional wastewater plan, in 1989 dollars. Annualized costs for the wastewater plan do not include operational and maintenance (O&M) costs, because the O&M costs of a new regional WWTP are expected to be roughly equivalent to those of the numerous existing franchises.

In addition to pollution reduction and cost, several other criteria were considered inevaluating the management alternatives:

- Feasibility. Technical, political and social issues could affect implementation. For example, residential density restrictions may also restrict the availability of low-income housing, may reduce the tax base and may be strongly opposed by developers and land owners.
- Environmental Benefits. In addition to pollution reduction, a management alternative may provide other environmental benefits, such as reduced stream-bank erosion and creation of wetlands habitat for wet detention basins, or groundwater recharge for reduction of impervious areas.
- Additional Benefits. Other benefits are also possible, such as the water-conservation benefits of water reuse or the recreational benefits of BMPs or permanent open lands.

Table 12 presents the ranking of management alternatives according to five criteria. Annualized cost, pollution benefit (based on TN and lead load reduction) and feasibility were considered the most important, and each was assigned a maximum value of 25 points. Other environmental benefits and additional benefits were given maximum values of 15 and 10 points, respectively. Thus, the maximum score for any alternative was 100. In case of a tie score, the alternative with the higher pollution benefit was ranked higher.

Alternative	Capital Cost	O&M Cost	Annualized Capital + O&M Cost
A	$394,620,000	$4,618,000	$39,660,000
B	$392,880,000	$4,618,000	$39,506,000
C	$392,880,000	$4,618,000	$39,506,000
D	$97,920,000	$1,224,000	$9,919,000
E	$197,760,000	$2,472,000	$20,033,000
F	$447,600,000	$5,150,000	$44,897,000
G	$447,600,000	$5,150,000	$44,897,000
H	$152,640,000	$1,756,000	$15,310,000
I	$252,480,000	$3,004,000	$25,424,000
A + WW Plan*	$640,331,000	$24,618,000	$61,479,000
F + WW Plan*	$693,311,000	$25,150,000	$66,716,000
G + WW Plan*	$693,311,000	$25,150,000	$66,716,000
H + WW Plan*	$398,351,000	$21,756,000	$37,129,000
I + WW Plan*	$498,191,000	$23,004,000	$47,243,000
WW Plan*	$245,711,000	$20,000,000	$21,819,000

Table 11. Conceptual Costs for Management Alternatives for Buildout Future Scenario.

Alternative	Annual-ized Cost	Pollution Benefit	Feasibility	Other Environment	Additional Benefits	Total	Rank
A	10	15	21	10	5	61	5
B	10	12	11	10	5	48	13
C	10	10	12	10	5	47	14
D	21	12	15	10	5	63	3
E	19	9	17	10	5	60	6
F	8	18	12	8	3	49	11
G	8	16	13	8	3	48	12
H	19	19	15	8	3	64	2
I	17	15	16	8	3	59	8
A+WW	2	21	21	10	5	59	7
F+WW	0	25	15	9	4	53	9
G+WW	0	22	15	9	4	50	10
H+WW	11	25	17	9	4	66	1
I+WW	9	21	18	9	4	61	4

Table 12. Evaluation Matrix for Alternative Management Strategies.

A method has not yet been established for evaluating the effectiveness of watershed load reductions on the achievement of Sarasota Bay National Estuary Program goals. Consequently, no "target" reductions have been established nor, therefore, any basis for recommending one loading-reduction alternative over another. This decision must, of necessity, be made based on cost as well as the need to reduce pollutants. The range of options presented indicates that a return to pre-1991 loadings may be technically possible, but perhaps not financially feasible.

Other Potential Management Strategies

In the event future investigations dictate that further loading reductions are necessary to achieve the goals established by the Sarasota NEP, additional measures can be considered. Retrofitting existing development with stormwater BMPs is possible. Currently, only about 13 percent of the urban development is served by stormwater BMPs. The majority of the existing development is concentrated along the eastern shore of Sarasota Bay, which presents added technical and financial considerations for retrofitting. Additional options include restoration of channelized areas, creation of stormwater wetlands and other alternatives.

Recreational Use

Recreational Access and Use Assessment

by John J. Whelan, P.A.

Executive Summary

This report analyzes the recreational use of Sarasota Bay as part of the Sarasota Bay National Estuary Program, which defines Sarasota Bay as extending from Anna Maria Island in Manatee County to Albee Road in Sarasota County.

Research sources included existing reports specific to recreation in Sarasota Bay, a shoreline survey, material collected from public workshops and meetings and numerous personal interviews with citizens and government officials involved with recreation.

The report includes a review of historical events affecting recreation on the Bay; a description of the present situation with regard to the natural-resource base; patterns of recreational use and current management programs; and a discussion of conflicts between recreational users and the natural resources, and among the users themselves. Projections of future use are discussed, and a number of recreation management options are presented.

In general, Sarasota Bay is a popular recreational resource, with more than two-thirds of the population of Manatee and Sarasota counties having used the Bay in the last year. Opportunities exist for further expanding access to the Bay, particularly with regard to visual access and the use of the shoreline.

Conflicts also exist, however. Certain boating practices endanger safety on the one hand, and the natural resource on the other. These conflicts could be greatly reduced by expanded boater education and other management techniques.

Introduction

The recreational use of Sarasota Bay has changed dramatically over the years. One hundred years ago the Bay was considered one of the best fishing spots in the world – someone rowing across the Bay might arrive with a dozen or so fish that had jumped into the boat. Today it takes exceptional skill to catch a dozen fish, and exceptional courage to consider rowing across the Bay. If recreational use grows at the same rate the populations of Manatee and Sarasota counties are projected to grow, 164,000 more people will be enjoying the Bay in 2010.

The Bay already supports a wide variety of recreational activities. Boating and fishing are very popular, but shoreline activities are the most popular. A survey conducted by the Florida Atlantic University Social Science Research Laboratory shows that 82 percent of the two counties' residents use Sarasota Bay to "just enjoy the view," with the next two favorite activities being walking along the shore (62.6 percent) and taking comfort from living near the Bay (60 percent). The Bay remains, even with population pressure, a resource that is greatly enjoyed.

Yet some people complain of a loss of quality in Bay recreation. Congestion at certain activity areas degrades the experience, and some people consider the Intracoastal Waterway to be a watery "highway." Conflict exists – conflict between users themselves, and conflict between users and the natural resource.

Reducing conflicts requires a number of management strategies. Because recreational conflicts most often are the result of how people act, education and law enforcement are most important. A license to use a motorcraft may be the simplest way to improve the implementation of both approaches.

People's behavior is not the whole problem, however. Dolphins, manatees, seagrass beds and other marine life compete with human users for habitat. It may become necessary to identify certain sections of the Bay as habitat preserves, closed to recreational watercraft.

It may also become necessary to reduce conflicts between types of recreation activities by keeping them separate. While government should approach the matter of restricting freedom of movement on the water with reserve – freedom of movement is one of the chief joys of recreational boating, after all – congestion leads to real danger and real loss of pleasure for many.

Finally, numerous environmentally benign shoreline activities are facilitated by public Bayfront property, such as streets that run along the shoreline or dead-end at the Bay. These openings provide windows to views and portals to shoreline enjoyment of the water. They can be increased to make the Bay more physically and visually accessible.

A Baywide recreation plan, therefore, should have two goals: to provide as much access to this shared resource as is compatible with preserving the resource, and to reduce conflicts.

Historical Perspective

Watching masts parade by on the water as one waits in a car for an open drawbridge to close, it is difficult to imagine a time without recreational use of Sarasota Bay. But early explorers, cartographers, naturalists, military agents and settlers in southwest Florida had little time for Bay recreation. What follows are some significant events that have directly or indirectly affected Bay recreation.

- 1870s: The notion of Sarasota Bay as a place for recreation originates. By that time the Webbs were advertising the Webb Resort Hotel at Osprey, and people were beginning to come to the local bays not just to make money, but to spend it. A variety of schooners, some built locally, were used in the bays. According to Karl Grismer's 1946 book, *The Story of Sarasota*, special vessels were built to accommodate the shallow depths of the local bays: the Blackburns' Sea Turtle, almost as wide as it was long, was said to draw less than two feet.
- 1882: "Sara Sota" is touted by Sarasota

John J. Whelan

Mr. Whelan is an architect and planner in Sarasota with 30 years experience in public recreation and environmental planning. His office has planned several major recreation projects in the Sarasota area, including the public use plan for the 24,000-acre Carlton Reserve. He has served on numerous public-interest boards, including three years as an appointed member of the Southwest Florida Water Management District's Manasota Basin Board. Mr. Whelan previously practiced in San Juan, Puerto Rico, for 15 years and served as a consultant to the Dept. of Natural Resources, Environmental Quality Board and the Planning Board.

booster Leonard Andrews as having a "beautiful bay, 15 miles long, averaging two miles wide, with immense amounts of fish, clams, and oysters." Much of the recreational potential of the area is based on the abundance of fish and shellfish. Because both fishermen and promoters are prone to exaggeration, early accounts of fishing by promoters are often discounted, but the following passage from Grismer certainly conveys the myth, if not the reality:

> In the waters of Sarasota Bay and Little Sarasota Bay were some of the finest oyster beds in America; oysters famed throughout the state for their exquisite flavor. The bays were also famous for their delicious clams, scallops and stone crabs. Enough shell food for a dozen meals could be gathered in less than half an hour. As for fish, well, tales by the children of pioneers are almost unbelievable. "You could hardly row across to one of the keys without ending up with a dozen fish or so in your boat," asserts Arthur B. Edwards. "The fish were so thick you'd hit them with your oars, and into the boat they'd flop!"
>
> Edwards tells of schools of fish so large they almost filled the Bay. He remembers one school that entered the Bay in the morning, kept moving northward all day long, and was still in sight when darkness fell. No wonder Sarasota Bay was considered one of the best fishing spots in the entire world – a real angler's paradise if there ever was one!
>
> In the old days, most pioneers liked mullet more than other fish. But if they preferred pompano, or trout, or redfish, or any one of 100 other species, all they had to do was go out in a boat for an hour or so, cast a net or fish a while and come back loaded down.

Recreational swimming and boating are not featured during the early years. Shoals and bars cut across most bays, and recreational swimming was not particularly fashionable anywhere in the United States prior to 1850.

- 1884: Commercial fishing has been a mainstay in Sarasota Bay for more than a century. But, according to Grismer, the advent of Tampa railroads and ice plants in the mid-1880s suddenly puts Sarasota Bay at a commercial disadvantage. The salted fish that local fishermen shipped are not as desirable as fish kept on ice.
- 1895: The dredge Suwanee cuts a channel across at Palma Sola Pass, in Upper Sarasota Bay, and another channel at Longbar southeast of Longboat Inlet in Sarasota Bay. Now boats can travel inland waters from Tampa to Sarasota; iced fish can now be shipped. In addition, this event reflects the growing technological/economic feasibility of dredging, and the perception that it may be better to modify the bays to accommodate boats than to design boats (such as the Sea Turtle) to accommodate the shallow bays.
- 1895: October 7, steamer Mistletoe begins service. By 1899 Mistletoe will make three trips a week between Sarasota and Tampa "stopping at Palm Beach (present location uncertain), Indian Beach, Cortez, and Anna Maria." The five-hour trip will connect with rail in Tampa and a horse-and-carriage hack in Sarasota.
- 1899: A photograph taken at the shore of Sarasota Bay shows the launch Gertrude and a sign announcing that she was available for trips to the Gulf Beach, "terms reasonable." Aside from the interesting fact that one could reach the beaches by launch, this marks the de facto shift of recreation toward the Gulf beaches.
- 1899: Ralph and Ellen Caples travel four hours from Bradenton to Sarasota, and fall in love with the view of the Bay. They appear to have passed over the beautiful views of the Manatee River that drew people like Edison and Firestone to the comparable Caloosahatchee River at Ft. Myers. Caples later encourages the Ringlings to buy land here.
- 1903: In September, the dredge Suwanee completes a three-foot-minimum channel from Little Sarasota Bay to Venice. Freight boats and launches take advantage of the waterway; now north-south recreational boating is also possible.
- 1907: The first yacht club is built in Sarasota, signaling the potential for wealthy, large-boat-owning residents to settle here.
- 1910: January 23, Mrs. Potter Palmer reads an ad in the *Chicago Tribune* and decides to investigate Sarasota. [Grismer p. 155] The arrival of the Palmers and Ringlings, with their Bayfront rather than Gulfront estates, establishes Sarasota and its bays as a distinguished destination for winter recreation for the wealthy.
- 1910: July 22, Sarasota's City Commission draws a line in the sand by mandating seawalls for the City waterfront.
- 1911: April 4, Sarasota votes for a water plant and sewage system. This act reflects both concern and ignorance. The concern is obvious; the ignorance lay in the fact that the main-trunk sewer outfall was laid 400 feet out into the Bay.
- 1911-13: Bayous Hanson, Nettie and Louise on Siesta Key are dredged. This is the beginning of dredging not strictly for commerce or navigation, but as an adjunct to real-estate development. Thus, in a single decade (1902-11) navigational and real-

estate dredging, sewage outfalls and seawalling all make their appearance. The legacy of these four activities continues to influence Bay recreation 80 years later.

• 1915: Harry Higel advertises "good bathing in the surf of the Gulf of Mexico, the waters of Sarasota Bay, canals and bayous in Siesta." Apparently Gulf and Bay swimming were considered roughly comparable at this time.

• 1917: Spring, the first bridge to Siesta Key opens. This bridge is soon followed by the six other mainland-to-barrier-island bridges. Ultimately only Longboat Key will lack a direct connection to the mainland, and only two passes (Big Sarasota and Midnight) will remain unbridged. With the building of bridges, a recreational shift to the beaches begins in earnest. Also in 1917, Phillippi Creek is dredged to six feet deep.

• 1918: March, despite protests, "hundreds"of pelicans are shot by Sarasotans who believe they are protecting fish needed for human consumption. This conflict pits utilitarian interests against protectionists, and presages future conflicts for which Florida was to become famous.

• 1921: July 1, what was one Bay system lying in a single county becomes administratively divided as Sarasota County is officially formed by dividing Manatee County. Then on October 22-23, Sarasota's working Bayfront of boathouses, a wholesale fishhouse, a railroad dock, fishing boats, launches and nets is destroyed in a hurricane. The city banishes commercial activities to Payne Terminal, making the downtown bayfront "purely recreational." Also destroyed by the same storm is the Cortez waterfront, which comes back stronger than ever as a commercial fishing center. These two 1921 events seem to reflect the differing interests of the two communities. Manatee's major city, Bradenton, pursues its river orientation far from the beaches, leaving the Bayfront to commercial fishing; riverless Sarasota emphasizes a recreational Bayfront, spurns commercial fishing and commits to providing quick access to beaches via bridges close at hand.

• 1926: February 27, Ringling Causeway opens, connecting downtown Sarasota with St. Armands and Lido keys.

• 1927: March 18, the 100-foot-long ship, City of Everglades (drawing six feet), arrives at Payne Terminal and delivers three tons of freight. The act by itself has virtually no recreational significance, but the spoil dredged from the channel to accommodate her forms City Island (a major recreational destination today that includes a restaurant, bait shop, marina, boat ramp, wildlife-rehabilitation facility, marine-science center, NEP office, BayWalk and outboard, sailing and water skiing organizational headquarters). The lack of subsequent waterborne freight using the "million-dollar deepwater harbor" helps solidify Sarasota Bay as a playground, not a work site.

• 1935: Sarasota visitors' guides are clearly pushing beaches, not Bay recreation. Despite the central role the bays have played in attracting tourists and residents up to this time, they are not even listed among the seven most significant attractions; the bays are described mainly in regard to fishing. This shift in emphasis from the bays to the beaches is significant, and continues to this day.

• 1939: WPA guide to Florida mentions Sarasota Bay: "The silver-scaled tarpon migrates from South American shores to the lower east and west coasts of Florida; its most promising grounds are the swift-running passes leading into Tampa and Sarasota Bays, Boca Grande, the Caloosahatchee River, the Ten Thousand Islands, and the waters off Miami, Fort Lauderdale, and Palm Beach."

• 1959: Arvida announces it will develop Bird Key. Aside from the direct recreational impact of covering a productive shoal and changing Bay circulation, this act sets the stage for the subsequent formation of a citizen's group, Save Our Bays, that will challenge proposals to dredge and fill Longboat Key and will evolve into an environmental organization.

• 1960s: The dredging of the Intracoastal Waterway that occurs at this time is highly significant to recreation. First, it makes the Bays usable for boats that draw more than a few feet of water. Second, it sets the stage for continuing battles over bridge openings. Third, it creates a wide variety of spoil islands, peninsulas and shoals, many of which are used recreationally. And fourth, it changes Bay circulation and water quality, contributing to the closure of Midnight Pass.

• 1970: City of Sarasota sites Van Wezel auditorium on the Bayfront, demonstrating continued willingness to use the Bayfront for non-water-dependent uses. This action is followed by locating the county library on the Bayfront.

• 1973: South Lido is acquired, part of the trend of major Bayfront acquisitions to save relatively natural lands from development. The trend continues at least until 1992 (Sister Keys). It takes 16 years to completely provision and dedicate South Lido Park; comparable long development times are reflected in Sarasota's Centennial Park.

• 1977: Seventh-annual Hobie Cat midwinter east Regatta is held in Sarasota Bay. The Hobie Cat may best symbolize the postwar explosion in modestly-priced, shallow-draft recreational craft. Hobie Cats are followed by reasonably priced sailboards (late 1970s), jet skis (1980s) and sea kayaks and rowing shells (late 1980s).

• Early 1980s: The shoaling, rapid migration to the north, closure of and inability to reopen Midnight Pass become the basis of a community-wide debate that has not ended to this day. Recreational effects commonly attributed to the closure include longer boating distance to the Gulf for some boaters, changes or decline in fishing and shrimping, wider beaches on North Casey Key and pedestrian access to North Casey Key from Siesta Key.

• 1985: First Offshore Grand Prix Race is held, bringing high-speed powerboats to the area. This multi-day racing extravaganza has come to dominate Sarasota's Fourth of July Weekend festivities. While most events take place in the Gulf, kilometer speed runs have earned Sarasota Bay a reputation as a boater's "Bonneville Salt Flats," where speed records are routinely broken.

• 1987: First official artificial reefs, popular sites for anglers, are placed in Sarasota Bay. Scientists debate whether these reefs add new fish to the system or merely attract and concentrate existing fish.

• Early 1990s: The Florida Dept. of Natural Resources and Sarasota cooperate to adopt extensive speed reductions in an effort to reduce manatee mortality. Water skiers, potentially the most affected, organize and successfully ward off speed restrictions in the most desirable skiing areas. Also, the City of Sarasota undertakes a major effort to improve downtown stormwater management and begin improving access from downtown to the waterfront. In addition, water-taxi service is initiated (after roughly a century's absence), allowing residents and tourists alike to visit the Sarasota Quay, Marina Jack, Selby Gardens and City Island without an automobile.

Natural Resource Base

Weather

One of the reasons for the Bay's popularity for recreation is the climate of the region. During certain periods of the year the climate is virtually ideal; during other periods, heat and humidity make it unpleasant. Both periods are appropriate times for Bay recreation: when the weather is nice, it is lovely to be on the Bay; when the weather is hot, it is a relief to be on the Bay.

While local temperature and humidity patterns strongly influence recreation on the Bay, wind has the greatest effect on the character of many recreational pursuits. Over a period of time, particularly if it comes from the west, wind can make Bay waters choppy: more fun for jet skiers, less fun for scullers. Calm wind on a hot day is no fun for a sailor, but of little consequence to a boater in a run-about. The popularity of jet skis and fast motorboats on the Bay indeed may be attributable to a summer weather pattern that encourages their use.

Diurnal changes are also significant. Calm mornings, hot mid-days and stormy afternoons affect when people go out on the Bay. Scullers and paddlers like cool, calm mornings; sailors enjoy the challenge of building wind speeds in the early afternoon. Everyone wants to be done before the onset of late-afternoon thunderstorms.

Sarasota Bay's weather is most influenced by its location on the west-central coast of Florida, with the warm Gulf of Mexico to the west and a flat land mass to the east. In the winter the more severe weather systems approach from the west and are associated with incursions of cooler air from the north, sometimes preceded by thunder clouds and rain. These systems bring sharp temperature drops and often a day or two of brisk, cold winds before the warm Gulf water exerts its moderating influence. In late winter and early spring these balmy periods are more numerous, with rainfall usually infrequent.

Later in the spring and during the summer and early fall, moist equatorial air is drawn into Florida's general circulation and the air becomes more unstable. Afternoon and evening thunderstorms and tropical storms from the south often develop.

The thunderstorm outbreaks result from the collision of local westerly sea breezes off the Gulf of Mexico with the off-land easterly airflow. With daytime heating of the interior land and the convergence of these two air systems, a line of thunderstorms, sometimes severe, is produced over the land. As the sun-driven sea breeze weakens in the afternoon and evening, this activity is pushed back over the Bay. For an hour or so, strong wind squalls reaching 50 mph or more, very choppy and dangerous seas, and drops in visibility to a few yards occur on Sarasota Bay.

Sarasota Bay, as defined for the Sarasota Bay Program, has a long narrow shape oriented northwest-by-southwest with a three-mile-wide expansion in the northern section. According to a meteorologist working with the Sarasota County Emer-

gency Management office, because of the greater water-vapor availability, this wider area attracts more rain and thunderstorms and is subject to higher winds. Although the Bay is somewhat protected by barrier islands, weather moving from west to east can quickly – and dangerously – change Bay conditions.

The influence of the weather on personal comfort determines how and when the Bay is used. Winter and early spring have the greatest number of occasions when lower temperatures, lower humidity and lower wind movement combine to make recreation on the Bay particularly pleasant. Sea fog and chilly days can also occur during this time; sea fog usually burns off during the morning, then often spreads back inshore later in the day and overnight.

As summer approaches, with more sunlight and greater humidity, the morning, late afternoon and early evening are usually more comfortable. Afternoon sea breezes can cause a welcome temperature drop; summer-evening thunderstorms can also lower temperature. Summer nights, however, can be oppressive, due to the increase in humidity and the lack of wind, especially after a storm.

Table 1 shows temperature averages. Wind speed is too variable to be usefully charted. In general, however, the following can be said of wind:

1. Easterly airflow predominates.
2. Westerly winds veering to northwest or north behind cold fronts are frequent in winter and early spring.
3. Westerly breezes falling to calm before becoming light easterly are common on spring, summer and fall afternoons.
4. Wind speeds are usually light in the early hours, but increase to 20-25 mph in the days with the strongest sea breeze.
5. Strong winds are usually confined to frontal systems moving down from the north in the winter and to tropical storms in the late summer and fall.

Temperature. (30 year average in degrees F.)

Month	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Max.	70	71	76	82	87	89	90	90	89	83	77	71	81
Min.	54	55	60	65	70	75	76	76	75	69	61	55	66

Table 1.

Water Depth

Sarasota Bay is for the most part less than six feet deep. However, the dredged passes to the Gulf and the Intracoastal Waterway provide deeper water. The ICW is kept dredged to a minimum depth of nine feet. Keeping the Gulf passes open is a more difficult task – a storm can quickly shoal an entrance – but the passes usually provide at least five feet of water.

The large widening of Sarasota Bay in its northern part provides water deeper than six feet over an area of about 14 square miles. This basin, thought of by many as defining Sarasota Bay, is one of the region's premier sailing basins. Its protected nature behind Longboat Key and its easy access from shore make it a popular site for national and international small-boat racing. It is well suited to dinghy classes, and is often used for sailing regattas for centerboard boats up to 25 feet in length.

Views

The most subtle contribution of Sarasota Bay to recreation is also perhaps the most pervasive: the view of the water. For most people, a view of the water – whether from a penthouse or at the end of a street – is a welcome relief from the urban environment. The Bay is seen from many vantage points on land, from causeways and bridges or from the shoreline. These views characterize the Sarasota Bay coastal community, and are the reason many people live here. To the degree that local communities can preserve and expand these opportunities, the public will benefit and the character of the region will be enhanced.

Existing visual access to Sarasota Bay can be grouped according to type: open, broad views of the water from bridges, bridge approaches, causeways, waterside parks and the like – views that are experienced by the most people and deserve the greatest vigilance to conserve.

Many streets dead-end at the water, offering attractive view points. These small bits of public land provide opportunities for small neighborhood amenities: a shade tree, a bench, a parking place.

A number of streets that run adjacent to the Bay isolate a strip of land that often is or could be developed for public use. In some cases, where such land was part of a development project and was left in some form of common ownership or management, it has been well-used as a handsome addition to the project; docks, slips, pavilions, benches,

walkways and parking have been included. Other areas are devoid of improvement.

Some sections of the shoreline have healthy mangrove stands that obscure eye-level views of the Bay. While it is imperative to preserve the health of these systems, opportunities may exist to build boardwalks through the mangroves to a small deck with benches for fishing and bird-watching.

Many restaurants on the water, some with marina facilities, provide wonderful views of the Bay. Furthermore, tall buildings in downtown Sarasota with private-club dining rooms provide extraordinary panoramas of the Bay.

Many vantage points are privately owned and are not directly a matter of government concern, but many are government property. Those public vantage points would benefit from a policy directed to enhancing public visual access and direct pedestrian connection with the water. What is called for is a sensitivity to these opportunities, a reluctance to approve changes that might diminish these views and a willingness to make small investments that would make these vantage points more accessible and more comfortable.

Patterns of Recreational Use

Sarasota Bay recreation has changed over the years. When we compare the recreational world of Sarasota Bay 100 years ago with today's situation, a number of long-term changes are clear:

1. It is now far easier to reach the Gulf beaches and waters to use them recreationally, which has probably displaced most Bay sunbathing and swimming.
2. The physical reality of the Bay has remained relatively constant as its water clarity and biological richness have changed. Despite some recent improvements in water quality, many living-resource-based recreational activities have declined, while physical-resource-based activities have increased. We no longer fish for tarpon on the Bird Key flats, swim in the mouth of Hudson Bayou or scallop. We do jet ski, wind surf and power around the Bay.
3. We have come full circle regarding the draft of vessels, from the early days of shallow-draft vessels and poling, through the "golden age" of dredging and deeper draft vessels, to a new explosion of shallow-draft recreational craft such as sail boards, jet skis, kayaks and rowing shells, all of which are invading areas previously less utilized.

What we know about local recreation comes from seven major recreational-use investigations: unfortunately, two of these have yet to be completed. The five completed works are: Berkeley Miller's 1987 study of registered boaters in Sarasota County; Jack Whelan's recreational workshop held in 1991; Brad Weigle's Manatee County Boater Observation study (1990); the NEP FAU Public Survey; and Randy Edward's 1991 Creel Survey. We are awaiting results of Berkeley Miller's current (1992) Bay recreation survey of the NEP area and Gus Antonini's major study of boaters (1992).

Current Use

There are many ways to enjoy the Bay and several ways to group these diverse types of recreation. It is useful to consider each type of watercraft:

1. "No-craft" enjoyment. The most common way to enjoy the Bay does not involve watercraft. Ten percent more people have waded along the Bay (62.6 percent) in the past year than have used the Bay for boating (52.9 percent). Driving, parking, bicycling and walking are all common means of viewing the bays; in addition, three out of five people surveyed (60 percent) in the FAU survey felt comforted by the fact that they live near Sarasota Bay.
2. Human-powered craft–kayaking, sculling, canoeing and rowing. Generally, these type of craft can be carried on the tops of cars, and need easy access for launching and different launch sites to accommodate various wind directions and conditions. Scullers need more than three feet of water and no powerboats.
3. Wind-powered watercraft–sailboarding, non-motorized watercraft. Sailboarders and small sailboats need easy access for launch ing and different launch sites to accommodate various wind directions and conditions. Sailboats need varying conditions depending on draft. Sailing activities vary, including racing, cruising, gunkholing, mooring and instruction.
4. Motorized-watercraft users. Fishing, cruising, waterskiing and tubing are major uses. Motorize- watercraft users need minimum two- to five-foot boat depths calm to moderate wind, docking facilities and well-marked channels; ramps, lifts or railways are also required. Jet skis need knee-deep water for take-offs, but once planing, only inches; both rough and smooth water are desirable. Either boat ramps or car-accessible sloping shorelines are necessary for launching.

Boating Activities

Bay-oriented recreational activities are summarized in *Figure 1.* The Manatee and Sarasota boater surveys dealt only with registered boaters, and focused on boat-oriented use; the 1990 FAU survey included other citizens as well. Because questions were not identical across the three surveys, it is difficult to compare the data directly. One inescapable conclusion is that cruising, fishing and wildlife observation appear to be boaters' most common activities.

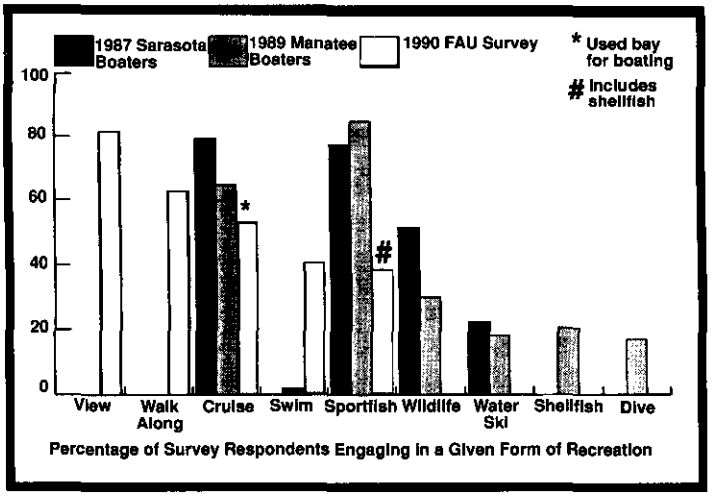


Figure 1.

Special Characteristics

Vistas (Visual Access)

Many people tend to assume boating is the most common recreational use of the Bay, yet the most common, most popular and possibly most overlooked recreational use of the Bay is simply looking at it from shore. The recent FAU survey found that four out of five (81.5 percent) of residents enjoyed viewing Sarasota Bay, compared to a little more than half (52.9 percent) who had been boating on the Bay in the past year.

These figures are supported by results of the admittedly non-random gathering of participants of the SARABASIS conference. While only two-thirds of conference participants had engaged in recreational boating on the Bay, 93 percent had engaged in viewing the Bay for aesthetic appreciation, photography or art. One does not need to be a boat owner to enjoy the Bay recreationally. It is easy to lose sight of the fact that most people's primary recreational experience of the Bay may be seeing it from a car window.

Bay-Edge Activities

Recreation on the Bay is oriented to the shoreline in many ways. Shore and wading anglers, walkers, photographers, picnickers, litter-pickers, nature observers and contemplative types all use Bay edges as destinations. For others, the edge of the Bay is a transition, not a destination. Someone launching a Hobie Cat, powerboat or jet ski uses the shoreline as a transition before the real fun can start. The needs of edge-destination and edge-transition users are distinct – sometimes compatible, sometimes conflicting. Experience suggests that most of the publicly owned Bay edge is well-used, particularly when adjacent uplands are accessible. It is interesting to note that close to half those surveyed (45 percent) in the FAU survey would prefer to see the Bay's shore as parks and recreational space. The figure jumps to close to two-thirds (64.7 percent) if those who would prefer to see "nothing" done with Bayshore are included.

The Palma Sola Causeway, for example, is an excellent place to observe a wide variety of shoreline activities. This long unofficial launching site supports sunbathing, food grilling, picnicking, volleyball, horseshoes, dog walking and swimming as well as sailboat and jet-ski launching. Despite the confusion of uses, observation and interviews with law-enforcement personnel suggest the mix works fairly well.

The number of places from which the public can approach the Bay are quite limited. If vistas can be thought of as windows to the Bay, these access points are "portals," doorways to the water. People can use them to launch boats or just stand at the edge. The important thing is that a significant amount of public enjoyment of the Bay results from the availability of many portals (not only boat ramps, but also street ends, neighborhood parks and other public Bayfront parcels), and the portals being kept open. Survey data suggest that the public is divided on the need for additional boat ramps. *Figure 2* summarizes survey data.

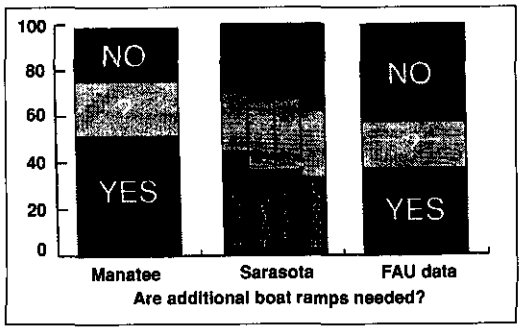


Figure 2.

Shallow-Water Activities

Shallow-draft watercraft are able to explore vast areas of the Bay, since they are not limited to channels or paths. Almost two-thirds (63.4 percent) of registered Sarasota boat owners surveyed in 1987

owned boats that drew less than two feet. If unregistered craft, canoes, sea kayaks, dinghies, sailboards and rowing shells are added, perhaps three-quarters of all craft on the water are shallow-draft. The average boater, therefore, experiences the flexibility of being able to go virtually anywhere.

The unregistered craft are wind- or muscle-powered. Wind-powered craft tend to seek open water with some fetch; muscle-powered craft tend to be closer to shore, both to avoid the wind and to enjoy the scenery.

From the Bay, the boater is surrounded by a shoreline that is generally accessible from the water. Four out of five boaters surveyed in Sarasota County could not think of an area of the Bay shoreline that they would like to be able to reach by boat but could not (Miller, 1987). With the exception of marked channels, few fixed constraints hamper motion. If the boater wishes to leave the Bay and clamber up on the shoreline, he or she must search for one of the few portals that connect the Bay with the land.

Indeed, all shallow-draft boaters who do not keep their boats in the water – and the vast majority do not – can be thought of as dependent on a portal containing a ramp and parking. The capacity of the Bay to accommodate this sort of recreation, therefore, is the combined capacity of those portals.

Boaters do a variety of things. Most boaters have taken fish from the Bay (70 percent), about half have taken crustaceans such as shrimp (48.4 percent) and crabs (42.35 percent) and one quarter have taken mollusks such as clams (27.7 percent) and oysters (23.9 percent). Half of all boaters visit islands, presumably spoil islands.

Channel or Deep-Water Activities

Deeper-draft vessels are restricted to naturally deep water and dredged channels and basins. Their map of the accessible Bay looks more like a road map or system of paths (most of these uses would also be appropriate in the Gulf).

Because of their displacement, many deep-draft vessels have the potential of creating serious wake problems for other Bay users at both high and low speeds. In addition, big boats are almost by definition responsible for most bridge openings. Deeper-draft vessels have been accommodated by the dredging of the ICW and other channels, and a wide variety of types and recreational activities are based on deeper-draft vessels, including sightseeing, fishing and cruising.

Temporal Characteristics

One might assume dramatic variations in seasonal recreation use, yet surveys conducted to date do not confirm this assumption. *Figure 3* depicts seasonality of use of registered boaters in Sarasota. The Manatee County boating survey concluded that 87.6 percent of registered boaters in Manatee County use their boats all year. One-third (34.8 percent) said they used their boats equally on weekends and weekdays, with twice as many using boats more on weekends (43.8 percent) than on weekdays (22.9 percent). Little pattern is evident in daily use, except that morning use is far more common than evening use. The Whelan workshop confirmed that virtually all groups claim to use the Bay in all seasons, although jet skiers did express a preference for spring and summer. The picture that emerges reflects our moderate climate – a generally constant level of use, sometimes deflated by poor conditions or inflated by holidays and special events, many of which are identified in *Table 2.*

Table 2.

Organizations host the following special events:

- Personal Watercraft annual Demo Day
- Sarasota Sailing Squadron's June Sailfest
- Sarasota Sailing Squadron's September Labor Day Regatta
- Windsurfers Suncoast Sailfest in conjunction with the Suncoast Offshore Grand Prix
- Sarasota Power Squadron cruises for reports to NOS on chart variations
- Anna Maria Power Squadron annual July picnic on Egmont Key
- Audubon Society's Christmas bird count in December
- Coastweek in the fall
- Coastal Clean-ups in the fall
- Spanish Point days
- Special Olympics fishing tournament
- Longboat fishing tournament

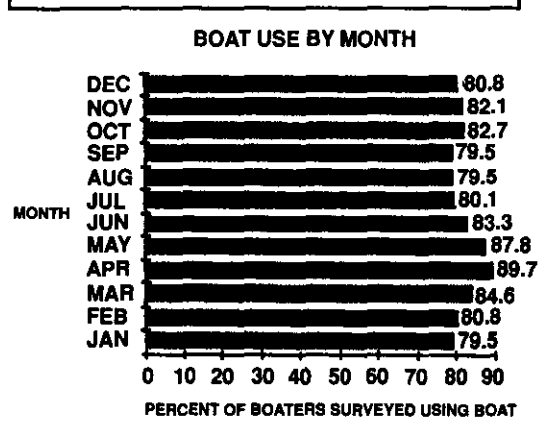


Figure 3.

Current Management Programs

Law Enforcement

The management of recreation on Sarasota Bay is chiefly the duty of law-enforcement departments. Florida Marine Patrol (FMP), Manatee County Sheriff's Dept. (MCSD), Sarasota County Sheriff's Dept. (SCSD), Sarasota Police Dept. (SPD), Longboat Key Police Dept. (LBKPD), Holmes Beach Police Dept. (HBPD), U.S. Coast Guard (USCG) and U.S. Coast Guard Auxiliary (USCGAux) all enforce laws and regulations regarding boating in coastal waters of the study area.

Each organization takes primary responsibility for the regulations adopted by its respective governments. In most instances, officers share information and responsibility for the various regulatory programs. For example, the Sarasota Police Dept. will assist the Florida Marine Patrol with rescues up to nine miles offshore, though the SPD jurisdiction ends at three miles.

FMP has the largest scope of responsibility – enforcing state resource laws and regulations as well as boating safety rules. Florida resource law covers recreational and commercial fishing, damage to mangroves, marine mammals and turtles. FMP has a database that catalogues its arrests and warnings by county. Longboat Key and Sarasota County also keep databases on boat-related citations.

USCG conducts search-and-rescue missions and law enforcement in the offshore Gulf of Mexico; it does not normally deal with enforcement in Sarasota Bay. *Table 3* outlines the law-enforcement forces assigned to Sarasota Bay.

All agencies are out full force on weekends and holidays. Holmes Beach and Longboat Key police patrol waters on weekends. Only the FMP has officers on duty daily around the clock, one between midnight and 8 a.m. in each county and two in each county during day and evening shifts.

The number of officers on the water does not change seasonally. MCSD reports that its busiest time is the fall and winter, when commercial fishing is most active and when the number of tourists on the water is highest.

All agencies predict a need for increasing numbers of officers to match increasing numbers of boaters, but none expects enough budget to hire additional officers until the end of 1993. Holmes Beach is just beginning a water patrol, training auxiliary patrol personnel for weekend shifts.

SPD, SCSD and MCSD all see their role as promoters of boating safety. They use warnings to teach boaters to be responsible, making arrests when safety violations seriously endanger people. MSDP gives out a boating-safety pamphlet with each warning. A SCSD officer makes a point of being visible, checking no-wake zones and stopping at all the marinas. Following a warning, few boaters repeat the offense, although tracking repeat offenders is not easy. Officers' patrol work is in part responding to complaints and calls, in part self-initiated.

Agency	# Officers	#'s Change Seasonally	Future Trends
SPD	2	no	no change
SCSD	2 & 2 auxiliary	no	no change
MCSD	2	no	no change
FMP	11	no	no change
HBPD	2 auxiliary	weekends only	no chamge
LBKPD	2	mostly weekends	no change

Table 3.

Holmes Beach Police will patrol Bimini Bay and interior waters, where many residents complain of speed and wake violations.

FMP describes its work as 80 percent officer-initiated and targeted on resource activities, primarily fishing. Aiming for a great deal of contact with fishermen, FMP will pull up alongside a fishing boat and ask to see license, registration, safety equipment and any fish caught.

In interviews, officers emphasized several problems as most common:

1. Careless operation – primarily the failure of the boat operator to protect the safety of his or her passengers. Common examples are allowing children to dangle their legs over the side and hitting wakes in a way that injures passengers or throws them out of the boat.
2. Night boating is especially dangerous.
3. Incompetency – novice boaters, often boat renters or tourists, get into trouble and crash into docks. Overloading boats, anchoring in the channel, getting lost and tying onto channel markers are common problems of novice boaters.
4. Personal watercraft – riders are reckless, putting themselves in danger. Excessive wakes, noise and conflicts with other users were also mentioned.
5. Speeding in no-wake zones – such zones are established primarily to protect boats at marinas with fuel pumps and to prevent accidents in narrow, congested

areas. Wakes throw refueling boats against the dock, and can severely damage them.
6. Ignoring restricted speed areas – Sarasota and Manatee counties require boaters to use idle speed within 300 feet of swimmers, waders, anchored or docked boats and boat-launching areas. Many boaters are ignorant of these unmarked restricted areas; many also disregard established, marked no-wake zones.
7. Operating under the influence – alcohol is the major cause of impairment. FMP records show only four arrests during 1990-92 from the two counties; other local law-enforcement agencies either do not record boat-alcohol arrests separately from auto DUI's or have no records of arrests. Arresting for impair ment is time-consuming and difficult for officers in boats. The suspect and his or her boat must be towed to a dock, then a field sobriety test must be conducted, the suspect transferred to a sheriff's vehicle and taken for further testing and observa tion. This whole process can take three to four hours of the marine officer's time.

Increases in the number of warnings for careless operation, failure to wear personal flotation devices (PFDs) while operating personal watercraft, towing skiers without a mirror or observer, improper lighting and violations of restricted areas over the three-year period support the perception of many that courtesy and safety on the water are declining.

Officers generally ask to see a boat registration when they first contact a boater, which leads to a high number of arrests and warnings. Problems with PFDs and lighting reflect boater ambivalence toward basic safety. Violations of restricted areas are largely wake and speed problems in areas that have been designated for no wakes or slow speeds. Citations for fishing without a license remained high two years after the saltwater license was implemented. Warnings and arrests for undersized fish increased four-fold between 1989 and 1990, and remained high during 1991, the result of a change of emphasis within the FMP. (Prior to 1990, FMP focused on boating safety and drug interdiction. Beginning in 1990, FPM directed its officers to focus on resource protection, including state and federal fisheries laws.)

A total of 33 boating accidents were reported by Sarasota County Sheriff's Dept. and Sarasota Police Dept. in 1991. (Manatee County records of boating accidents for the same period are unavailable.) No Sarasota boating fatalities occurred that year, although 104 people died statewide while boating. Since 1987, nine deaths in Sarasota County have been related to watercraft. (Ken Tuttle, personal communication, April 1992).

1991 Boating Accident Statistics	
Agency	# accidents
Sarasota County SD	26
Sarasota PD	7
Total	33
*records not available from Manatee County	

Table 4.

Rescue-Assist Confusion

During 1991, the four flotillas of the Coast Guard Auxiliary that cover the study area performed 93 assists, saving $1.5 million worth of property.

In the late 1980s, commercial towing businesses began operating in Sarasota and Manatee waters. Tow operators are licensed captains who assist disabled boaters for a fee. They monitor radios and respond to calls for help, as well as spotting disabled boats.

USCG Auxiliary boats are barred from towing any boat that has already requested help from a commercial towing company. Law-enforcement officers assist disabled boats only in emergency situations or if the boat operator is clearly unable to pay the commercial towing fee. USCG Auxiliary boats assist only if the disabled boat captain refuses a commercial tow, and their dispatcher gives them permission to tow. Frequently commercial towers get on the radio and question the Auxiliary boats' authority to tow. The Auxiliaries are helping distressed boaters as a public service, while the commercial towers see the Auxiliary as reducing their livelihood. The debate over which is a better service for boaters will unfold during the next several years.

USCG Auxiliary Flotilla 84 Commander George Sipich states that the advent of commercial towing locally has taught boaters that running out of gas can be an expensive mistake; as a result, boaters are taking steps to prevent breakdowns and are more likely to offer each other help.

Restricted-Speed Area

Long-standing restricted-boat-speed areas in the Sarasota County portion of the study area are: the New Pass-South Longboat Key area, the Grand Canal, the mouth of Phillippi Creek, Stickney Point Bridge,

Summary Table of Arrests and Warnings 1989-91 Florida Marine Patrol Records for Sarasota and Manatee Counties							
	1989		1990		1991		Three Year
Violation	Arrests	Warnings	Arrests	Warnings	Arrests	Warnings	Totals
Harvesting shellfish from restricted, prohibited, unclassified areas	0	6	2	9	2	3	22
Manatee County no-wake zone	0	0	14	47	6	8	75
Fish from State Road bridge	24	30	1	31	0	30	116
Registration not on board, improper reg.	136	457	115	580	28	580	1896
Careless operation of vessel	29	54	21	54	26	77	261
Violation of established restricted area	21	41	51	103	16	94	326
Failure to wear PFD operating personal watercraft	0	0	7	0	5	7	19
Towing skiier without mirror or observer	8	3	16	13	21	28	89
Insuffcient PFDs on board, other PFD problems	119	201	114	272	100	291	1097
Lighting required/SFD'S inland rules	25	215	21	349	18	353	981
Recreational fishing violations:							0
Saltwater fishing license required	0	0	120	343	123	239	825
Size limits	24	34	127	166	151	125	627
Bag limits	3	2	25	2	20	4	56
Season		0		1	10	2	13
Totals	389		634	1970	526	1841	

Table 5.

Heron Lagoon, Elligraw Bayou, Blackburn Point Bridge and Albee Road Bridge.

In December 1991, the Governor and Cabinet adopted a new rule establishing restricted speed zones in the study area to protect endangered manatees. The rule designates slow-speed zones, idle-speed zones, no-entry zones (only Pansy Bayou), maximum-35-mph zones and maximum-25-mph zones. Exemptions from speed restrictions are available for commercial fishermen and fishing guides.

Two water-sports areas have been designated for water skiers, one with a 35-mph limit around Skiers Island in Roberts Bay, and another without speed restrictions south of City Island in the Ski-a-Rees practice area. The Cabinet stated in the rule that they would reconsider speed restrictions in the Ski-a-Ree area at the end of 1992 if no local ordinance restricting speed had been adopted.

Speeds are unrestricted in the deep waters of Sarasota Bay, Big Pass, the western half of New Pass and in Little Sarasota Bay from Blackburn Point Bridge almost to Spanish Point. Generally, slow speeds are required between City Island and the Ringling Causeway, in Hudson Bayou, in Buttonwood Harbor, from Phillippi Creek to the Stickney Point Bridge and in South Creek. With the exception of these areas, Bay waters south of Stickney Point bridge are restricted to slow speed outside marked channels and to 25 mph in marked channels.

Speed signs have not yet been posted, and the FMP is in the process of developing plans for enforcement. Many boaters are critical of the rule, stating that "slow speed" is not defined, and neither boaters nor law enforcement will be able to judge when 25 m.p.h. has been exceeded.

On the other hand, slow speeds in highly congested areas will not only provide manatee protection, but will improve boating safety. The rule is a big step in the direction of restricting high-speed boating to certain portions of the Bay area.

Conflicts

User vs. User

Boating in Manatee and Sarasota Bay waters is generally a pleasure. People smile and wave, and usually operate their boats in a safe, courteous fashion. However, weekend recreational boaters in the study area also experience congestion, discourtesy, friction and competition with other boaters. While this is not the universal experience, it is a matter of increasing concern.

Boating traffic was the second most important problem cited by respondents to an SBNEP opinion survey (Florida Atlantic University, 1990). Two-thirds of those surveyed were very or fairly concerned about the number of boats on local waters.

The examples below are actual experiences related by representatives of various recreational groups at a workshop in the summer

of 1991:

Close Calls – Immediate Danger to Humans

•Jet skiers in narrow mangrove tunnels.

•Pontoon boats at night on Palma Sola Bay almost ran over two fishermen in the water (with no lights).

• Passenger bow-riding falls in the water, and the operator then turns away from him, not toward him, bringing the propeller closer to the fallen passenger.

• At night on the ICW, a boat approaches without lights.

• Almost rear-ended under bridge after slowing down for a no-wake zone.

• With two boats traveling together, a jet skier jumped the wake of the first boat, then fell in front of second boat, risking being run over by the second.

Use Competition/Friction

• Crossing the Intracoastal Waterway in a canoe on a Sunday afternoon.

• Crossing the Intracoastal on a weekend afternoon on a jet ski.

• Sailors, rowers, prams, sailing dinghies put themselves in harm's way along and in the ICW.

• Wakes from big cruisers in ICW disrupt all other users.

• Noise of boat engines so loud one can't hear his own TV on Bayou Louise.

• Boaters tell scullers, "You have no business being here."

Deliberate Provocation/Discourtesy

• Jet skier buzzes or circles a sailboat at anchor or fishing boat.

• Carefree Learner floating classroom sprayed by skier.

Congestion

• "Like Interstate 75 on Roberts Bay" – sensory overload.

• "Indianapolis Speedway" – small boats with large ones.

• Bumper-to-bumper on weekends – extreme congestion.

The same workshop group gave detailed, written responses to a questionnaire. One question asked them to identify other types of Bay recreation that conflicted with their use. Their answers indicated the following recreational conflicts:

1. Personal-watercraft users conflict with fishermen and swimmers.
2. Large wakes damage boats in the boat basin at the Sailing Squadron and in other anchorages.
3. Fast powerboats and personal water craft conflict with windsurfers.
4. Large wakes and powerboats conflict with scullers.
5. Yachts (being unable to maneuver quickly enough to avoid collisions) conflict with personal watercraft and fast boats.
6. Average and small boats conflict with water skiers (especially in the ICW), personal watercraft and reckless boat operators.
7. Weekend recreational boaters conflict with recreational anglers.
8. Environmental, educational and conservation groups reported experiencing conflicts with powerboats, personal watercraft, water skiers, discourteous boaters and discarded monofilament fishing line.

Personal watercraft, large wakes, fast boats and water skiers are frequently cited as conflicting with other uses. Personal watercraft conflict with kayaks and canoes, yachts, swimmers, anglers and windsurfers.

Large wakes conflict with sailboats and scullers. Fast boats conflict with canoes, windsurfers and yachts. Water skiers conflict with small boats, canoes and kayaks.

Recreational users were also asked to identify other uses of the Bay with which their own use was compatible:

1. Jet-ski users are compatible with water-skiing, sledding, touring, freestyling tricks, racing.
2. Among non-motorized-watercraft users, windsurfers and kayakers are compatible with everything but fast boats and jet skis. Scullers were compatible with all non-motorized uses.
3. Motorboat users reported compatibility with all other uses.
4. Environmental, educational and conservation organizations feel they are compatible with all non-motorized uses.

Two circles of compatible users were reported. One circle encompasses the fast boats: water-skiers, personal watercraft, sledding and racing boats. A second circle includes all non-motorized boats: scullers, sailors, windsurfers, kayaks, canoes and nature observers. Interestingly, the motorboat groups felt they were compatible with all other types of users, reflecting both a positive self-image and a lack of awareness of their incompatibility with non-motorized boats.

User and the Nature Resource

Marine Mammals:

Bottlenose dolphins

Approximately 100 bottlenose dolphins reside year-round in Sarasota Bay. During the spring and summer, mothers and calves can be found in the shallow waters of Palma

Sola Bay and Anna Maria Sound. This is where pinfish, pigfish and striped mullet – dolphin prey – are found in large numbers during these seasons. Additionally, adult bull sharks swim in the offshore Gulf in the summer, and newborn dolphins are safer in shallow coastal waters. In the fall and winter, mothers and calves are more frequently found in the passes, where mullet form large schools in the passes for spawning at that time. In general, dolphin density is much greater north of a line connecting Buttonwood Harbor to Long Bar Point than it is to the south (Wells, 1988).

Apparently, mother dolphins seek calm, protected waters with seagrass bottoms for calving and the early care of newborns.

A roughly inverse relationship may exist between dolphins' use of an area and the degree of human impact in that area. As a general rule, large mammals learn to reduce their interactions with humans if the contact is harassing or disruptive. A preliminary analysis of the local dolphin population showed a statistically significant drop in numbers of dolphins sighted in marked channels on summer weekends and holidays, when boating traffic is the heaviest compared to weekdays. At the same time, weekend sightings of dolphins over shallow areas were significantly higher compared to weekdays (Wells, 1988).

Dolphins may avoid heavy boat traffic to escape noise pollution and to reduce the chances of collision for themselves and their young. Three percent of the Sarasota dolphin population shows injuries from propellers; additional dolphins bear scars that could be either from shark attacks or boat propellers. The youngest and oldest dolphins are most vulnerable to boat collisions. (In recent years, a calf was hit by a boat during the Suncoast Offshore Grand Prix.)

For several years a sightseeing boat in Little Sarasota Bay routinely fed a bottlenose dolphin, to the delight of paying passengers. The illegal practice has now ceased. This dolphin developed the dangerous, unnatural behavior of swimming directly into the path of fast boats to get them to slow down and offer it food. Reports still are heard of one or two bottlenose dolphins near Blackburn Point that approach boats and seek contact with people.

Recently several reports have been made of jet skis chasing and harassing dolphins in shallow water. This is illegal, and could become a serious encroachment into the critical shallow water refuges of dolphins during the May-July calving season and on summer weekends.

Infrequently, dolphins accidentally swallow plastic bags, and one or two local dolphins each year show signs of entanglement with monofilament line, primarily gill nets. During the five years prior to 1992, two or three local dolphins died either directly or indirectly after entanglement with monofilament (Jay Gorzelany, personal communication, July 1992).

The major conflict areas for dolphins are the shallow, seagrass-covered bottom of Palma Sola Bay and Anna Maria Sound in the spring and summer, as well as Leffis Key to Longboat Pass.

West Indian Manatee

The highly endangered manatee is typically found around the fringes of the Bay from April-December. Their numbers are lowest during January-February, when they leave Sarasota Bay to find warm-water refuges elsewhere at power plants and springs. Their distribution in Sarasota Bay corresponds to areas of good seagrass coverage (Wells, 1988). Manatees in local waters depend on seagrass meadows for forage.

Boats are the primary cause of death for manatees in local waters. Over the five-year period 1987-91, 19 manatees died in local waters; six deaths have occurred in Roberts Bay and Phillippi Creek alone. Nine of the 19 carcasses showed clear evidence of mutilation from boat propellers or from collisions with boats. An additional seven deaths were perinatal – researchers suspect many of these deaths were caused when mother and calf were separated while fleeing boats (Jessica Katel, unpublished data, 1992).

Sarasota County recently received state approval for special speed zones intended to protect manatees in local waters. Over the

Table 6.

	Local Manatee Deaths 1987-1991													Cause of Death					
Month/Year	County	Location												Boat Prop	Perinatal	Boat Barge	Boat Impact	Undetermined	Natural
		SB	BC	PC	LBK	BB	RB	SC	GC	PRB	AMI	GS	NP						
07-87	Sarasota						1									1			
08-87	Sarasota												1				1		
06-88	Sarasota					1								1					
07-88	Sarasota											1						1	
10-88	Manatee										1				1				
10-88	Manatee									1									1
11-88	Sarasota	1												1					
03-89	Sarasota			1														1	
09-89	Sarasota						1										1		
05-90	Sarasota								1						1				
06-90	Sarasota							1							1				
07-90	Sarasota			1													1		
09-90	Sarasota						1							1					
11-90	Sarasota				1										1				
11-90	Manatee										1			1					
11-90	Manatee				1										1				
05-91	Sarasota			1													1		
07-91	Manatee		1												1				
07-91	Sarasota	1													1				
Column Totals		2	1	3	2	1	3	1	1	1	2	1	1	4	7	1	4	2	1
		SB	BC	PC	LBK	BB	RB	SC	GC	PRB	AMI	GS	NP	Prop	Perinatal	Barge	Impact	Undetermined	Natural

SB= Sarasota Bay BB= Blackburn Bay PRB= Perico Bayou
BC= Bowlees Creek RB= Roberts Bay AMI= Anna Maria Island
PC= Phillipi Creek SC= South Creek GS= Gulf Siest
LBK= Longboat Key GC=Grand Canal NP= New Pass

9.00 Clearly boat caused
7.00 Perinatal
2.00 Undetermined
1.00 Natural
19.00 Total over five years
3.80 Average per year

new speed zones will be tested, and their success in reducing local manatee deaths will be measured.

Dead manatees have been recovered from Sarasota Bay, Bowless Creek, Phillippi Creek, Longboat Key, Blackburn Bay, Roberts Bay, South Creek, Grand Canal, Perico Bayou, Anna Maria Island, New Pass and Siesta Key.

Birds

Table 7 summarizes the Pelican Man's Bird Sanctuary's annual rehabilitation report to the U.S. Fish and Wildlife Service for 1991. The table includes only bird species likely to use Sarasota Bay waters, and does not include the annual numbers from two other local wildlife rehabilitators. Therefore these numbers are conservative for the Bay area. Pelican Man is the largest of the local rescue efforts. In 1991 alone, 1,743 pelicans were injured. The report indicates that an impressive 1,537 were rehabilitated and released. Injured sea gulls numbers were also very high – 1,563.

The annual report does not record the cause of injury, but interviews with two local rehabilitators, Pelican Man's Bird Sanctuary, Inc., and Wildlife Rescue, Inc., indicate that most injuries to birds in the Bay area can be attributed to recreation.

Birds using Sarasota Bay are injured and killed by collisions with boats, entanglement with discarded monofilament and litter, coating with oil and gas discharged from motors and intentional harassment. Their natural behavior is altered by feeding and purposeful as well as naive disturbance of rookeries and roosts.

Wildlife rescuers often assist pelicans with smashed wings and crushed breasts, most likely the result of collisions with fast-moving boats. Both intentional and accidental collisions can be reduced by boat-speed restrictions.

Table 7.

1991 Summary of Selected Bird Species Treated at Pelican Man Sancutuary, Inc.

	Permanent					
Species	Died	Pending	Cripple	Euthanized	Released	Total
Pelican	71	14	11	110	1537	1743
Cormorant	49	4	7	31	143	234
Seagulls (all species)	377	18	23	465	680	1563
Herons (all species)	101	6	6	59	138	310
Egrets (all species)	21	2	5	27	44	99
Terns (all species)	47	6	4	16	48	121
Loons	9			9	30	48
Mergansers	10			4	7	21
Shorebirds (all species)	13			9	27	49
Ospreys	5		2		2	9
Bald Eagles	1					1
	704	50	58	730	2656	4198

Many birds are badly hurt by entanglement with hooks, monofilament and plastic rings used to hold beverage cans together; these rings get caught on the beaks of ducks and cormorants and on the feet of wading birds. Trash often blows out of boats or is left by shoreline users; stormwater conveys trash to the Bay as well.

Regular cleaning of shorelines can reduce litter-causing injuries. Wildlife Rescue, Inc. reports a predictable absence of injuries to birds from litter for four months following each clean-up.

Hooks and monofilament cut birds' skin and lead to infections. An unfortunate cycle of anglers feeding pelicans at fishing piers leads to pelicans trying to eat the bait off hooks. When these pelicans eventually get next several years the enforceability of these hooked, the angler often cuts the line rather than reeling the bird in and removing the monofilament, and the pelican suffers illness or death. If anglers were barred from feeding pelicans at fishing piers, and pier anglers pressured fellow anglers to reel in and remove hooks from pelicans, this cycle could be broken. Tourist anglers may be more inclined to cut their line than residents, so a special education effort to reach this audience could be important.

Often power lines that parallel bridges are festooned with hooks and monofilament from unskilled anglers' casts. Pelicans, cormorants and wading birds become entangled and die gruesomely. Frequent cleaning of these powerlines by the power companies would prevent many of these deaths.

Birds also suffer from boat wakes and special events. Large boat wakes disturb birds nesting on rookery islands along the Intracoastal Waterway south of the Siesta Drive bridge. Personal watercraft using the South Lido Beach Park canals disturb green herons and little blue herons. Each year during the Fourth of July fireworks, young dependent birds are frightened out of their nests at the rookery adjacent to City Island and perish (Belinda Perry, personal communication, June 1992).

Seagrass

Seagrass acreage in the study area has declined dramatically during the past 40 years; reduced water transparency from dredging, wastewater and stormwater account for this historic decline. Recently seagrass acreage has been increasing in the study area, with the exception of Little Sarasota Bay. With reduced wastewater discharges, the area south of Whitaker Bayou is just beginning to show some increase in

seagrass.

Recreational use also contributes to seagrass loss. Aerial photos show white scars crisscrossing every grassbed in the study area; these scars are created by boat propellers churning up bottom sediments and cutting rhizomes. Studies indicate that the scars are slow to heal, taking two to 10 years to recover.

Fragmentation of grassbeds by propeller scars may lead to reduced diversity and degradation of the beds' habitat and nursery roles. Scarring obviously reduces the acreage of seagrass; scientists express concern that heavily scarred beds are vulnerable to total disintegration in catastrophic events such as hurricanes. Depending on speed and depth, motorboats passing over grass can create harmful turbidity, even without the propeller contacting the bottom.

The Sarasota Bay Program supported a demonstration project to test whether education and marker buoys would reduce scarring by recreational boats. Results of the study are mixed, indicating that buoys lead to more boats entering the grassbed, while reducing overall scarring by 20 percent. Detailed results appear in the Early Action Demonstration Project chapter.

Boaters that scar seagrass beds appear to be both naive and experienced. The naive boaters find themselves over grass accidentally and are ignorant of the importance of grass to Bay fisheries, tending to power their way out to reach deeper water quickly. The experienced boaters see the grassbed as a destination, usually for fishing, and believe they can motor in and motor out without significant damage to grassbeds. Management options range from more education and buoys to various degrees of boater exclusion, with the most extreme position being prohibiting all motor traffic from entering certain grassbeds.

A related problem is intentional propeller-dredging of channels from docks to deeper water. A property owner with a shallow-water dock and a deep-draft boat may use his large boat propeller to create a channel between his dock and deep water. This activity is illegal.

All grassbeds in the Bay show some scarring. Scars are abundant in Anna Maria Sound, Palma Sola Bay, Sister Keys flats, City Island grassbed, Siesta Cut flats and Roberts Bay.

Mangroves

Mangroves and their associated fauna are degraded by boat wakes along constricted channels. Wakes erode the sediment, and batter prop roots and pneumataphores. This is clearly a problem at Longboat Harborside Moorings, and along the Intracoastal Waterway at the mouth of Phillippi Creek. Ironically, mangrove shorelines along narrow channels are safer for boaters than hardened shorelines.

When boat traffic is heavy, constricted areas with seawalled shorelines become dangerously turbulent, as boat wakes reflect off the hard, vertical walls.

Projection of Future Use

The number of people who may want to use Sarasota Bay for recreation will grow with a growing population. The Bay essentially serves Manatee and Sarasota counties; the combined population growth rate of these two counties for the period 1990-95 is projected to be about 12 percent (from 488,000 to 547,000). From 1990 to 2010, the area resident population will grow by 41 percent (from 488,000 to 688,000 people.) If the tourist population grows the same rate, and if the proportion of the population who use the Bay for recreation remains constant, then a projection can be made that the total recreational use of the Bay also will grow by the same 41 percent in 20 years.

The growth of population is not the only factor in the growth of recreation demand, however – changing tastes in recreation strongly influence how the Bay is used. Technology influences recreation, as the rapid growth in jet-ski enthusiasts shows. Taxes on pleasure craft also influence their use. Diminishing fish populations may discourage anglers. The cost of fuel and boat maintenance may have an effect. Such matters are highly conjectural, and cannot provide a dependable foundation for quantifying future demand for recreational use of the Bay.

The question of future demand, moreover, is influenced as much by what is to be done with the projection as it is by the accuracy of the prediction. If, as discussed elsewhere in this report, recreation will be limited by the need to avoid further degradation of the resource, investment in improved access will depend on what can be allowed (in both economic and environmental terms) rather than a presumption of demand based on population projections and preference studies.

It is useful, nevertheless, to review changes observed over the last 10 years in various kinds of recreation demand. While available information is essentially anecdotal, it serves to illustrate the ever-shifting, unpredictable character of water-based recreation.

The Sarasota Sailing Squadron is an open-membership club operating since 1940 on the public land at City Island. It provides a number of small-boat programs that attract sailors from the entire region. In 1980 its membership was about 350; in 1990 it was about 600, a growth of 71 percent in 10 years.

The Sarasota Scullers Assn. was organized in 1988; as of mid-1992 it had 35 members and was growing rapidly. Local Sarasota High Schools have rowing teams, and the sport appears to have been strongly established.

Sailboarding in Sarasota Bay has also grown. According to a major sailboard shop serving the Bay, the sport grew by 200 percent between 1980-87. Since 1987 a 33-percent decrease has occurred, with indications in 1992 of a modest comeback. Economic conditions and conflict with jet skis are thought to have caused the decline.

Perhaps the most dramatic change has been in jet ski use. One seller says that eight years ago he sold 30, but this year sold 100, a 333-percent increase.

Large powerboat use does not appear to be growing at all, and builders of large craft have recently reported a reduction in orders. John Holmes, who owns a major boat-repair facility at Blackburn Point Road, reports that his work has been virtually unchanged over the last 10 years. His view is that newcomers do not buy large boats.

In summary, the general demand for all kinds of access to Sarasota Bay may grow by approximately 41 percent in the period 1990-2010. Whether that converts to 41 percent more facilities of any particular type depends on unpredictable changes in recreational patterns and on the level of stress that will be allowed on the resource.

Management Options

The use of Sarasota Bay will grow. As population increases, the number of people who want to enjoy the Bay certainly will grow. However, the capacity of the Bay to accommodate recreational use is not elastic; it cannot be stretched to provide for an ever-increasing population.

This, of course, is the problem that every resource-based recreational attraction has: the very qualities that attract users can be lost with greater use. It is tempting to theorize that the tipping point can be predicted, and that a carrying capacity for a natural system can be estimated and recreational use kept within that limit.

Unfortunately, with a large natural system that attracts many types of recreation the work of establishing a systemwide carrying capacity becomes unmanageably complex. Each type of use has its own set of effects, and each aspect of the natural system its own vulnerabilities to those impacts.

Rather than predict how many people might acceptably occupy Sarasota Bay, we need to make certain assertions that can simplify matters.

The first assertion is that while Sarasota Bay continues to offer high levels of recreational opportunity to the region it serves, certain conflicts do exist between users and the natural resource and among the users themselves. Until those conflicts are under control, nothing should be done to increase those conflicts. The principle at work is that preservation of the recreational resource must take precedence over use of the resource.

The second assertion is that the Bay is a recreational "common," public property open to everyone. The last resort in damage control should be reduction of access. Environmental damage is not just a matter of numbers of people; it is also in large measure a matter of what people do. The principle then should be that improvement of behavior takes precedence over any strategy to cut back present levels of access to Sarasota Bay.

The third assertion is that the Bay is a gratuitous asset to the communities it borders, one they indivisibly share with their neighbors. The Bay should not be forced to play a role in meeting a local government's obligations to its voters. Stewardship of the entire Bay takes precedence over individual community planning.

Recreational Management Options: Education

Much of the conflict experienced by users of the Bay results from ignorance, incompetence and rudeness. Education can help reduce this problem, and is generally considered to be the most promising strategy to avoid conflict. Education programs already in place need to be expanded and augmented. The most important objective is that all users be required to have a minimum level of understanding of boat operation and environmental protection. Five separate educational programs are called for:

Boater-targeted
Youth-targeted
Tourist/Visitor-targeted
Angler-oriented
Further research

Option 1a
To require operators of boats with specified horsepower engines to have a license, given on the basis of a test or the completion of a course of instruction.

Option 1b
To expand voluntary education programs and to require offenders of regulations controlling recreation to take appropriate courses.

Option 1c
To expand voluntary education programs, especially in user groups, and increase publicity about their availability.

Option 1d
To enlist information media in public-recreation education.

Option 1e
To enlist public and private schools in education programs.

Capital Improvements

Investment in facilities, projects and services should be targeted to solving existing problems, not just providing more access. There are two types of investments: those that are one-time inputs and those that are on-going. Five areas of investment are called for:

Recreational facilities
Reduction of pollution/impacts
Services
New techniques/technologies
Avoidance

Option 2a (one time for each)
Invest in a variety of recreational facilities aimed at reducing conflicts. Moorages, ramps, shoreline view points and better navigational markings would be included.

Option 2b (one time for each)
Invest in pollution/impact reduction by providing stormwater-runoff control at shoreline recreational sites, clear marking of grassbeds, relocated ramps and attention-attracting signage.

Option 2c (one time for each)
Invest in improved management by upgrading neighborhood access and increasing access points and land-based services for visiting boaters.

Option 2d (on-going)
Invest in improved services through routine trash pick-up and shoreline clean-up programs, more trash containers at access points and routine removal of fishing line and hooks from powerlines.

Option 2e (on-going)
Invest in a continuing search for improved recreational opportunities, particularly those that would reduce "hot-spot" congestion.

Management

Expanded planning and implementation are needed to allow government to keep up with an ever-changing pattern of recreational use on the Bay. Because of the growing pressure on a vulnerable natural system that is at the center of the economy and cultural identity of the neighboring communities, governments must be especially vigilant and responsive.

Option 3a
To institute a system of Bay zoning that would close certain grassbeds to boat traffic, provide special areas for jet skis, add no-wake zones and/or set aside special nursery areas.

Option 3b
To provide for the better integration of management activities through the establishment of a Sarasota Bay Authority with review authority for shoreline planning and construction.

Option 3c
To require the integration of local government comprehensive planning affecting Bay recreation issues to ensure that the needs of the Bay take precedence over individual planning.

Option 3d
Exploit opportunities to make improvements through simple administrative changes such as changing acceptable channel depths (rather than dredging), streamlining on-water arrest procedures and having government employees lead by example in the use of safe boating practices such as the use of personal flotation devices.

Environmental Improvement/Protection

An investment made to improve damage to the environment usually is more attractive to voters if that same investment leads to enhanced recreation. For this reason and others, the environment and recreation should be thought of together.

Option 4a
To acquire more public parks in Bay drainage basins, providing more means to hold and treat run-off while adding to recreation.

Option 4b
To acquire remaining natural shoreline as public recreation areas, providing more control of shoreline degradation while adding to recreation.

Laws and Regulations

Freedom is an important aspect of recreation. Life is full of imperatives that stifle us; recreation is our release. For this reason, resource-based recreation planning should make every effort to allow the greatest latitude for freedom of action consistent with maintaining the quality of the experience and preserving the resource. Unfortunately, in a complicated world complete freedom is not feasible. Laws and regulations are needed to avoid danger to humans, damage to the environment and loss of commonly shared values. To the degree, however, that the objectives of laws and regulations can be met by other means, they should be. If education can reduce the need for policing, it should. If reorienting management practices can avoid prohibitions, they should be reoriented. In the end, however, if the natural system is to be improved, new laws and regulations and more policing must be considered.

Option 5a

To extend speed/wake restrictions to areas near fueling docks, congested areas and high wildlife-use areas.

Option 5b

To limit high boat speeds to certain areas within the Bay, and to reduce allowable speeds at night.

Option 5c

To require rear-view mirrors on power craft.

Option 5d

To require licensing of boat operators in conjunction with education programs and the development of a data base on flagrant offenders.

Option 5e

To prohibit feeding of wildlife, particularly pelicans and dolphins.

Option 5f

To require the use of nylon line and wire hooks in the place of monofilament and steel hooks.

Option 5g

To increase penalties for serious infractions such as fish size-limit violations and "prop dredging."

Option 5h

To increase enforcement regulations concerning boat-speed regulations, poaching and improper boat handling.

Table 8.

	1. WATER TRANSPARENCY	2. STORMWATER RUN-OFF	3. SEAGRASS AND SHORELINE HABITAT	4. DREDGING: CONFLICTS: ENHANCE BAY	5. MANAGE ACCESS	6. INTEGRATED MANAGEMENT	7. LIVING RESOURCES
1. EDUCATION							
Option 1a.	•		•	•	•	•	•
1b.	•		•	•			•
1c.	•		•	•			•
1d.	•		•	•			•
1e.	•		•	•			•
2. CAPITAL IMPROVEMENT							
Option 2a.	•	•	•	•	•		•
2b.		•	•		•	•	•
2c.		•	•		•	•	
2d.			•				•
2e.					•		
3. ADMINISTRATION							
Option 3a.			•			•	•
3b.						•	
3c.						•	
3d.						•	
4. ENVIRONMENTAL IMPROVEMENT							
Option 4a.	•	•			•		
4b.		•	•		•		
5. LAWS AND REGULATIONS							
Option 5a.	•				•		
5b.			•	•	•		•
5c.					•		
5d.			•	•	•		•
5e.							•
5f.							•
5g.				•			•
5h.			•	•	•		•

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Technical Synthesis of Sarasota Bay

Technical Synthesis of Sarasota Bay

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Executive Summary

Much has been learned from the technical work conducted on Sarasota Bay (from Anna Maria Sound to Venice Inlet) during the past few years. The extent and severity of the problems within Sarasota Bay are more substantial than originally believed, particularly in regard to the levels of toxic contaminants found in tributaries and the degree of habitat loss. In addition, recent evidence suggests that the extent of eutrophic conditions is most probably underestimated throughout the Bay.

The nomination document supporting entrance to the National Estuary Program stated that the majority of problems in Sarasota Bay were related to overuse of its rather limited resources. At that time, it was believed that habitat loss and overuse were the most pressing issues. However, data collected through the Program indicate larger-scale problems than originally perceived.

Metals contamination, as well as contamination from pesticides and PCBs, is believed to be a significant issue in Hudson Bayou, Cedar Hammock Creek, Bowlees Creek, Whitaker Bayou and Phillippi Creek. In addition, the potential exists for contamination in the unsampled upstream portions of other tributaries.

While such areas comprise a relatively small proportion of the total area of Sarasota Bay, they make up a large proportion of the extremely important low-salinity nursery habitat for Sarasota Bay's fisheries. Data also indicate that vitally important tidal wetlands, some of them located in contaminated tributaries, have declined by approximately 39 percent during the past 40 years, with equally dramatic declines occurring in freshwater wetlands.

Oysters from tributaries with sediment contamination showed elevated levels of copper and zinc compared to other sites in Florida, and were greatly elevated in lead when compared to both state and national data sets. This information indicates that metals contamination, the product of stormwater

runoff and illicit point-source discharges, is an important issue in Sarasota Bay. Stormwater pollution is also the major source of nutrient loadings, accounting for approximately 47 percent of the nitrogen and phosphorus entering the Bay.

Data collected for the Program suggest that nutrient pollution is an important issue, since Sarasota Bay currently receives approximately three times as much nitrogen as would be loaded from a pristine, undeveloped watershed (M. Heyl, personal communication). It is also apparent that Bay circulation and flushing patterns, as well as sediment resuspension and transport, play an important role in determining the magnitude of water-quality degradation associated with nutrient over-enrichment.

In some areas of Sarasota Bay, anecdotal information and preliminary studies indicate that the animal communities found in seagrass meadows have reduced species diversity, perhaps due to recurrent hypoxia associated with algal blooms. Algal blooms, which are not uncommon in parts of the Bay with reduced circulation, appear to be related to nutrient over-enrichment. Persistent and noxious algal blooms can indicate water-quality problems that might require large-scale, potentially expensive remedies.

Preliminary data from continuous monitoring of dissolved oxygen (D.O.) and faunal-utilization studies suggest that parts of the Bay are more degraded than is indicated by the State of Florida's Trophic State Index (TSI). The TSI classifies almost all of Sarasota Bay as "good," with only Little Sarasota Bay ranking as "fair." However, the index does not contain a specific term for critical pre-dawn D.O. sags. Given the well-documented importance of recurrent low D.O. levels on species diversity and abundance within estuarine locations, including preliminary information from Sarasota Bay, it might prove useful to incorporate such information into a modified TSI.

Technical Synthesis of Sarasota Bay

David A. Tomasko, Ph. D.
Dr. Tomasko received his Ph. D. in Biology from the University of South Florida in 1989. His dissertation research, carried out under the guidance of Professor Clinton J. Dawes, centered on the analysis of clonal growth properties of seagrasses. After finishing his degree at U.S.F., Dr. Tomasko took a one-year post-doctoral position at the University of Texas Marine Science Institute in Port Aransas, TX. Studies there focused on the light requirements of seagrasses. After Texas, Dr. Tomasko took a position with the Florida Keys Land and Sea Trust and researched the effects of nutrient pollution from septic tanks on the seagrasses of the Florida Keys. Since April 1991, Dr. Tomasko has worked with the Sarasota Bay National Estuary Program as a Senior Scientist.

Impacts of Pollutants on Sarasota Bay

Metals

Habitats located outside the mouths of the tributaries to Sarasota Bay do not appear to be heavily impacted by metals contamination (Dixon, 1992; Lowrey, 1992). The data from the sediment- and shellfish-contamination studies indicate that elevated metals concentrations appear primarily in the tributaries, with anthropogenic enrichment typically increasing as one progresses upstream.

Areas of notable metals enrichment include Hudson Bayou, Cedar Hammock Creek, Phillippi Creek, Whitaker Bayou and Bowlees Creek, as well as areas near points of substantial stormwater runoff. Levels of mercury (the only regulated metal) were below federal action limits for health and safety, but metals concentrations in shellfish were well above Florida averages for lead, zinc and copper.

For metals, the routes of entry into Sarasota Bay vary. Most of the zinc entering Sarasota Bay comes from direct atmospheric deposition and precipitation, while most lead enters via stormwater runoff (CDM, 1992). Metals deposited on paved surfaces by direct atmospheric deposition would then be incorporated into stormwater runoff.

The routes of entry for metals other than lead and zinc have not been determined for Sarasota Bay, but they might be expected to behave in similar manners as have been documented in other major estuaries, specifically Chesapeake Bay. Data from Chesapeake Bay indicate that in addition to zinc, significant amounts of lead, copper and cadmium enter the Bay via direct precipitation on the open water (Haberman *et al.*, 1983). Lead, along with cadmium, is incorporated into stormwater runoff via dry deposition of automobile exhaust onto paved surfaces, as well as through the deterioration of brakes and tires (Haberman *et al.*, 1983).

Another source of metals contamination comes from marine activities. In Chesapeake Bay, copper loadings related to boater's uses of antifouling bottom paints were thought to equal loadings from industrial and municipal sources (Haberman *et al.*, 1983). With more than 30,000 registered boats in Manatee and Sarasota counties, the potential role of antifouling paints on copper loading into Sarasota Bay deserves further attention. In addition, the use of copper-containing herbicides for weed control along roads may be associated with elevated copper levels found in stormwater-control structures (Lowrey, personal communication)

In some tributaries, problems with metals enrichment are exacerbated by contamination from pesticide residues and PCBs (Dixon, 1992; Lowrey, 1992). The synergism between different metals, or metals and pesticide residues, is mostly unknown. Consequently, more detailed investigations would seem appropriate to determine the biological effects of sediment contamination by multiple factors.

Low-salinity habitats are essential for juvenile snook, redfish, tarpon, spotted seatrout, striped mullet and pink shrimp (Edwards, 1991). As these areas become increasingly contaminated by metals, both lethal and sub-lethal effects would act to reduce the sizes of future populations of recreationally and commercially important species (Haberman *et al.*, 1983).

Role of Nutrients

The nutrients nitrogen and phosphorus play important roles in determining the trophic status of Sarasota Bay. Under conditions of increased nutrient availability, one would expect elevated levels of phytoplankton (with reduced water clarity), elevated levels of epiphytic algae (which would shade seagrasses) and greater amounts of drift algae (capable of shading seagrasses and producing recurrent low pre-dawn dissolved-oxygen levels). With lower nutrient loads, less algae can be supported.

Nitrogen, rather than phosphorus, appears to be the primary limiting nutrient for phytoplankton in Tampa Bay (Johansson, 1991), and nitrogen is most probably the limiting nutrient for phy-

toplankton, epiphytic algae on seagrass blades and drift macroalgae in Sarasota Bay (see review in Lapointe *et al.,* 1992a). However, even low levels of phosphorus enrichment might be sufficient to stimulate algal blooms in freshwater ponds and streams throughout the watershed (Taylor, 1967).

Baywide, approximately half of all nitrogen and phosphorus loadings come from stormwater runoff, and roughly one-quarter of loadings come from direct atmospheric deposition (CDM, 1992). The remaining nutrient loads are divided among baseflow (groundwater contributions to tributaries), septic tanks and point sources.

Wastewater

Point sources of pollution can cause localized water-quality problems, but the overall status of water quality in Sarasota Bay does not seem to be strongly impacted by point sources of pollution (CDM, 1992). In addition, many point sources of nutrient pollution have been upgraded in recent years. The documented reduction over time of phosphorus and nitrogen levels in waters offshore of Whitaker Bayou (Lowrey, 1992) may be associated with the upgrade to nutrient-removal technology at the City of Sarasota's wastewater-treatment plant.

While not prominent Baywide, septic systems play a significant role in nitrogen loading in Bay segments whose watersheds have concentrations of septic tanks (i.e., Roberts Bay, Little Sarasota Bay, Blackburn Bay). While properly functioning septic systems do not pose health problems, their primary function is that of minimizing health risks through reducing bacterial contamination, rather than the removal of nitrogen and phosphorus in effluent.

For the soils characteristic of the Sarasota Bay region, carbonate-binding sites generally prevent groundwater transport of phosphorus to nearby surface waters (IFAS, 1985). In contrast, the processes of absorption, biological uptake, denitrification and volatilization might remove only 20-40 percent of the nitrogen load before septic-tank effluent reaches groundwater (IFAS, 1985).

Once in the groundwater, nitrate is relatively free to travel, as opposed to ammonium, which might still absorb onto binding sites. The method used in the CDM study (1992) for calculating the impact of septic tanks on nitrogen loadings is the best effort to date for the Sarasota Bay area, as it was locally calibrated using data on nutrient concentrations in receiving waters. Given that Sarasota County contains approximately 45,000 septic tanks – the vast majority of systems in the Bay watershed – it is essential that their impacts on nutrient loadings be documented.

In parts of the Bay watershed, particularly in Sarasota County, package sewage-treatment plants are common. The levels of treatment and means of effluent disposal for these plants vary. Plants with direct surface discharge must meet advanced wastewater-treatment (AWT) levels for biological oxygen demand, total suspended solids, total nitrogen and total phosphorus; respectively, 5, 5, 3, 1 (mg / l). In contrast, several plants treat effluent only to secondary levels, with up to seven times the nitrogen concentration of AWT effluent (approximately 20 mg/l), and four times the phosphorus concentration of AWT effluent (approximately 4 mg/l).

If percolation ponds are used for these secondary-treatment plants, the nutrient-loading potential for these plants might be best estimated using information on groundwater migration of nutrients within septic-tank effluent streams. Package plants with secondary treatment and percolation ponds would be a more condensed source of nutrient pollution compared to an equivalent number of customers using septic tanks.

Consequently, replacing septic systems with secondary-treatment plants using percolation ponds may exacerbate problems in some areas, and might not result in any reductions in total nutrient loadings to nearby surface waters. Connecting septic systems to secondary plants with re-use of effluent, or to advanced wastewater-treatment plants with or without re-use, would be the only way to ensure a decline in nutrient loads associated with wastewater.

Stormwater

Stormwater loadings of nitrogen and phosphorus would be expected to decrease if agricultural land is replaced by residential land uses. However, if natural areas are developed for housing, stormwater loadings of nutrients would be expected to increase (data from CDM, 1992). Estimates of nutrient-removal efficiencies of wet detention ponds, the most efficient stormwater-treatment systems, average only 30-percent removal for nitrogen, and only 50-percent removal for phosphorus (Heyl, 1992). Currently, stormwater-control structures are required only for new developments involving the subdivision of land, not for development of single homes on single lots.

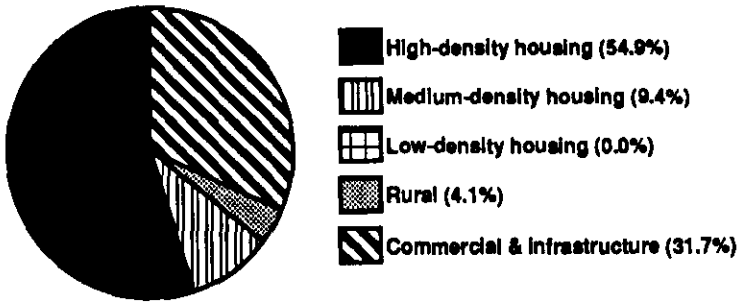
Approximately 40 percent of the Bay's watershed is in residential land use (CDM, 1992). Due to extensive use of lawn fertilizers, the nutrient concentration of runoff from these residential areas is second only to

various agricultural land uses (CDM, 1992). As such, it seems obvious that source control of nutrient runoff (e.g., educating homeowners about the impacts of lawn fertilizers on Bay waters) would be an essential tool for improving water quality in Sarasota Bay.

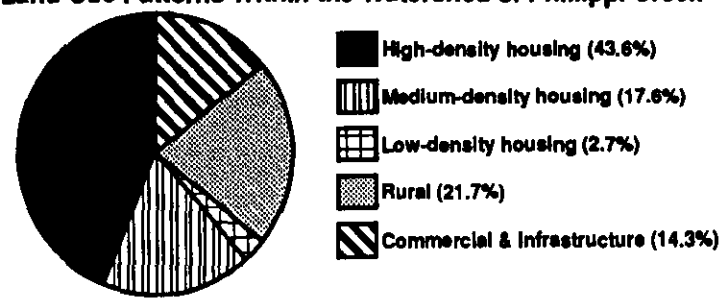
Management options must consider the diversity of land-use patterns that occur throughout our watershed. *Figure 1* shows the difference in land-use patterns among Hudson Bayou (an urbanized watershed), North Creek (a rural watershed) and Phillippi Creek (intermediate between urban and rural). As such, management strategies for stormwater control must be designed on a watershed-by-watershed basis.

Figure 1.

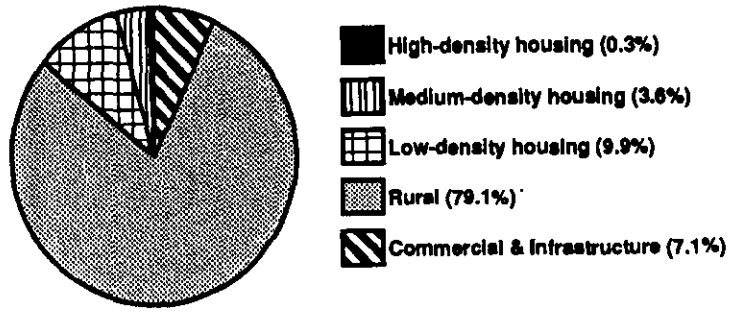
Land-Use Patterns Within the Watershed of Hudson Bayou



Land-Use Patterns Within the Watershed of Phillippi Creek



Land-Use Patterns Within the Watershed of North Creek



Connections Between Nutrient Loads and Water Quality

The recently completed nutrient-loading evaluation provides useful data on the sources and quantities of nutrient loading on a watershed-by-watershed basis. However, the model cannot predict changes in water quality associated with increased or decreased nutrient loads. Factors such as circulation and sediment-nutrient fluxes need to be taken into account.

For instance, when nitrogen loadings from various watersheds are plotted against the annual average total Kjeldahl nitrogen (organic N plus ammonium; TKN) concentration within receiving waters, no clear pattern appears *(Figure 2)*. The same lack of correlation occurs when phosphorus loadings are plotted against annual average-water-column total phosphorus (TP) levels, and when nitrogen loadings are plotted against annual average-water-column chlorophyll a concentrations *(Figure 3)*.

Reasons for this lack of correlation include differences in the segment volumes to which loads are applied as well as differences in flushing rates of various segments and potential differences in nutrient cycling associated with dissimilar sediment dynamics. As such, areas degraded by elevated loading would not necessarily be found in the immediate vicinity of the loading point, but possibly would be some distance away.

As an example of the tenuous relationship between nutrient loading and segment-wide water quality, Little Sarasota Bay has much poorer water quality (higher TKN and TP, lower clarity, shallower depths for its seagrass meadows) than both Roberts Bay and Blackburn Bay, even though Roberts Bay and Blackburn Bay receive considerably greater nitrogen loads than Little Sarasota Bay. A likely reason for this apparent discrepancy is the location of Little Sarasota Bay in the null zone for circulation within this region, as well as the proximity of Roberts Bay and Blackburn Bay to Big Pass and the Venice inlet, respectively, which provide better flushing (Sheng and Peene 1992).

Similarly, recently obtained current and salinity data indicate that water quality in Anna Maria Sound and Palma Sola Bay is influenced by the Manatee River and Tampa Bay (Sheng and Peene, 1992). This influence might result in poorer water quality than that produced by the nutrient-loading estimates for the watersheds directly draining into these areas.

Within a given area, with hydraulic variables remaining similar from measurement to measurement, water quality can

ment to measurement, water quality can correlate well with loadings. A plot of nitrogen loadings versus chlorophyll a levels in Hillsborough Bay (a part of Tampa Bay) shows a clear pattern over a period of 22 years *(Figure 4)*. The Sarasota Bay data set, on the other hand, is from a single year, and represents the initial stages of developing specific relationships between water quality and nutrient loads on a segment-by-segment basis.

Water quality in areas of Sarasota Bay with reduced flushing would probably be slower to respond to nutrient-loading reductions, due to the higher residence times and the increased importance of nutrient release from sediments, which would be less likely to be transported to other locations. In the cases of Little Sarasota Bay and Palma Sola Bay, water quality might not improve as quickly and/or dramatically after reducing land-based pollution as would be expected to occur in areas such as Roberts Bay, Blackburn Bay and the areas offshore of Bowlees Creek and Tidy Island.

Without a coupled circulation/water-quality model, only limited qualitative forecasts can be made as to the expected benefits of implemented management options. Although we cannot at present predict the exact response of the Bay's waters to reductions in nutrient loading, much evidence exists as to the expected positive benefits associated with reduced nutrient loadings.

In the Potomac River, a 95-percent reduction in point-source loads of both total phosphorus and biological oxygen demand was brought about mainly by upgrading municipal sewage-treatment plants to AWT standards (Alderson, 1988). Aquatic grass habitat in the Potomac River has dramatically increased during the past few years, with much of this increase attributed to reduced water-column chlorophyll levels and increased water clarity (Carter and Rybicki, 1986).

Similarly, 80- to 90-percent reductions in point-source phosphorus loading into Lake Erie and Lake Ontario have led to declines in water-column phosphorus levels and decreased abundances of nuisance algae in these phosphorus-limited systems (Alderson, 1988).

Johansson (1992) has documented the improvements in water quality in Tampa Bay that have accompanied reduced nutrient loading by the fertilizer industry and the upgrading of the City of Tampa's main wastewater-treatment plant to Advanced Wastewater Treatment (AWT). Increased water quality has allowed seagrasses to return

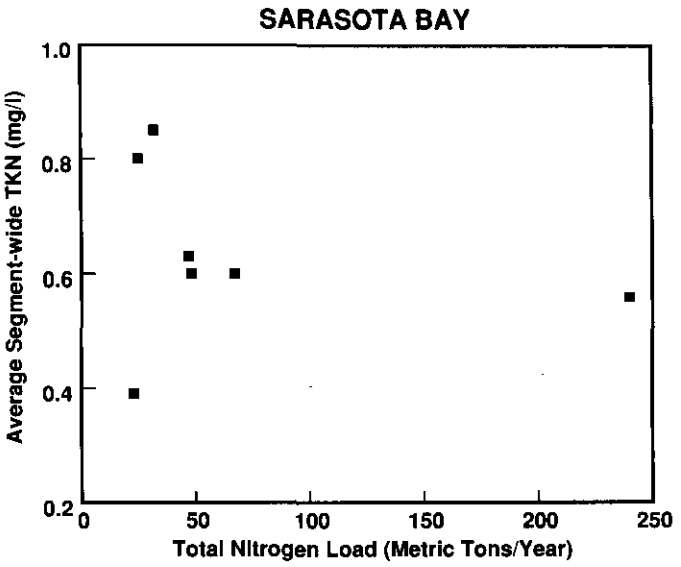
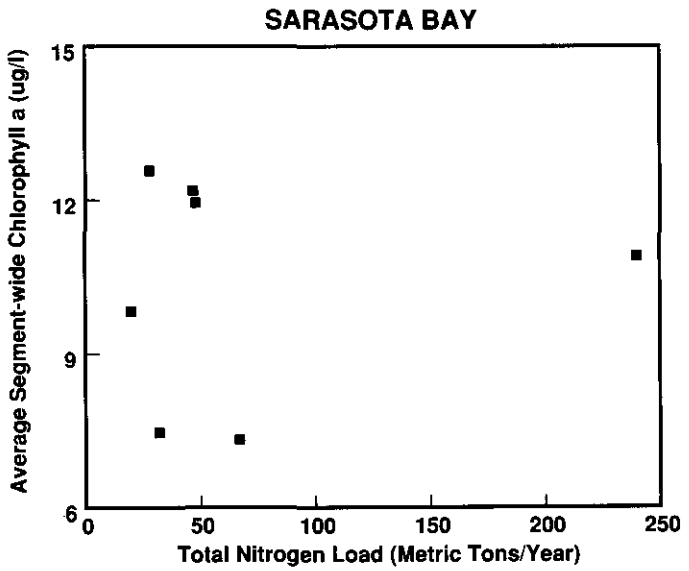


Figure 2.



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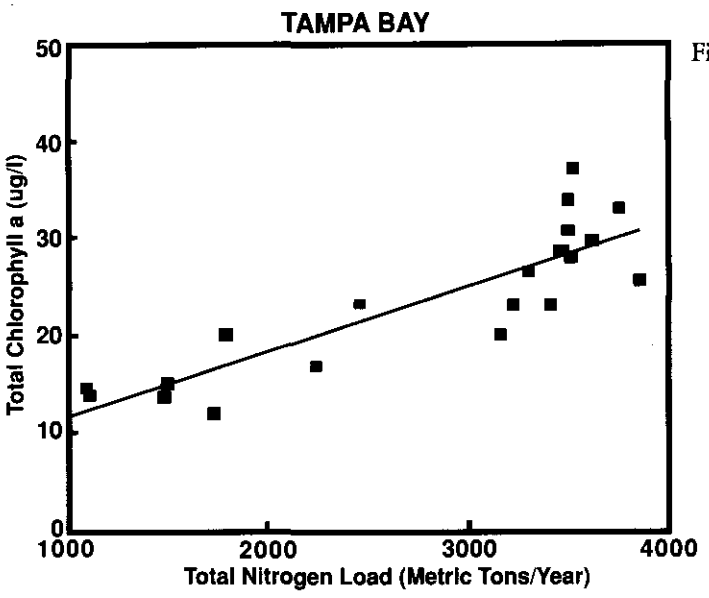


Figure 4.

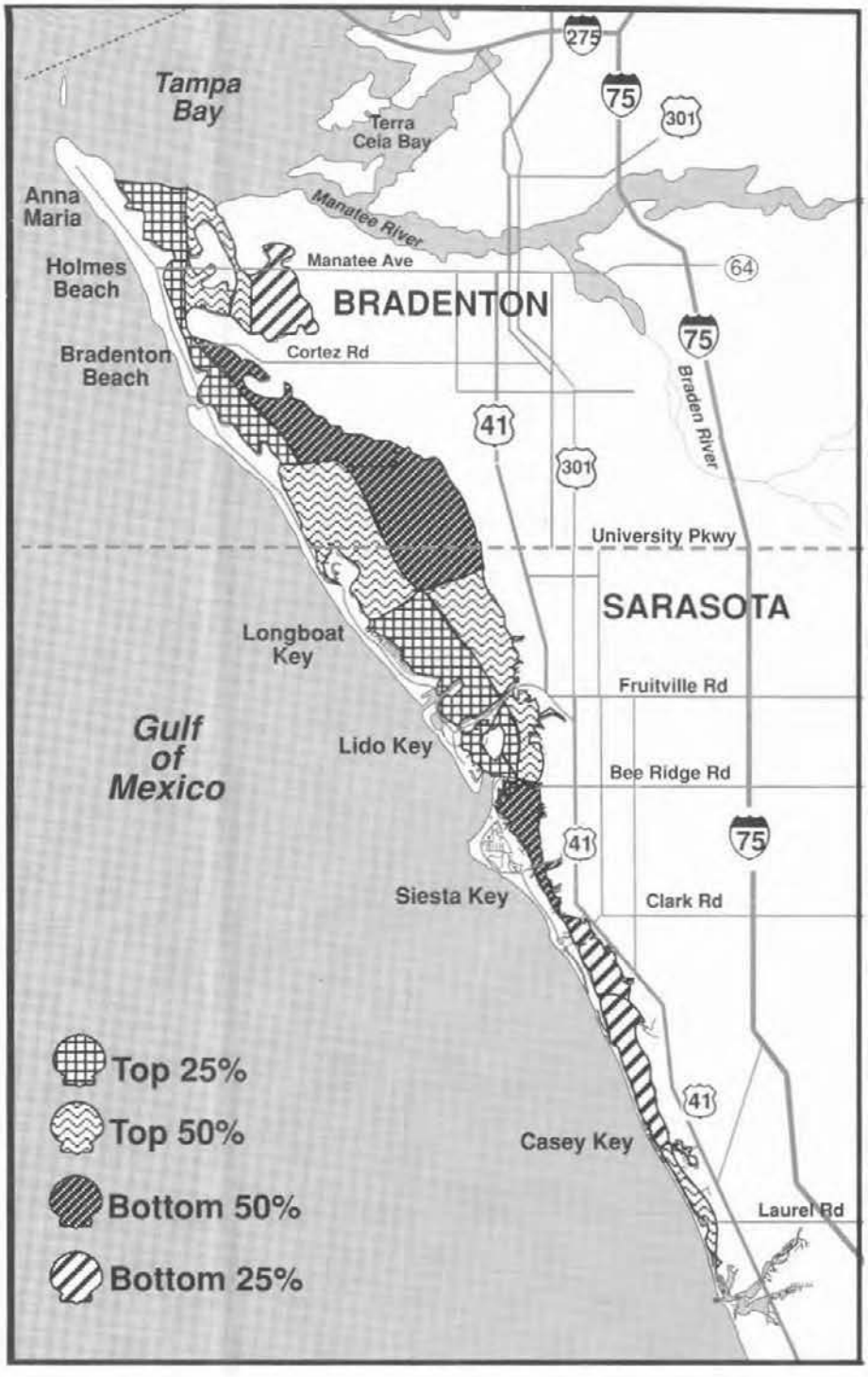


Figure 5. Relative water clarity index for Sarasota Bay.

to areas where they had previously been killed off by poor water quality (Johansson, 1992).

In the part of Sarasota Bay near the mouth of Whitaker Bayou, seagrasses were thought to be eliminated in the past due to the discharge of secondarily treated sewage from the City of Sarasota's wastewater-treatment plant (Dr. Robert Orth, personal communication). Perhaps associated with the implementation of nutrient-removal technology at this plant, declines in water-column nitrogen and phosphorus have been detected in this region (Lowrey, 1992).

As a test case using seagrass transplants as bio-indicators of improved water quality, shoal grass (*Halodule wrightii*) was transplanted into an area just south of Whitaker Bayou in October 1991. The majority of these transplants had survived at least until March 1992, indicating water quality sufficient to maintain shoal grass in that area. At that time, an older established seagrass bed merged with the transplants. The loss of plot markers made continued monitoring impossible (Tomasko, unpublished data).

Water Clarity

Water Clarity and Seagrasses

Water clarity varies from region to region throughout Sarasota Bay. Nearshore areas are more heavily influenced by terrestrial runoff and bottom resuspension due to currents and wave action (Sheng and Peene, 1992), with concomitant increases in suspended and dissolved substances. Suspended substances increase both the scattering and absorption of photosynthetically active radiation (PAR), while dissolved substances increase the absorption of PAR, mostly in the region of blue light (McPherson and Miller, 1987). Areas closer to passes are exposed to water more characteristic of the Gulf of Mexico, with greater water clarity.

The availability of light, as modified by various light attenuators, is the primary abiotic factor controlling the areal extent and productivity of seagrass communities (see review in Dennison, 1987). Seagrasses, which cover nearly 26 percent of Sarasota Bay's bottom (8,319 acres; Culter, 1992), are indispensable for the roles they play in nutrient cycling, primary production, sediment stabilization and fisheries utilization (see reviews in Zieman, 1982; Thayer *et al.*, 1984). Accordingly, it is crucial that we understand the relationships between various light attenuators, water clarity and the health of seagrass systems within the Bay.

Many studies have documented the decline of seagrasses associated with degraded water clarity (e.g., Cambridge and McCoomb, 1984; Orth and Moore, 1984; Giesen *et al.*, 1990). In addition, a limited amount of information exists on the resurgence of seagrasses associated with improvements in water clarity in Australia (Shepard *et al.*, 1989) and in Tampa Bay (Johansson, 1992).

The shallow slope of the bottom of Sarasota Bay would allow for dramatic

increases in seagrass coverage with minimal increases in water clarity. According to bathymetric data for Sarasota Bay (Sheng *et al.*, in preparation), roughly 46 percent of Little Sarasota Bay is less than two feet deep at Mean Lower Low Water (approximately three feet at Mean Sea Level). This depth is equal to the deep edge of grassbeds in the central portion of Little Sarasota Bay.

If water clarity in Little Sarasota Bay were to improve to values typically found in Roberts Bay, seagrasses could grow to one more foot of water depth. In Little Sarasota Bay, that would result in an increase in *potential* acreage from 986 acres of Bay bottom to 1,434 acres, a possible increase in seagrass habitat of 448 acres (equal to 45 percent of existing habitat).

Light availability not only delimits most seagrass meadows at their deep edges, it can also regulate the biomass and productivity of seagrasses within meadows. Short (1990) has shown a linear response between light levels and the biomass of seagrasses grown under controlled conditions. Hall *et al.* (1990), using field experiments in Tampa Bay, have shown that turtle grass, *Thalassia testudinum*, has reduced density, biomass and productivity when shaded. Since the faunal utilization of seagrass beds varies directly as a function of the density of seagrass meadows (Stoner, 1983; Sogard *et al.*, 1987), light-limited seagrass meadows would be expected to contain fewer fish and invertebrates than meadows in areas of greater water clarity.

Geographic Differences in Water Clarity

Figure 5 illustrates the geographic variation in water clarity found throughout Sarasota Bay. It should be noted that *Figure 5* is based on a *relative* water-clarity index (i.e., segments were compared against each other, rather than using an absolute scale). Nonetheless, the map quantifies what has been observed by many boaters and anglers: Palma Sola Bay and Little Sarasota Bay have reduced water clarity, and Blackburn Bay and waters offshore of downtown Sarasota have better water clarity than Roberts Bay and the waters offshore of Bowlees Creek. The greatest water clarity is found closest to the various passes.

To determine the usefulness of the current method of measuring light penetration, segment-wide values for light attenuation were plotted against the depth of the deep edge of seagrass meadows within these segments. Elsewhere, a significant relationship has been found between these two variables (e.g., Vicente and Rivera, 1982; Dennison, 1987; Giesen *et al.*, 1990; Duarte, 1991). Such a pattern exists for Sarasota Bay *(Figure 6)*, indicating that the current method of measuring light penetration seems sufficient for predicting depth limits for seagrasses. Also, improvements in water clarity needed to establish seagrasses at a deeper depth limit can be estimated.

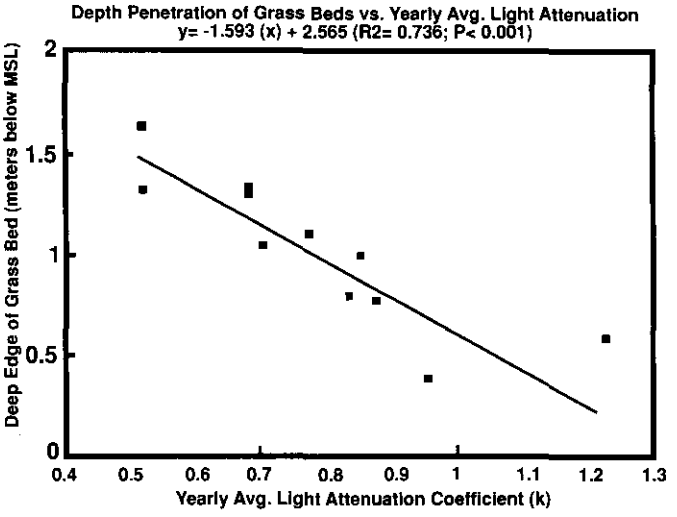


Figure 6.

Importance of Different Light Attenuators

The state of the science in seagrass biology has not progressed much beyond the point where it can be stated that increased water clarity is good and decreased water clarity is bad. This information does little to aid resource managers in determining how improvements in water clarity can be achieved. If the relative importance of various light attenuators (i.e., color, turbidity, chlorophyll a) is not known, it is difficult to devise appropriate courses of action to increase water clarity.

Knowledge of which factors are most responsible for light attenuation can be used to draft specific resource-management options. For instance, previous work on the east coast of Florida has shown that boat wakes can create sufficient sediment resuspension to increase turbidity values, thus decreasing water clarity (U.S.F.W.S., 1979).

Information from the water-quality monitoring program has been used to determine which light attenuators are most closely associated with variation in water clarity in Sarasota Bay. Based on information from multiple-regression analysis, turbidity does not seem to be an overly important contributor to light attenuation in those segments of the Bay where this association was examined. The data suggest that varia-

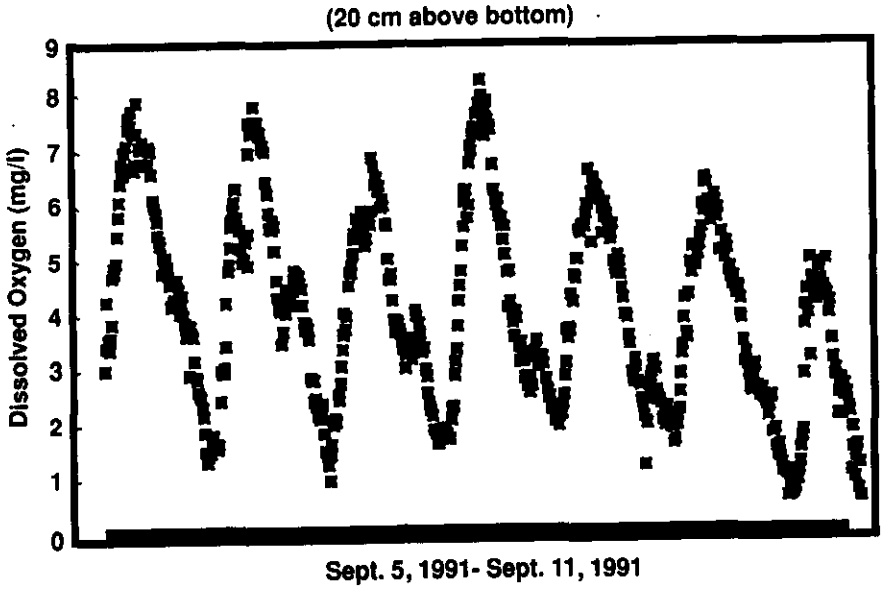
tion in turbidity accounts for only two to five percent of the variation in light penetration for waters in various parts of the Bay. However, these data were not collected during weekends, when boating activity increases. It might be that only at such times would a relationship emerge between turbidity and light attenuation.

A linkage between water-column chlorophyll values and light attenuation does exist for various parts of the Bay, where variation in chlorophyll a accounts for 23-47 percent of the variation in water clarity. As phytoplankton populations (the source of water-column chlorophyll a) are most probably limited by nitrogen loading in these areas (Johannson, 1992), locating the dominant sources of nitrogen loading could result in management activities designed to reduce loadings. A predicted consequence would be less chlorophyll a, greater water clarity and increased acreage of seagrass habitat.

Variation in the amount of dissolved substances (color) in any particular segment of the Bay is related to variation in circulation patterns and the relative importance of freshwater flows to a segment. In areas where dissolved organic substances are dominant light attenuators, few options other than increased circulation/flushing would be sufficient to improve water clarity.

The data on circulation and transport in Sarasota Bay showed poor tidal flushing in Palma Sola Bay and Little Sarasota Bay (Sheng and Peene, 1992); these same two areas are in the lower 25 percent of all Bay segments for a variety of light-related water-quality variables (Lowrey *et al.*, 1992). The improvement in water quality achieved by increased circulation, however, must be evaluated in context with possible increases in salinity, and any potential reductions in low-salinity habitats.

Figure 7. Dissolved Oxygen Levels in Little Sarasota Bay.



Dissolved Oxygen

Critical Levels of Dissolved Oxygen

Dissolved oxygen (D.O.) plays a critical role in regulating the health of estuarine systems. Unfortunately, low dissolved oxygen has become increasingly common in a variety of estuarine and marine areas, from the coasts of Denmark and Sweden to Chesapeake Bay and the Gulf of Mexico (e.g., Turner and Allen, 1972; Rosenberg, 1990; Rossignol-Strick, 1985; Stachowitsch, 1984). Typically, low dissolved-oxygen levels are the result of human-induced nutrient enrichment of nearshore waters, often referred to as cultural eutrophication (Ryther and Dunstan, 1971; Officer *et al.*, 1984; Rosenberg, 1985).

Physiological effects of hypoxia ($\leq$ 2 ppm D.O.) on fish and shellfish are well-known (Butler *et al.*, 1978; Kapper and Stickle, 1987; DeFur *et al.*, 1990). Behavioral changes in marine organisms can also be induced by hypoxia (Hagerman and Szaniawska, 1986; Kramer, 1987). If marine organisms cannot evade hypoxic waters, as in blue-crab migrations (Bailey and Jones, 1989), they must be able to adapt to conditions or perish. The eggs and larvae of bay anchovies, *Anchoa mitchilli,* are extremely susceptible to hypoxic conditions (Chesney, 1989), and their survival and geographic distribution within estuarine systems might be somewhat controlled by hypoxia.

Dissolved Oxygen Levels in Sarasota Bay

Little information currently exists to suggest that low D.O. plays an important role in reducing the vitality of habitats in Sarasota Bay. Excepting some of the tributary stations, few areas have reported problems with hypoxia and/or anoxia (0 ppm D.O.) during the daylight hours typically sampled.

As related to the problems of hypoxia and anoxia in Sarasota Bay, the maxim "an absence of evidence does not constitute evidence for absence" should be kept in mind. When water-quality sampling efforts are undertaken later in the day (accurate measurements of water clarity require the sun to be nearly overhead), D.O. levels can be much higher than their daily minimum in areas subject to eutrophication.

Daily variation in D.O. is illustrated (*Figure 7*) using data obtained by continuous

recording devices placed in Little Sarasota Bay by the University of Florida. *Figure 8*, which is a rearrangement of the same data as in *Figure 7*, demonstrates the typical relationship between hours of sunlight and D.O. levels.

For most of Sarasota Bay, the evaluation of the extent of hypoxic conditions will require monitoring efforts at pre-dawn times, or the use of continuously recording instrumentation.

Pre-dawn D.O. sags are probably the most important water-quality variable affecting species diversity and abundance in estuarine locations. Reliance on D.O. sampling during daylight hours biases water-quality classification schemes to the point where optimistic evaluations of water quality are often unwarranted.

Preliminary data from an ongoing study on faunal utilization of various grassbeds indicate that "pristine" and "impacted" seagrass beds (subjectively classified as such) have quite different faunal assemblages and levels of species diversity, despite occurring in areas of equal status according to the Trophic State Index (Leverone and Marshall, 1992). Indeed, impacted meadows of shoal grass contained only a small fraction of the numbers of caridean shrimp as were found in healthier meadows of shoal grass.

Results from Culter (1992) indicate that approximately 4,800 acres of Bay bottom (15 percent of the total area) are "disturbed," with many of these locations being anoxic sinks for fine sediments. However, it is not known if hypoxic conditions in Sarasota Bay are persistent enough to cause substantial differences in animal communities.

Present and Future Habitat

Status and Trends of Various Habitats

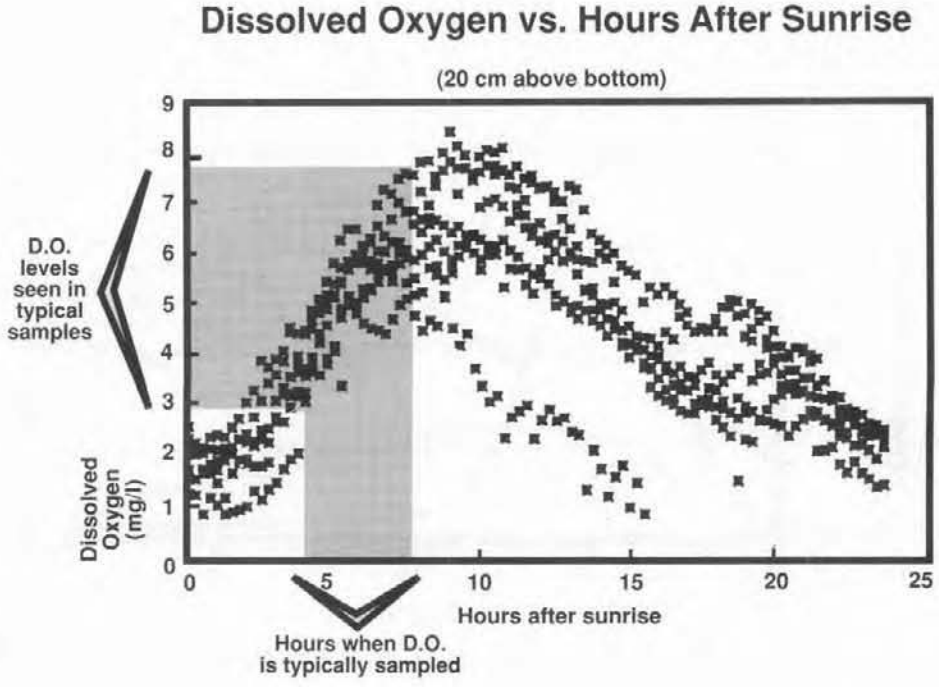
Much has been written about the value of freshwater and tidal wetlands in terms of shoreline stabilization, wildlife utilization and filtering of runoff. From 1950 to 1990, Sarasota Bay lost an estimated 1,609 acres of tidal wetlands, a 39-percent decline (Estevez, 1992); freshwater wetlands show a similarly dramatic decline during that time (Beaman, 1992). Also, more than 75 percent of freshwater wetlands within the Bay's watershed are altered to some degree by dredge-and/or-fill activities (Beaman, 1992).

The spatial variation in patterns of wetlands loss can be summarized as follows: Manatee County has lost proportionally more of its original freshwater wetlands than Sarasota County, and Sarasota County has lost proportionally more of its original tidal wetlands than Manatee County. This configuration of wetlands loss reflects dissimilar demographic trends and agricultural practices within the watershed (Estevez 1992).

Although seagrasses have declined approximately 30 percent Baywide compared to historical coverage (Mangrove Systems, Inc., 1988), areas such as Longboat Pass and New Pass show positive trends for coverage. In the Longboat Pass area, it appears that seagrass increases may be due to growth on flood-tidal shoals created by pass dredging (Darryl Hatheway, personal communication). In the New Pass area, better water quality (Lowrey, 1992) appears to be allowing seagrasses to grow into deeper areas that were previously unvegetated (Culter, 1992).

In Little Sarasota Bay, data indicate significant shifts in the species composition of seagrass meadows (Culter, 1992). Areas previously vegetated with turtle grass (*Thalassia testudinum*) are now mainly vegetated with shoal grass *(Halodule wrightii)* and widgeon grass *(Ruppia maritima)*. As shoal grass often replaces turtle grass in areas of degraded water quality (Reyes and Merino, 1991; Tomasko and Lapointe, 1991; Lapointe *et al.*, 1992b), this species shift would indicate significant changes in water quality in portions of Little Sarasota Bay.

Figure 8.



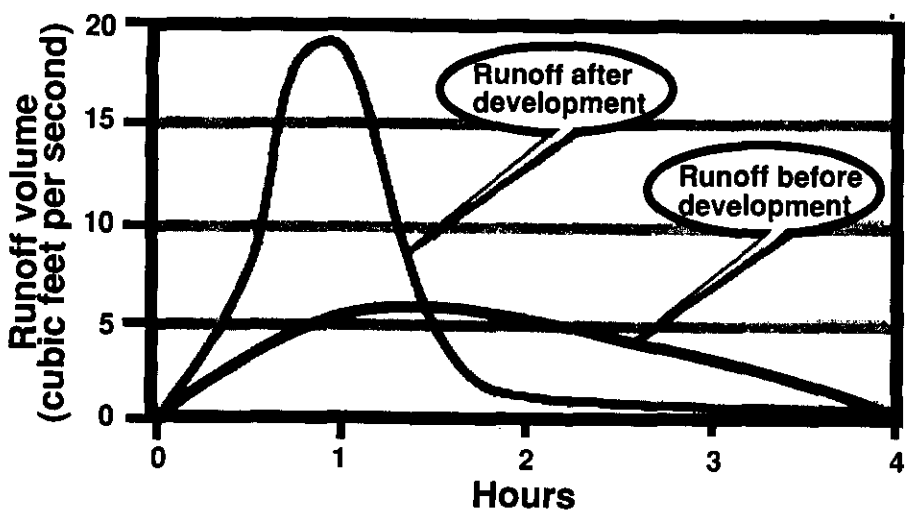
Functions of Wetland Habitats

Mangrove ecosystems have been shown to play an important role in shoreline stabilization (see reviews in Odum *et al.*, 1985). Although salt-marsh grasses are important shoreline stabilizers in higher latitudes, they have not been extensively studied in west-central Florida (Estevez and Mosura, 1985). Regardless, it can be stated with confidence that the extensive decline in tidal wetlands, both in area and edge, produced concurrent declines in shoreline stability. Unstable shorelines erode more easily, with resultant increased sediment resuspension, increased turbidity and decreased water clarity. Freshwater wetlands perform similar functions in terms of shoreline stabilization along creeks and ponds.

In addition to stabilizing shorelines and functioning as wildlife habitat (see reviews in Odum *et al.*, 1985; Lewis and Estevez, 1988), wetlands filter runoff before it enters creeks, ponds and the Bay itself. Due to differences in funding sources and research directions, tidal wetlands are better understood than freshwater wetlands in terms of shoreline stabilization, but freshwater wetlands are better understood than tidal wetlands as relates to filtering of stormwater runoff.

Dense vegetation along creek banks slows the velocity of runoff, thus increasing the infiltration of water into surface soils and groundwater. As a result, the "first flush" of runoff is dampened, and metals and nutrients are more likely to be absorbed onto soil particles and/or incorporated into plant biomass. In the absence of filtering vegetation, stream velocities are initially elevated compared to natural systems; in addition, after the "first flush" stream velocities drop off more rapidly in the absence of filtering vegetation *(Figure 9)*.

Figure 9.



(Adapted from Maryland Wildlife Administration, Integrated Watershed Plan)

Streams and creeks without vegetative cover exhibit a pattern of "feast or famine." When rains occur, velocities and pollutant loads are magnified; when dry weather dominates, creeks have reduced flow and volume. In that estuarine areas exhibit decreased productivity with both too much *and* too little freshwater inflow (see review in Browder, 1991), wetlands habitats should be protected and restored to the fullest extent if only for their function as filters of stormwater runoff. The critical importance of reestablishing natural patterns of freshwater input into estuarine areas is evidenced by the priority consideration granted it by the Task Force on Resource-Based Water Quality in Tampa Bay (Agency on Bay Management, 1990).

Even if all remaining wetlands could be completely protected from loss due to development (an unlikely scenario), Sarasota Bay would still be left with but a fraction of its original wetlands habitat. Those few remaining wetlands exhibit various levels of disturbance, due to ditching, invasive species, pruning, insect damage and freeze damage (Estevez, 1992). Accordingly, increased wetlands, brought about by restoration and/or creation activities, would seem to be an appropriate course of action. With limited funds for such activities, a prioritization of properties for wetlands restoration/creation could be appropriate. Such a ranking of areas could be based on a holistic approach to estuarine functioning.

In addition to preserving remaining wetlands and restoring/creating wetlands to ameliorate the effects of past losses, strategies must be developed to deal with anticipated future losses. One can easily foresee additional declines in wetlands due to continued development throughout the watershed. Although the rate of wetlands destruction due to development may be slowed by current and future legislation, it seems reasonable to assume that both freshwater and tidal wetlands will continue to be lost. In addition, an accelerated rate of sea-level rise, associated with global climate change, might produce additional losses of wetlands.

Wetlands issues connected with accelerated sea-level rise include the following: 1) hardened shorelines and development of upland areas might eliminate the possibility of landward migration of wetlands; 2) encroachment of invasive species might hinder landward migration of wetlands; 3) sediment-accumulation rates in wetlands might be insufficient to accommodate elevated rates of sea-level rise.

Although uncertainties abound in predicting global climate change and sea-level rise, a prudent course of action might include a variety of activities. Purchasing acreage upland from existing wetlands might alleviate the problems associated with wetlands migration in areas with appropriate slopes and land-use patterns. Wetlands delimited at their upland edges by seawalls, causeways and/or extensive reaches of invasive species might be very expensive to maintain with an elevated rate of sea-level rise.

Relationships Between Recreation and Habitat

Recreational activities are varied in their dependence on habitat quality. Some activities, such as boating or cruising, can take place just as easily, and be just as enjoyable, regardless of the location in Sarasota Bay. The level of enjoyment of other activities, such as fishing, snorkeling and bird-watching, are dependent upon the health of the Bay at that particular location.

Recreational anglers engage in various types of fishing. Individuals who use cast nets to capture mullet can do quite well in locations where adults of other species are more difficult to catch. Consequently, recreational fishing can be a quite diverse activity, with various people requiring various habitats; one person's fishing hole may be viewed as a lifeless void by other anglers.

A problem that arises with characterizing the various habitats in Sarasota Bay is the emphasis placed on determining the "value" of such habitats. While the area around the former Midnight Pass seems to be functioning as a nursery for various juvenile fish (Edwards, 1992), seasonal aggregations of sought-after species – as are typical of open pass areas – no longer occur. As a result, this area is no longer a focal point for recreational fishing. A question arises, both in this example and in many others, as to the type of habitats we are aspiring to preserve, enhance or create.

While one may argue the merits of maintaining a mosaic of estuarine habitats, others might argue for maximizing the area of those habitats in shortest supply. In turn, identifying habitats in shortest supply depends on what species are being considered. Pass-type communities are obviously very different from quiescent, lagoonal environments. Both these areas are important, but which is most vital depends on what species are being considered, which might also vary with the age of the targeted species.

As shown in the chapter on Fisheries, the primary issue affecting recreational fishing in Sarasota Bay is that of more people fighting for their slice of a diminishing pie. A tenfold increase in population during the last 40 years has greatly increased fishing pressure. During the same period, dramatic declines in fisheries habitat have occurred (an approximate 39-percent decline in mangrove area, and a 30-percent decline in seagrass area). A relationship appears to exist among declines in habitat, increased fishing pressure and the finding that the average angling experience is less productive than it used to be.

Based on this scenario, it seems that protecting remaining fisheries habitats, although essential, is not sufficient. To truly increase the level of enjoyment of recreational angling, new fisheries habitat must be created on a continuing basis.

Basin-Wide Management Options

To stimulate discussion, the following list of potential management options is provided. The list contains management options inclusive of, but adding to, the original goals of the Sarasota Bay National Estuary Program.

1) Construction of stormwater-control devices in priority watersheds for reduction of metals contamination of nursery habitats (i.e., Hudson Bayou, Cedar Hammock, Bowlees Creek, Whitaker Bayou, Phillippi Creek). Also, identify other areas at risk (Addresses SBNEP Goals 1, 2, 3 & 7).

2) Increased naturalization of watersheds through:

a. Successful promotion of the Florida Yard Program
b. Purchase of buffer zones along water bodies
c. Restoration of publicly owned water front property (Addresses Goals 1, 2, 3, & 7).

3) Reducing nutrient pollution and eutrophication through:

a. Connecting septic systems to on-line central sewage-treatment systems
b. Converting secondary treatment plants with percolation ponds to AWT and/or reuse systems
c. Utilizing wet detention ponds, rather than desiltation basins, for stormwater-control devices
d. Developing a predictive circulation/water-quality model to quantify the effect of reduced nutrient loading on Baywide water quality (Addresses Goals 1, 2, 3 & 7).

4) **Increasing water clarity through:**
   a. Reducing nutrient loading, which causes phytoplankton blooms capable of attenuating underwater light
   b. Where appropriate, reducing boat-induced turbidity
   c. Where appropriate, reducing abnormally high values of color by improving circulation (Mainly addresses Goal 1).

5) **Protect existing seagrass and wetlands habitat from continued loss due to development (Addresses Goals 1, 2, 3 & 7).**

6) **Increase wetlands habitat through restoration of:**
   a. Spoil islands (where appropriate)
   b. Publicly owned waterfront property
   c. Private waterfront property (through encouraging homeowners to seek alternatives, where possible, to hardened shore lines) (Addresses Goals 1, 2, 3 & 7).

7) **Continue to fund applied research aimed at determining linkages between land-based pollution, water quality and fisheries utilization of various habitats. (Addresses Goals 1, 2, 3 & 7).**

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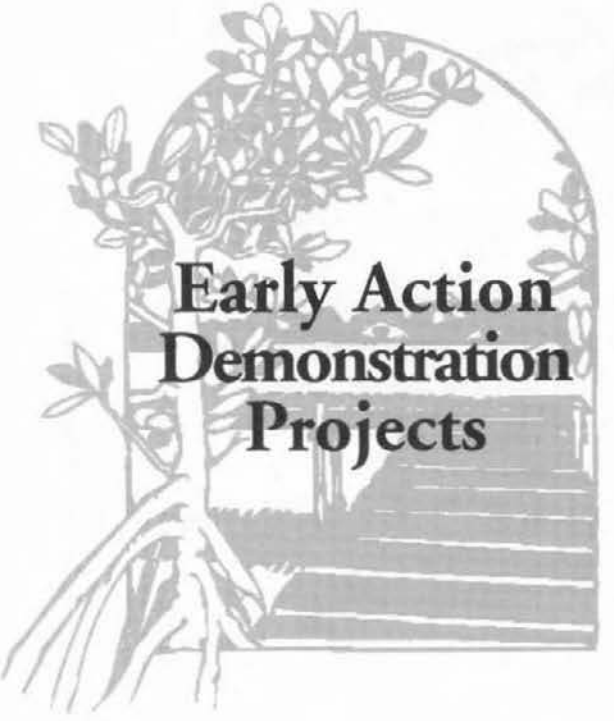

Early Action Demonstration Projects

Early Action Demonstration Projects

by Susan W. Walker
Sarasota Bay National Estuary Program

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Executive Summary

Since its inception in June 1989, the Sarasota Bay National Estuary Program (SBNEP) has made "action now" a principal theme. Program staff and members of the Management Conference have monitored and evaluated local government actions to improve Sarasota Bay; the Program also worked with local governments to develop and implement a series of Early Action Demonstration Projects that demonstrate the effectiveness and costs of some techniques for solving the Bay's problems.

Local governments surrounding Sarasota Bay have recently made significant strides toward restoring and protecting the Bay; actions addressing wastewater and stormwater pollution have been particularly effective in reducing pollutant loads to the Bay. The Program continues to work with local governments to expand efforts in solving stormwater and wastewater problems.

Meanwhile, creating effective tools for testing restoration techniques required the Program to focus "action now" projects on major Bay problems. The three priority issues identified by the SBNEP Management Conference are: 1) inadequate wastewater treatment; 2) stormwater runoff and; 3) loss of natural habitat. Given the considerable attention of local governments in addressing wastewater treatment, the Program chose to target habitat loss and stormwater runoff for Early Action Demonstration Projects.

Completed or ongoing projects include 11 habitat-related projects and two stormwater-management projects. Funding for the projects is provided from local, state and federal sources, including local governments, the Manasota Basin Board of the Southwest Florida Water Management District, the Pollution Recovery Trust Fund of the Florida Dept. of Environmental Regulation and the U.S. Environmental Protection Agency through Early Action Demonstration Project grants.

The intertidal habitat-restoration projects, conducted with four different local governments, will restore 80 acres, representing 4.4 percent of Sarasota Bay's intertidal habitat lost since 1950.

Implementation of the stormwater projects will reduce the quantity and improve the quality of stormwater discharge in specific basins, while providing valuable insights into stormwater-management techniques for highly urbanized coastal areas.

In addition to successfully developing restoration techniques and cost estimates, Early Action Demonstration Projects also help local government staffs develop expertise in restoration techniques, improve inter-agency coordination, provide opportunities for citizen volunteerism and serve as an outlet for public education on Bay problems and potential solutions.

Early Action Demonstration Projects

Susan Wellington Walker
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Discussion

Wastewater Treatment

During the past 15 years, Manatee County and the City of Sarasota spent more than $250 million for infrastructure improvements in regional wastewater systems.

In Manatee County, major improvements to the Southwest Regional Wastewater Treatment Plant decreased nutrient loads to the upper portions of the Bay. The plant, which serves Longboat Key, the City of Anna Maria, Holmes Beach, Bradenton Beach and the mainland watershed of Manatee County, treats wastewater to secondary levels. Improvements to the system during the past three years include installing a deep-well injection system, expanding reuse capabilities and installing a tail-water recovery system to recirculate reuse water, which irrigates agricultural fields near the treatment plant. The county and the Program continue to monitor Bay waters near the tail-water system. Manatee County currently is expanding its reuse operations into residential areas.

In 1991, the City of Sarasota completed converting its wastewater-treatment plant from secondary to Advanced Wastewater Treatment (AWT), combined with reuse of this highly treated effluent. The city previously discharged secondary effluent into the Bay at Whitaker Bayou.

Although the upgrade to AWT reduced nutrient loading to the central Bay seven-fold, difficulties with the reuse system caused the city to violate intermittent-discharge limits, resulting in fines from the Florida Dept. of Environmental Regulation. By 1993, however, the city's reuse capabilities will be expanded to further reduce the need to discharge into the Bay.

Although Sarasota County plans a regional wastewater-treatment system for the Little Sarasota Bay area, construction has not begun. Sarasota County's wastewater is predominantly treated by on-site septic systems and 71 small sewage-package-treatment plants, neither generally recommended for urban areas. Both the septic systems and package-treatment plants have significant potential to pollute the Bay with excess nutrients. The threat of groundwater contamination also exists.

The Program is sharing information from various technical projects to assist the county staff in setting priorities for centralizing wastewater treatment.

Habitat Loss

The *State of the Bay Report 1990* (Roat and Alderson, 1990) described the extent of habitat loss and encroachment of exotic plant species as major impacts threatening Sarasota Bay. Intertidal habitat has declined 39 percent in Sarasota Bay, as discussed in the Tidal Wetlands chapter of the *Framework for Action.*

Rapid development replaced much of the Bay's shallow-water habitat with neighborhoods, and once-pristine shorelines were replaced by seawalls, bulkhead and rubble. Past dredging activities altered Bay bottom and destroyed seagrasses. Loss of seagrasses is estimated at 25-30 percent Baywide; in some areas, loss estimates reach 80 percent.

To meet the challenge of restoring lost habitats and eliminating further losses, the Program and local governments developed and implemented a series of habitat-restoration projects. To date, approximately 80 acres will be restored to productive intertidal habitat, which is equivalent to 4.4 percent of habitat lost since 1950.

Some important lessons learned during the course of the projects include:

- Communities will support intertidal habitat-restoration in areas where public access is intensive or passive.
- Intertidal habitats should be designed to include fresher water lagoons, which are habitat for recreationally important finfish species.
- The cost of restoring intertidal habitat in heavily impacted dredge-spoil areas is $25,000-$30,000 per acre.
- Maintenance for removing Australian pine and Brazilian pepper trees should be performed approximately every four to six months, particularly if berms or upland hammocks are created as part of restoration plans.
- Preliminary data strongly suggest that artificial habitat modules for seawalls increase fishery habitat in residential canals.
- Transplanting seagrass can be a valuable

tool for characterizing localized water quality, and may be used as a biological indicator of water-quality improvements.

Stormwater Runoff

During the past two years, both Sarasota and Manatee counties have developed Stormwater Environmental Utilities. Sarasota County's utility also serves the City of Sarasota.

The county adopted a rate structure and is developing plans for improving stormwater management in two priority watersheds, Phillippi Creek and Hudson Bayou. Sarasota County is also developing a stormwater-management strategy required by the U.S. Environmental Protection Agency. The Sarasota Bay Program is cooperating with these action-oriented planning efforts by sharing data and assisting with management strategies.

Manatee County also created a stormwater utility, and adoption of a rate structure is expected in 1993. Following that action, strategies for improving priority watersheds – probably Bowlees Creek and Cedar Hammock – will be developed.

To assist both counties in testing actual stormwater-management techniques, the Program helped develop two innovative stormwater projects. These projects will significantly reduce the quantity and improve the quality of stormwater runoff in the areas where they are implemented. Lessons learned from the projects can then be applied in other basins.

Manatee County's project for improving stormwater management in the Airport Drainage Basin of Bowlees Creek is scheduled to begin design and construction in 1993.

A project in Sarasota County's Clower Creek is underway. Major results include:

- For the most part, present stormwater-control systems are functioning properly, yet do not provide optimal reductions in pollutant loadings.
- Significant reductions in nutrients, solids and flows can be accomplished at relatively low cost in previously developed basins by improving existing stormwater-management structures.
- While wet detention provides maximum nutrient and sediment removal, these systems are costly and require acquisition of sizable land parcels, often unavailable in urban basins.
- Defining stormwater-management problems and developing effective solutions is highly complex and requires in-depth review of conditions in each basin. Therefore, the counties' commitments to complete stormwater-management planning by basins appears to be appropriate.

Citizen Involvement

A common criticism of government-funded studies of the environment is that little action results. Conducting Early Action Demonstration Projects helped the Sarasota Bay community better understand the Bay's problems, while demonstrating tangible actions that would help provide solutions. The projects also encouraged citizen participation in Bay restoration, helping to build momentum for broader-based volunteer efforts in the future. Long-term environmental education in the community received a boost from the development of new destinations for exploring and understanding the Bay's fragile ecology.

Some important aspects of public involvement in Early Action Demonstration Projects include:

- Media coverage at various stages of project development help spread the word about Bay problems and solutions being tested.
- Volunteer clean-ups and plantings at habitat-restoration sites provide hands-on participation for citizens eager to be part of saving the Bay.
- People take full advantage of educational signage, brochures and tours at restoration sites, demonstrating the public's thirst for knowledge about the Bay.
- Interaction with teachers, students and school administrations helps expand the reach of educational opportunities at habitat-restoration sites.
- Coordination of educational programs with local institutions, such as Mote Marine Laboratory's involvement at the Sarasota BayWalk, also expands the educational possibilities of these projects.

School students plant marsh grass at a habitat-restoration site.

Sarasota Bay National Estuary Program Early Action Demonstration Projects				
Project	**Participating Organization**	**Media**	**Anticipated Benefits**	**Costs (000s)**
City Island	EPA, FDER, City of Sarasota	Habitat	Restore 4-5 acres of intertidal	$200
Leffis Key	EPA, FDER, Manatee County	Habitat	Restore 34 acres of intertidal	$320
Quick Point	FDER, Manasota Basin Board, Town of Longboat Key	Habitat	Restore 30 acres of intertidal	$300
6th Street	EPA, FDER, City of Sarasota	Habitat	Restore 7 acres of intertidal	$130
Palmer Point	FDER, Sarasota County	Habitat	Restore 4 acres of intertidal	$100
Seawall Enhancement	EPA, Mote Marine Lab, Private	Habitat	Create reefs for canal front homes	$87
Caples Seawall Removal	FDER, New College	Habitat	Remove 300 ft. of seawall; plant native vegetation	$15
Benthic Habitat Repair	EPA, FDER, Mote Marine Lab	Habitat	Cap anoxic sediments; restore bottom	$250
Seagrass Signage	EPA, New College	Habitat	Protection for scarring of bottom habitat	$30
Sister Keys	Sister Keys Conservancy	Habitat	Documentation of seagrass habitat	$5
Seagrass Transplant	SBNEP staff	Habitat	Seagrass recolonization	N/C
Clower Creek	EPA, Sarasota County	Stormwater	Improve flow and water quality in 1 sq. mile of creek basin	$224
Airport Drain	EPA, Manatee County	Stormwater	Improve 300 acres of watershed with wet detention	$250
				TOTAL $1,911

Table 1

Project Summaries

Following is a summary of the 13 Early Action Demonstration Projects developed by the Program and local governments since 1989. *Table 1* lists the projects, associated costs and participants.

Sarasota BayWalk at City Island

Sarasota BayWalk is a 4.5-acre site owned by the City of Sarasota and located on a dredge-spoil island adjacent to New Pass. The site had been highly impacted with non-native plant species, primarily Australian pine and Brazilian pepper trees, and has served as a disposal site for road-construction debris.

Historically, the site had been used for disposing spoil material when nearby channels and passes were dredged. Ditching for mosquito-control purposes was extensive throughout the site. Some native red, black and white mangroves existed on the site as well as a salt-barren area.

The Sarasota BayWalk habitat-restoration and enhancement project was submitted in Spring 1989 by Mote Marine Laboratory; it included the development of highly productive one- or two-acre habitat modules. The concept was expanded to include the entire 4.5 acres with participation from Florida Dept. of Environmental Regulation.

The objective of the project was to create highly productive, diversified and integrated habitats of ecological importance by removing non-native plant species, lowering land elevations to promote optimal habitat growth and enhancing existing mangrove and intertidal areas with additional plantings.

Another objective of the project was to provide additional public access to the Bay and opportunities for increased public education and awareness about the value and importance of the various estuarine habitats. The restoration effort also served to inform the community about Program goals and activities.

Site design and specifications were developed with extensive input from the Technical Advisory Committee. In November 1990, removal of exotic species, excavation of six intertidal pools and construction of a boardwalk began.

The pools were excavated to varying depths to attract diversified estuarine species. Scallops, once abundant in Sarasota Bay, have been found in the created tidal ponds, as have other shellfish, crustaceans and invertebrates. Juvenile mullet, redfish, black drum and other native fish species have been found within the ponds.

More than 20,000 native plants, mostly *Spartina alterniflora,* were planted in December 1990 by more than 100 volunteers, many of them school students. A 90-percent plant survival rate was estimated. Throughout 1991, interpretive signage was designed and a comprehensive monitoring plan was developed and implemented. Signage was installed and BayWalk brochures produced to inform visitors to the site of increasing pressures on limited natural resources from population growth and development.

The BayWalk site is used extensively by Sarasota and Manatee county schools for student field trips to inform students of the importance of the estuarine ecosystem and the need to preserve its resources. The Sarasota BayWalk was formally dedicated April 9, 1992.

The City of Sarasota, as lead agency in cooperation with Florida Dept. of Environmetal Reguation (DER), Florida Dept. of Natural Resources (DNR), Sarasota County Natural Resources Dept., Sarasota County Parks and Recreation Dept. and the U.S. Environmental Protection Agency, developed the project over the course of three years.

The SBNEP provided technical and scientific guidance as well as citizen input to the project. The U.S. Environmental Protection Agency provided $50,000 as Early Action Demonstration Project funds for the project. The City of Sarasota provided in-kind services and project oversight. The Florida DER provided $150,000 from the Pollution Recovery Trust Fund; the Florida DNR provided over 25,000 native plants and staff for planting activities. Total cost of the project was $200,000.

Ongoing activities include a monitoring program to determine species diversity and utilization of the site; survival rate of recently transplanted seagrasses; and overall health and ecological function of the site. A maintenance program to periodically remove exotic plant species has been developed.

The BayWalk continues to attract thousands of area residents and tourists. School students from Sarasota and Manatee counties continue to tour the site in conjunction with educational outreach activities planned by Mote Marine Laboratory, located directly adjacent to the BayWalk. Environmental education materials focusing on the ecological importance of the estuary were developed by teams of teachers from both counties. Teacher-training workshops have been held to inform educators on how to effectively use the educational materials in the classroom and field. The Program continues to reach out to community groups to provide opportunities to tour the Sarasota BayWalk.

Coquina BayWalk at Leffis Key

Leffis Key is a 30-acre site, owned by Manatee County, located along the Sarasota Bay shoreline on the southeast tip of Anna Maria Island, just north of Longboat Pass. The site is directly adjacent to Coquina Beach. It is estimated that more than two million people visit Coquina Beach annually, making it one of the most heavily utilized recreational areas in the Manatee-Sarasota county area.

The disposal of dredge-spoil material within the center of Leffis Key destroyed approximately 15 acres of native mangroves, with significant declines in mangrove coverage on the perimeter of Leffis Key. The central portion of the site is sandy and has become vegetated by non-native plant species such as Australian pine, Brazilian pepper and privet. Seagrass beds to the north and south of the key are popular destinations for fishing.

Leffis Key was once an island. However, the deposition of spoil material on and around the island resulted in establishment of a causeway between Leffis Key and Anna Maria Island. This man-made connection, creating a peninsula, has altered tidal circulation around the island, negatively impacting living resources.

Some rim ditching for mosquito-control purposes is evident along the north side of the spoil area. The northern portion of the site is the least impacted by dredging activities, and includes approximately 10 acres of undisturbed mangrove and some salt-barren habitats.

The Coquina BayWalk habitat-restoration and enhancement project was submitted by Manatee County as an Early Action Demonstration Project in 1990. After competing with other projects nationwide, Coquina BayWalk at Leffis Key was ranked second in the nation and selected for funding.

The objectives of the BayWalk project are to restore one of many dredge-spoil areas in Sarasota Bay as a model for other areas, increase the area of functional mangrove, wetland and shallow-water habitats, improve Bay circulation, increase levels of managed access to the northern sections of Sarasota Bay and its resources, increase available spawning and juvenile fish habitat and increase Bay educational and interpretive facilities available to both local residents and tourists.

The Technical Advisory Habitat Subcommittee, in concert with the Florida Dept. of Environmental Regulation, assisted Manatee County Parks and Recreation Dept. in developing a conceptual design for the project. Manatee County Public Works participated in surveying, topographic mapping and final design of the site.

Initial clearing and exotic-species removal occurred in Summer 1991. Excavation of intertidal pools and tidal inlets and boardwalk construction began in Spring 1992.

The project plan calls for recreating an island by removing the fill material connecting the key and Anna Maria Island, thus re-establishing and enhancing tidal circulation. A footbridge will be installed to provide visitor access to Coquina BayWalk. Fill material from the key and adjacent north and south shorelines (Coquina Beach Bayside Park) will be used to create dunes to serve as visual and audio barriers to road traffic. The site will be revegetated with salt-marsh, intertidal and upland plants by Fall 1992. Interpretive signage will be installed, and an educational brochure produced to inform visitors to the site of the ecological importance and interdependence of the mangrove forest and other surrounding habitats.

Manatee County schools will use Coquina BayWalk as an environmental-education site, in conjunction with existing marine and estuarine curriculum, to inform students about the estuarine system and the need to preserve its resources.

Participants in the Coquina BayWalk project, led by Manatee County, include Florida DER, Florida DNR, the City of Bradenton Beach, Florida Sea Grant and the U.S. Environmental Protection Agency. The SBNEP is providing technical assistance and citizen input to the project. The U.S. Environmental Protection Agency provided $75,000 as Early Action Demonstration Project funds for Leffis Key. Manatee County is providing significant in-kind services such as design, site preparation and excavation, as well as $9,000 from the county's pollution-recovery account. The Florida DER provided $140,000 in 1990 for the project; an additional $100,000 contribution is anticipated in 1992. The Florida DNR will provide native plants. The total cost of the Coquina BayWalk project is likely to exceed $320,000.

The site will be monitored quarterly for plant survival, plant recruitment and percent coverage of each plant species. The site will be maintained by Manatee County's Dept. of Recreation and Parks.

Quick Point Preserve Habitat Restoration

Quick Point, an ecologically diverse 34-acre site, is located on the southeastern tip of Longboat Key just north of New Pass. Originally held in private corporate ownership, the site was donated to the Town of Longboat Key. Significant habitats include numerous red and black mangroves, an interior lagoon, oyster reefs, salt flats and upland areas with cactus and cedar. Past dredging activities have had adverse impacts on mangroves and other habitats at Quick Point.

Objectives for the restoration-and-enhancement project include restoring one of many dredge-spoil areas that has been further impacted by mosquito ditching, increasing the area of functional mangrove, wetland and shallow-water habitats and improving Bay circulation and water quality by increasing intertidal flushing and filtering stormwater runoff.

The Town of Longboat Key, with technical assistance from the Program, submitted the project to the Manasota Basin Board as a 1992 cooperative funding project. The Florida DER is also a participant in the project with Pollution Recovery Trust Fund resources and technical assistance.

An environmental assessment of the site is complete, and conceptual plans have been approved. The plans call for limited access via a wood walkway from Overlook Park under the New Pass Bridge. Selected exotic vegetation will be removed. A tidal connection to the existing internal lagoon will be excavated, and a second tidal lagoon constructed. Several wetland areas will be created and replanted with native vegetation.

The Quick Point Preserve will be maintained by the Town of Longboat Key. Longboat Key provided $100,000 from the Parks and Open Space Land Acquisition Fund to match $100,000 in resources from the Manasota Basin Board of the Southwest Florida Water Management District. FDER provided $100,000 from the Pollution Recovery Trust Fund. The Program will assist in project coordination and technical guidance. Total cost for restoring Quick Point is $300,000.

6th Street Canal and Sarasota Civic Center Restoration

The 6th Street Canal, leading from a former public boat ramp to Sarasota Bay, is located on the Bayfront in the City of Sarasota. The area has been developed as a cultural center and includes the Van Wezel Performing Arts Center, Sarasota Exhibition Hall and Selby Public Library. A master plan that includes the 6th Street Canal area has been developed by the City of Sarasota to enhance the culturally, environmentally and economically important Bayfront area.

The 6th Street Canal project focuses on restoring and enhancing a mangrove and intertidal area, "softening" canal shorelines with vegetation or rip-rap to demonstrate alternatives to hardened shorelines and promoting changes in public attitudes of Bay-area residents and tourists through educational signage.

The conceptual plan includes creating a half-acre tidal-wetland lagoon, removing hardened shoreline and establishing an intertidal marsh. Exotic vegetation will be removed and the shoreline revegetated with native plant material. Efforts will be made to reuse existing rip-rap and broken seawall as bedding material for oysters. The project will double the area of mangroves and shallow-water habitat beneficial as nursery and feeding areas for marine life. Stormwater runoff will receive beneficial filtering through the enlarged and enhanced wetland system.

The site plans also include boardwalks, walkways and interpretive signage. Once completed, it is anticipated that this site and the surrounding area will be highly visible to

both local residents and tourists due to its close proximity to other popular area attractions.

The project is being managed by the City of Sarasota Planning Dept. with assistance from the Engineering Dept. The city will organize volunteers for site clean-up, planting, future monitoring and also removal of the boat ramp.

The value of in-kind services from the City of Sarasota is $20,000. The Florida DER provided $76,000 from the Pollution Recovery Trust Fund for design, seawall and exotic-plant removal, excavation and grading, boardwalks and native plants. The Florida DNR will provide native plant material at an estimated cost of $4,000. The U.S. Environmental Protection Agency provided $30,000. The SBNEP is assisting the City of Sarasota with technical guidance. Total cost of the project is $130,000.

Palmer Point Habitat Restoration

Palmer Point Park is located on the northeast tip of Casey Key on Little Sarasota Bay, adjacent to the former site of the now-closed Midnight Pass. As the Midnight Pass inlet migrated northward, natural accretion enlarged the Palmer Point site and created a tidal marsh. The site also has received spoil material, probably as a result of dredging of the Intracoastal Waterway and access channels. The three-acre site has been impacted with exotic vegetation, primarily Australian pine and Brazilian pepper.

An exclusive residential area is nearby, with associated stormwater that drains to the site, creating a natural impoundment. The impounded stormwater and tidal waters have served as a breeding ground for saltwater mosquitos. Area residents have raised concerns over the mosquito populations and associated health risks.

The goal of the Palmer Point Park project is to restore this spoil area to a productive habitat that receives regular tidal flushing, thereby eliminating the mosquito-breeding habitat.

The project is sponsored by Sarasota County Mosquito Control District with assistance from Sarasota County Parks and Recreation and Natural Resources Dept. The FDER has expressed interest in the restoration project with Pollution Recovery Trust Fund resources. The project is planned for 1993 at an estimated cost of $100,000.

Seawall Habitat Enhancement (Habitat Modules)

Seawalls and seawalled canal systems provide minimal habitat for recreationally important juvenile fish, oysters and other marine life. Development of techniques for enhancing the habitat value of existing seawalls could greatly improve and restore the overall functioning and productivity of Sarasota Bay, directly addressing the Program's goal to restore and sustain fish and other living resources.

The objectives of the Seawall Habitat Enhancement project are to design and install a variety of artificial structures of different materials in canal communities to create seawall habitat for juvenile stages of important fish species, monitor and evaluate the effectiveness of the artificial habitat structures, monitor and evaluate environmental impacts of the structures and develop widespread public interest in enhancing seawall environments.

In Fall 1991, four types of artificial habitat modules were designed and constructed. Homeowners in a canal community were contacted to participate in the project by placing a module in front of their seawall. In Spring 1992, 16 modules were deployed by volunteers.

Initial monitoring in Spring 1992 determined that the modules are doing exceptionally well. The total number of juvenile fish around the 16 modules were estimated at 3,000-5,000 individuals. By comparison, not a single fish was seen at any of the four control (un-enhanced seawall) sites.

The modules will continue to be monitored for 18 months to determine their relative effectiveness. Practical considerations important to permitting processes, such as stability, effects on surrounding communities, sedimentation, effects on circulation, public perception and aesthetics will be evaluated. Cost, ease of installation, durability, longevity and aesthetics will also be considered.

The Seawall Habitat Enhancement project is being managed by Mote Marine Laboratory, which is providing $4,750 of in-kind services. Design and fabrication of the modules was provided by an area boat manufacturer. The value of these in-kind services is estimated at $7,000. The Florida DER committed $10,000 from the Pollution Recovery Trust Fund to the project. The U.S. Environmental Protection Agency provided $65,000 in Early Action Demonstration Project resources. The SBNEP is providing technical assistance and direction. Total cost for the Seawall Habitat Enhancement project is $86,750.

Caples Seawall Removal and Shoreline Naturalization

A crumbling 1930-era seawall was located on the mainland at the Caples Campus of the University of South Florida in Sarasota. The deteriorating seawall adjoined another larger seawall to the north that fronts the Ringling Museum of Art property. The Ringling seawall was threatened by behind-the-wall scouring due to the failing Caples seawall. A sandy estuarine beach had accreted at the southern end of the Caples seawall.

Located in mid-Bay, this shoreline receives a high level of wave energy, exacerbated by winter storms and northwest winds. The crumbling Caples seawall provided limited shallow intertidal-habitat value, and continued wave refraction impacted on the near-shore bottom habitat. As the condition of the seawall continued to decline, the shoreline became littered with rubble that was hazardous to people who use the waterfront. Shoreline protection was minimal.

The Caples Shoreline Naturalization project was designed to remove the 325-foot seawall, prevent significant erosion at the northern juncture with the Ringling Museum wall and encourage the restoration of the estuarine beach. Another objective of the project was to create an educational program encouraging seawall removal and shoreline restoration where possible throughout the Bay area. The Caples Shoreline Naturalization project would serve as a model for some Bay property owners.

The Caples project demonstrates alternatives to seawalls.

The effort began in Fall 1990 with project design and removal of exotic vegetation (Australian pine, Brazilian pepper and several palms). Ten transects were established, and topographic profiles were developed. Water quality was sampled and submerged and terrestrial vegetation was characterized, as was submerged fauna. Sampling and characterization studies were performed by New College Environmental Studies Program students, providing an educational opportunity to learn about the estuarine environment and Bay issues.

In June 1991, the seawall was removed and broken, and the clean material placed at the juncture of the Ringling Museum wall to minimize further scouring and provide a gradual transition to the naturally accreating sandy-beach shoreline at the southern portion of the site. During the following fall and winter months, the shoreline was allowed to erode and establish its own equilibrium. The shoreline receded approximately 30 feet from its original seawalled position.

Bi-monthly monitoring of shoreline topography and vegetation was conducted. The newly created intertidal and shoreline habitats were planted with native vegetation in Spring 1992.

Shoreline profiles will continue to be monitored, as will plant survival and health. An educational program targeted toward Bayfront property owners will be developed. The SBNEP Citizens Advisory Committee plans to sponsor a permit-writers workshop to explore alternatives to shoreline hardening. The workshop is a high priority within the 1992 Citizens Action Plan.

The Caples Shoreline Naturalization Project is being managed by students of the Environmental Studies Program at New College, with technical assistance from FDER, FDNR and Program staff. The FDER contributed $10,000 to the project. New College provided significant in-kind services.

Benthic Habitat Repair (Sediment Capping)

More than 4,800 acres of Sarasota Bay bottom has been damaged by dredging activity or other associated coastal development (see Bay-Bottom Habitat Chapter). Much of the past dredging was done to create waterfront property or finger-fill canal communities, resulting in deep holes with water depths of 12-18 feet. In Bay areas with poor water circulation or low-velocity currents, these holes have served as sinks for fine-grained, often anoxic, sediments that support very little plant or animal life.

Resuspension of the flocculent bottom layer during storm events or from boat propeller wash contributes to poor water quality.

One of the largest of the deep borrow holes is in Anna Maria Sound, south of Cortez Bridge near Leffis Key on Anna Maria Island. The hole is surrounded on three sides by productive seagrass meadows. At its center, the hole is approximately 18 feet deep. The soft bottom sediments are estimated to be at least 10 feet thick and suspected to be anoxic.

The project will cover the entire bottom of the hole with a thin cap (approximately two to three feet) and fill approximately one-quarter of the hole, using clean native material from the Leffis Key Habitat Restoration site. By elevating a portion of the hole into the photic zone, approximately 9,800 square yards of habitat suitable for seagrass transplanting and recolonization would be created. Objectives of the project include demonstrating the technical feasibility of capping fine-grained deposits to isolate them from resuspension into the overlying water and raising the level of the impacted bottom to restore it to biological productivity.

The Benthic Repair Project is innovative in at least two ways: it represents the potential for a fundamental shift in policy toward viewing dredging as a tool for beneficial, positive environmental change by converting existing negatively impacted areas into productive use with simple, minimal technology; the capping process can also complement other habitat-restoration projects – such as Leffis Key – by productively using excess spoil material that would otherwise be a project liability.

The recommended methodology for controlled, accurate placement of the cap is to re-slurry the clean fill material in a holding area and pump it through a stationary dredge to a submerged diffuser at the hole. Use of the diffuser minimizes upper water-column impacts, improves placement accuracy and controls sediment spreading, thus reducing negative impacts to benthic and seagrass communities. Silt barriers will be used to protect the adjacent seagrass beds from any siltation.

Reconnaissance, precision bathymetry, permitting and preliminary design will begin in Fall 1992; sediment capping and seagrass transplanting are scheduled for Summer 1993. A comprehensive monitoring plan is a major component of this project.

Mote Marine Laboratory will manage the project with assistance and co-sponsorship of the U.S. Environmental Protection Agency, FDER, Manatee County and Florida Sea Grant. The Technical Advisory Committee of the SBNEP will provide technical expertise. Total estimated costs for the project are $250,000.

Habitat-restoration projects provide opportunities for public education.

Seagrass Signage

During the last 40 years the seagrass-bed acreage in Sarasota Bay has shrunk an estimated 25-30 percent. Motorboat-propeller cuts are one of several factors potentially responsible for declines in productive seagrasses. Motorboat propellers have carved thousands of sandy, curvilinear trenches in productive seagrass beds. Accrued over the years, each scar may take several years to heal.

The purpose of the Seagrass Signage Project is to design and implement a signage program to protect selected seagrass beds in Sarasota Bay from motorboat-propeller damage, promote the need to protect these beds and monitor the effectiveness of these actions.

Objectives of the project include clearly marking the boundaries of selected grass beds, posting interpretive signs to teach boat operators the impacts of propeller scars and the value of grass beds, correlating changes in propeller scarring with locations of the markers, using this information to evaluate the effectiveness of the program and educating the boating public via brochures on the value of seagrass beds to the Bay ecology and the purpose of the demonstration project.

The Seagrass Signage project began in Winter 1990 with the selection of three seagrass meadows to be marked with buoys, delineating the edges of channels adjacent to the grass beds. The three grass beds that were selected are near Sister Keys in the northern portion of the Bay, adjacent to City Island in mid-Bay and directly north of Siesta Key and

bordered by Big Pass in the southern Bay.

Three types of buoys were designed, manufactured and placed at the edge of selected grass beds. Concurrent with the placement of the markers, materials designed to educate boaters were disseminated throughout the Bay community.

To educate and inform area boaters about the ecological importance of seagrasses and the role motorboat propellers have in their decline, a brochure titled "Seagrasses, Luxuriant Bay Meadows" was designed and produced in December 1990. More than 8,000 copies of the brochure have been distributed through boat-ramp signs, slide presentations, SBNEP programs and community marine-related events. An adhesive-backed, laminated sticker depicting what a boater should do to exit a shallow grass bed if he or she runs aground was designed to be affixed to the consoles of motorboats. The decals were distributed at slide presentations, at area marinas for rental boats and at other boat-oriented distribution points.

Two boat-ramp signs were installed, one at the City Island public boat ramp and the other at the Coquina Bayside Park public boat ramp. These signs inform boaters of the need to protect seagrasses and to use proper exit behavior off a grass flat. The seagrass brochure is also available at the boat ramps.

A 15-minute slide show for boaters was assembled and presented to local groups. Newspaper and newsletter articles and television-news spots informed the public about the seagrass signage program as well as the value of seagrasses and the boaters' role in grass-bed damage.

Effectiveness of the program was evaluated from two different perspectives. One measured direct damage to the three grass beds by mapping the propeller-cut trails. The other focused on potential damage by examining boaters' behavior patterns.

Aerial photographs of the grass flats were taken to record the number and location of prop-cut trails before and after the buoys were placed. By comparing the number of propeller cuts formed per unit of time both before and after marker installation, it was possible to measure whether markers affected the amount of boat-propeller damage to the grass beds.

Observation studies of two seagrass meadows recorded boater behavior before and after buoy placement. It provided data concerning boat entry to the grass bed, speed and course change near the markers, grass-flat exit procedures and general information about boat size, boater activities and boat type. Because the boater survey indicated that half of the stranded boaters were purposely in the seagrass bed fishing, it can be concluded that boater education is a pivotal component of the Seagrass Signage project. An education program will inform boaters of the ecological importance of seagrasses and proper exit behavior.

Preliminary data indicate the signage project is effective in reducing the impact of propellor scarring. The data from initial monitoring of pre-marked seagrass beds and beds marked with signage suggest that propellor scars have been reduced in length each month by amounts of at least 30 percent.

As an example, the Sister Keys signage project – with 43 acres that were marked and monitored – had a 35-percent reduction in linear footage of damage to seagrass beds by propellor scars, and Big Pass seagrass beds – with 14 acres that were marked and monitored – had a 30-percent reduction.

However, the marked seagrass beds do appear to attract boaters, but those boaters seem to be going slower as they enter the seagrass beds. This is viewed as a positive sign of the project's effectiveness.

The Seagrass Signage Project was developed and managed by the Environmental Studies Program of New College, University of South Florida at Sarasota. Eleven New College students were trained to observe and record boater behaviors. The U.S. Environmental Protection Agency provided $25,000 in resources; the SBNEP provided $5,000 for the project, technical guidance and citizen input. Total cost of the project is $30,000.

Sister Keys Seagrass Survey

The Sister Keys are four islands in northwestern Sarasota Bay located off the northeast tip of Longboat Key. They make up a 100-acre area of mostly undisturbed mangrove wetlands and uplands surrounded by lush, productive seagrass beds. These keys are the largest remaining open-water mangrove islands between Tampa Bay and Charlotte Harbor, and their associated seagrass beds constitute one of the largest remaining seagrass communities in Sarasota Bay. Sportsfishermen and commercial fishermen alike enjoy the resources provided by the surrounding seagrass meadows.

The seagrass beds of Sister Keys have already been impacted indirectly by development that has occurred along Longboat Key to the west and Tidy Island to the east. Development of Sister Keys would likely have significant negative impacts on surrounding water quality, intertidal and subtidal habitats.

The Sister Keys Seagrass Survey was

developed to provide information to the Town of Longboat Key regarding the aquatic environment surrounding Sister Keys.

Specifically, objectives of the study included identification of the seagrass species present around the islands, listing of fish and invertebrate species found in the waters surrounding the islands, bathymetry measurements and a compilation of information regarding nearby and local seagrass beds and the detrimental impacts on seagrass beds due to wastewater effluent and dredge-and-fill activities.

Natural habitats found in the wetland areas of Sister Keys include intertidal salt marshes and mangroves. The mangrove fringe of the island is composed of the four species of mangrove: red, black, white and buttonwood. The surrounding shallow Bay waters support highly productive benthic and seagrass communities. Three seagrass species dominate the Sister Keys subtidal habitat: turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*) and manatee grass (*Syringodium filiforme*). The size of the nearshore seagrass meadows, as estimated using aerial photographs, is approximately 840 acres.

Species collection and observation for the Sister Keys grassbeds occurred over a three-day period in October 1990. A total of 24 species of fish and 26 species of invertebrates were documented from the grassbeds of Sister Keys during the study.

Bathymetry readings for the grass flats were taken along four transects with maximum depths ranging from 1.01 feet Mean Lower Low Water (MLLW) on the east side of the island to 2.96 feet MLLW on the north side of the island. Depths of these grass flats are consistent with depths observed on many grass flats in Sarasota Bay.

Development of the Sister Keys islands, which would require installation of septic systems, would result in increased nutrient loadings from sewage effluent to surrounding seagrasses. The resulting nutrient loadings would likely have a negative impact on health and abundance of the seagrasses.

Turbidity from any development-related dredging activities will also negatively impact the Sister Keys seagrasses due to the loss of available light needed by the plants for photosynthesis. Increased boating activities, such as residents commuting to and from the islands, could potentially cause increased scarring of the grassbeds by boat propellers.

In June 1992 the Town of Longboat Key purchased the Sister Keys and will manage the environmentally significant islands as open space.

Seagrass transplants can be used as biological indicators of water-quality improvements.

Seagrass Transplanting

Seagrasses are an important habitat in the estuarine system. With an extensive rhizome root structure and above-ground leaf clusters, seagrasses help to stabilize the Bay bottom, retard currents and remove sediments, which helps to reduce erosion and improve water clarity. Seagrass communities also provide habitats and nursery grounds for a variety of fish, invertebrates and other marine species. In Sarasota Bay, seagrass meadows provide feeding and resting locations for the endangered manatee. In addition, the seagrass communities provide input into the food web of the estuarine system via leaf litter, epiphytic microalgae and drift macroalgae.

The Seagrass Transplant project directly addresses three goals of the Sarasota Bay National Estuary Program: improve water transparency, restore lost seagrasses and eliminate further losses, and restore and sustain fish and other living resources in Sarasota Bay. The objectives of the project include identifying and selecting appropriate donor seagrass beds and transplant areas, transplanting shoal grass (*Halodule wrightii*) into selected areas, and monitoring survival and health of these transplanted seagrasses and recolonization of seagrasses in donor beds. Shoal grass is the preferred species for transplanting, because it can grow quickly in shallow, more estuarine waters. Shoal grass also is more tolerant of poorer water quality than other species of seagrasses.

Data from the Programs's Water Quality Monitoring Program indicate that sufficiently high water clarity and sufficiently low water-column nutrient levels exist to support shoal grass in the shallow fringing areas near

Whitaker Bayou. The absence of shoal grass in the submerged waters offshore of Centennial Park is thought to be due to the past discharge of secondary-level wastewater into nearby Whitaker Bayou. With the City of Sarasota's Wastewater Treatment Plant now upgraded to tertiary treatment, water quality is better than in many areas currently vegetated with shoal grass.

Since seagrass health is a significant indicator of water quality, a transplanting effort was designed to determine if water quality in the area just south of Whitaker Bayou has improved such that shoal grass can now grow in this previously impacted area.

In October 1991, the Sarasota Bay Program, in cooperation with the Florida Dept. of Natural Resources and citizen volunteers, transplanted approximately 160 shoal-grass units from a donor bed located in Pansy Bayou.

In December 1991, the donor and transplant sites were monitored by citizen volunteers with SBNEP staff oversight. It was determined that overall survival at the transplant site was approximately 80 percent. Recovery of the donor bed was indicated. The sites were monitored a second time in February 1992; the overall transplant survival rate appeared to be about 66 percent, while the donor meadows showed evidence of continued recovery.

Program staff and citizen volunteers will continue to monitor the sites for survival and regrowth. Additional potential sites will be evaluated for future seagrass-transplanting efforts.

Clower Creek Stormwater Management

Clower Creek drains approximately one square mile (300 acres) of a small urbanized basin on the mainland to Little Sarasota Bay. The watershed is typical of many watersheds throughout the Sarasota Bay area and coastal Florida. The Clower Creek drainage basin is approximately two to three miles in length and one-half mile wide. The headwaters of the creek are in heavily urbanized development, with the lower part of the creek draining an intensive residential-development area and some open space. A large commercial shopping mall and other shopping centers located within the watershed only one-half mile from Sarasota Bay.

The majority of the approximately 150 commercial acres in the basin have on-site stormwater-retention and detention ponds. Approximately 95 acres of residential area in the Clower Creek basin generally provide no stormwater management. Sarasota Square Mall is the largest commercial development in the Clower Creek basin, with an area of approximately 95 acres within the 150-acre total. Pelican Cove, a high-density residential development, comprises 50 acres of the residential area in the basin.

Clower Creek has been the focus of much attention since the construction of Sarasota Square Mall in the early 1980s and subsequent expansion of the mall. Residents of Pelican Cove have indicated that sedimentation and flow rates in the creek have dramatically increased since the intense commercial development occurred. Increased flows and creek-bed movement have resulted in stream-bank erosion and additional suspended solids and nutrients discharging to the Bay.

Stormwater runoff has been identified as a major contributor to the problems of Sarasota Bay. Increases in stormwater loadings have been implicated as one cause of Baywide declines in salinity and increased turbidity. To address this complex issue, the Program has set a goal of improving the quality and reducing the quantity of stormwater runoff.

The Clower Creek project will reduce further sedimentation and related water-quality impacts to Little Sarasota Bay, prevent stream-bank erosion by reducing sediment deposition and flows in Clower Creek, provide an opportunity to evaluate the feasibility and costs of retrofitting stormwater-management systems and provide an opportunity to educate homeowners about stormwater runoff.

The project began in Spring 1990, with Sarasota County Stormwater Management Division as the lead agency. A consultant was selected to characterize the Clower Creek drainage basin and determine stormwater flows, total suspended solids and nutrient loading rates. Cost estimates of recommended improvements and preliminary designs were prepared, as well as cost estimates for prioritized alternatives for plan implementation.

A detailed computer model was developed to compute stormwater runoff from the creek's sub-basins, then model the results after routing the runoff through available retention and detention systems and determine the resultant flows in the Creek. A flow-monitoring and rainfall-gauging station was installed at the Brookhouse Drive bridge in Pelican Cove in Summer 1990.

Rainfall data from four storms was collected by Sarasota County staff, and water-quality data was collected from three of the storms. The collected data was then used to estimate the pollutant load entering

Little Sarasota Bay from rainfall alone. The annual loading values were used to estimate the effectiveness of the nine alternative improvements. Model calibration occurred in Spring 1991.

After extensive review of the nine alternatives by Sarasota County, FDOT, FDER, SWFWMD, SBNEP and others during Winter 1992, four alternatives were recommended: 1) channel improvement of 1,300 feet of Clower Creek; 2) installation of sodded-ditch checks in the swales along U.S. 41 and Vamo Road; 3) routing the flow from the Park East Mobile Home Park into the existing detention pond; 4) effectively utilizing the existing creek-bed weirs.

An improved cross-section of the constricted portion of creek channel with a planted littoral zone would stabilize channel banks and reduce bank erosion. The ditch checks are designed to trap the first flush of runoff, which contains the most concentrated pollutants, and force this flow to percolate into the soil. By re-routing stormwater runoff from the Park East Mobile Home Park through an existing detention pond reconstructed to meet wet-detention criteria, significant reductions in nutrient loadings and suspended solids would result. Periodic maintenance dredging of the two existing weirs near the mouth of the creek upstream of the Pelican Cover Harbor entrance would remove trapped sediments and offer significant reductions in siltation of the harbor entrance and Little Sarasota Bay.

Two other recommendations include routine county-supported maintenance of storm-sewer systems, channels and culverts, and implementation of best-management-practices program (i.e., fertilizer-application control, pesticide-use control, solid-waste collection and disposal and street cleaning) by Pelican Cove Homeowners Assn. The estimated cost to implement all recommendations is $152,600.

Sarasota County contributed $30,000 in 1989 for the Clower Creek Stormwater Management project. The U.S. Environmental Protection Agency provided $70,000 from Early Action Demonstration Project resources. The Pelican Cove Homeowners Assn. has been an active participant in the development of the project. The Program has provided technical expertise and citizen input. Total cost of the project to date is $100,000.

Additional resources have been committed by Sarasota County Stormwater Management to implement recommended improvements. The Florida Dept. of Transportation has committed to designing and constructing sodded-ditch checks along U.S. 41 in conjunction with scheduled improvements to the roadway this summer.

Airport Drain Stormwater Management

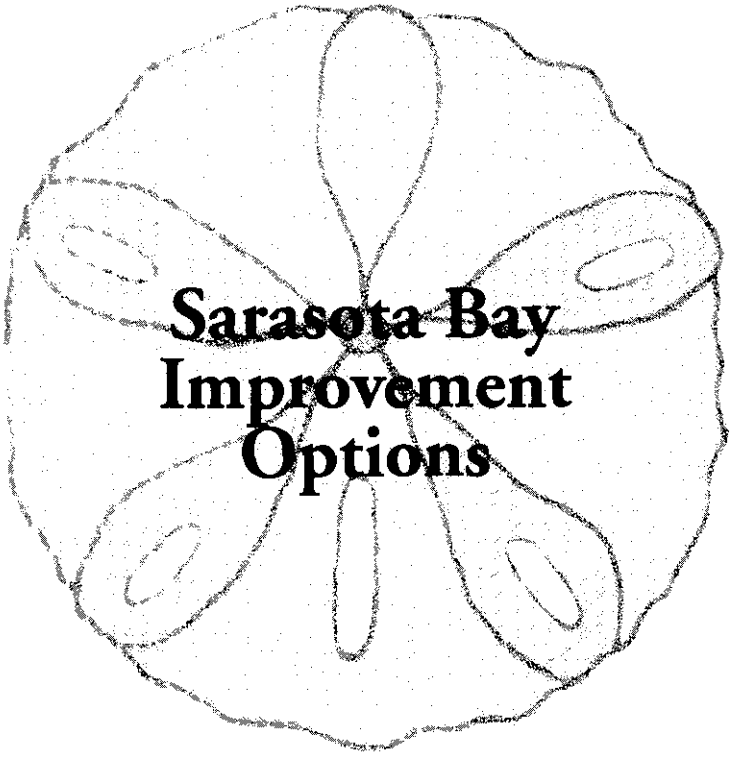
The Sarasota-Bradenton Airport stormwater drain is one of four basins in the Bowlees Creek watershed located near the airport. Bowlees Creek has been identified by the SBNEP as a major source of nutrient and toxic-substance loading to the central portion of Sarasota Bay.

The Bowlees Creek watershed consists of diversified land uses. Approximately one-fourth of the basin is single-family residential; another fourth is occupied by industrial parks, while the remainder of the basin is a combination of residential, commercial and transportation land uses.

The airport drain, at its downstream location, has a siltation basin that is small and ineffectively located on the drain. Manatee County removes approximately 200 cubic yards of sediment annually. Immediately downstream of the siltation basin, the drain is lined with concrete. The current stormwater-management structures are not adequate to capture the high levels of sediment and heavy metals entering Bowlees Creek.

The Airport Drain Stormwater Management project was submitted by Manatee County Public Works as an Early-Action Demonstration Project in 1992. The project consists of expanding the existing desiltation basin and combining a wet-detention stormwater-treatment system to improve water quality. Manatee County owns five acres of land directly west of the drain, making the airport drain location ideal to demonstrate the effectiveness of the in-stream system. The objectives of the project are to capture sediments, reduce nutrient and heavy-metal loadings, reduce erosion and enhance water quality in the Bowlees Creek watershed.

Design of the expanded desiltation basin and wet-detention system will begin in Fall 1992. Construction is anticipated to begin by Fall 1993 and be completed by Winter 1993. Manatee County Public Works will manage the project, with technical guidance and design approval by the SBNEP Technical Advisory Committee. Sources of funding for the project include the U.S. Environmental Protection Agency, the Manasota Basin Board and Manatee County Public Works, for an estimated total project cost of $250,000.



Sarasota Bay Improvement Options

Sarasota Bay Improvement Options

The Bay management options listed here are provided as a basis for discussion on potential restoration and protection strategies for Sarasota Bay. Options presented here are *not* National Estuary Program recommendations, but are the result of discussions among scientists, managers, and citizen and technical advisors. Additional, detailed options are provided by the principal investigators at the end of each technical chapter in the *Framework for Action.*

These options are not all-inclusive, but may contribute to effective, comprehensive restoration strategies supported by technical work conducted by the Sarasota Bay Program during the past two years. These and other options will be analyzed for possible inclusion in the final Sarasota Bay *Comprehensive Conservation & Management Plan,* due in Summer 1994. That plan will recommend Bay improvement actions, parties responsible for those improvements and funding sources that should be applied to restoring Sarasota Bay.

Introduction

An effective restoration and protection plan for Sarasota Bay must focus on the Bay's major problems. During the past two years, the National Estuary Program has conducted 14 technical projects, 13 early action demonstration projects and numerous public-outreach activities to investigate and define the Bay's problems.

Results of this work point to several areas in which action should be taken to improve Sarasota Bay:

1. Habitat
2. Water and Sediment Quality
3. Finfish and Shellfish
4. Recreational Access and Use
5. Citizen Involvement
6. Bay Management

Improving the Bay will not be accomplished quickly, and will require consistent policy and action, continued ecosystem monitoring and the development of public/private partnerships.

Habitat

In the Sarasota Bay watershed, 39 percent of intertidal wetlands, at least 16 percent of freshwater wetlands and about 30 percent of seagrass habitats have been lost. Moreover, approximately 5,000 acres (15 percent) of Bay bottom have been disturbed by dredging, often resulting in areas of significantly reduced biological productivity.

Dredge-and-fill activity for residential and commercial development led to most losses of intertidal and seagrass habitats, while freshwater wetlands were lost to both agriculture and urban development.

As population expands, wetlands will continue to be lost and degraded – albeit at a significantly reduced rate, due to current regulation – and few incentives exist to enhance or restore wetlands throughout the basin. Additional major losses of seagrasses are unlikely, but damage is expected to continue from direct physical impacts such as boat-propeller scarring and dock construction. Improvements in water quality would result in substantial increases in seagrass habitat.

Management Options: Wetlands

A strategy to optimize intertidal and freshwater wetland habitats should include multi-jurisdictional coordination, naturalization and enhancement, protection and acquisition.

1. Multi-jurisdictional Coordination:

A. The Sarasota Bay region should implement coordinated wetlands restoration, creation, enhancement and acquisition activities.

B. The Sarasota Bay region should enhance local efforts in wetlands preservation and education.

2. Naturalization and Enhancement:

A. Implement physical habitat management (enhancement, naturalization, restoration and creation) in suitable areas.

B. Remove invasive, non-native plants, particularly from wetlands. This could be accomplished through programs implemented by county governments.

C. Soften shorelines in appropriate areas to provide habitat, reduce turbidity and reduce stormwater runoff, while improving aesthetics and access. Possible techniques might include replacing seawalls with vegetated sloping shorelines, rip-rap, terraces or combinations of alternatives.

D. Increase the number of freshwater wetlands. One possible method would be using treated wastewater to restore natural hydrology to impacted wetlands or to create new wetlands.

3. Protection

A. Assure no net loss of Bay habitats from direct physical impacts of any size by requiring that compensation for permittable damage be applied to restoration activities.

B. Improve local comprehensive plans and ordinances to better protect existing wetlands.

C. Educate and encourage private property owners to protect and provide habitat on their properties.

4. Acquisition

A. Place in public ownership areas of ecological importance to Sarasota Bay. Explore opportunities for purchase, conservation easements, living trusts, transfer of development rights, etc. Incorporate current rates of sea-level rise when planning acquisitions.

Management Options: Seagrasses and Other Submerged Habitats

1. Focus water-quality improvement strategies on increasing productive seagrass habitat.

2. Protect seagrasses from scarring by boat propellers. Protection methods could include improving navigational aids, increasing boater education and establishing conservation areas that limit access by motorboats and provide multiple benefits to Bay resources.

3. Restore areas of disturbed Bay bottom whenever feasible.

Water and Sediment Quality

Since the 1800s, water quality in most of the Bay and its tributaries declined as nitrogen loadings to the Bay increased to 300 percent greater than pristine (undeveloped watershed) conditions. Increased nitrogen loadings are attributed to stormwater runoff and wastewater discharge.

Both Manatee and Sarasota counties have established Stormwater Environmental Utilities to address stormwater pollution. Recent improvements in wastewater treatment in Manatee County and the City of Sarasota have resulted in measurable improvements in water quality in some parts of the Bay. However, inadequate wastewater treatment in the lower Bay continues to contribute significant loadings.

Turbidity is another factor affecting water quality in the Bay. Sources of increased turbidity from human activities include stormwater, wastewater and resuspension of Bay sediments.

Altered circulation patterns also affect water quality, particularly in northeastern Palma Sola Bay and Little Sarasota Bay.

Sediments in particular tributaries show high levels of lead, residues of pesticides and traces of PCBs. Stormwater runoff is the source of these toxic contaminants.

Management Options: Water and Sediment Quality

1. Establish zones near the Bay and its tributaries for priority action to improve water and sediment quality. Actions may relate to stormwater, wastewater and habitat management strategies.

2. Reduce nitrogen loadings to the Bay.

Wastewater Options for Nutrient Reductions

Sarasota County is pursuing centralized wastewater treatment where septic tanks and package treatment plants are prevalent. The county plans to construct a new plant near Bee Ridge and Clark roads and to purchase several package plants. The City of Sarasota's wastewater-treatment plant is operating at approximately half its treatment capacity, and by increasing reuse sites, could provide service to portions of Sarasota County. Targeting areas on septic systems near the Bay and tributaries would result in significant nutrient reductions.

A. Eliminate nitrogen loads from septic systems. Methods may include targeting areas on septic systems near the Bay and tributaries for centralized treatment; investigating use of nutrient-removal technology for septic systems; and establishing greater septic-system setback requirements for areas near surface waters. (The Pollutant Loading Assessment reports that a 900-foot setback from surface waters for installation of septic systems would protect the Bay from additional nutrient loading.)

B. Sarasota County should develop a centralized wastewater-treatment system to serve areas on septic systems and package treatment plants, particularly near the Bay and tributaries. Such a system should incorporate agricultural and residential reuse of treated effluent. The county should investigate a combination of public and private service including the proposed Bee Ridge treatment plant, expansion of Central Utilities' plant and service from the City of Sarasota. The county should also investigate nutrient-removal technology for septic systems, particularly in less densely populated areas and barrier islands.

C. The City of Sarasota should optimize the treatment capacity of its wastewater-treatment operation to allow the city to expand service to priority areas in Sarasota County. Effluent disposal concerns should be addressed.

Stormwater Options for Nutrient Reductions

A. Seek to establish natural wildlife corridors or greenbelts to slow stormwater runoff, improve treatment and provide habitat opportunities.

B. Promote improved landscape maintenance practices, concentrating on communities near the Bay and tributaries.

C. Improve maintenance of existing stormwater-treatment facilities for nutrient reduction and habitat value.

D. Review the potential for implementing physical alterations for water quality improvement in manmade, non-navigable portions of state waters. (i.e., Hudson Bayou, Phillippi Creek, Bowlees Creek and Cedar Hammock Creek).

3. Protect the Bay from toxic contaminants.

A. Reduce impervious surfaces where possible. Methods may include reducing the number of paved parking spaces required for large commercial developments and using grassed lots or other pervious systems for overflow parking.

B. During road expansions, seek to treat all stormwater runoff from the roadway wherever possible.

C. Stormwater Environmental Utilities should focus on areas with high levels of toxic contamination, such as Phillippi Creek, Hudson Bayou, Cedar Hammock Creek and Bowlees Creek. After stormwater treatment is addressed, the utilities should investigate opportunities for removing contaminated sediment and/or isolating contaminants by capping sediments in appropriate areas.

4. Reduce turbidity and erosion.

A. Establish speed limits and no-wake zones along appropriate portions of the Intracoastal Waterway.

B. Use capping and removal of sediments in appropriate areas to reduce resuspension.

5. Improve circulation.

A. Improve circulation in northeastern Palma Sola Bay. Investigate the use of road culverts and/or flap gates on the Palma Sola Causeway.

B. Improve circulation in Little Sarasota Bay. Consider reopening Midnight Pass (further analysis of this option is pending mediation).

Finfish and Shellfish

Finfish and shellfish populations have declined significantly from impacts of population growth and increased resource use. Loss of nursery habitat for finfish and contamination of shellfish by stormwater have been identified as major problems.

Management Options: Finfish and Shellfish

1. Increase and protect fishery habitat, particularly for early juveniles of recreationally and commercially important species.

A. Design habitat-restoration and enhancement projects to maximize fishery habitat and productivity.

B. Restore tributaries as a fisheries habitat.

C. Restore and enhance shellfish habitats.

D. If seawall habitat modules are deemed effective through the pilot project underway, promote the use of modules along seawalls in appropriate areas.

2. Protect existing fish populations.

A. Establish conservation areas that limit access or activity in selected, highly productive areas of the Bay.

B. Explore enhanced fishery management measures (bag limits, seasons, gear) for Sarasota Bay, combined with careful monitoring.

C. Promote proper catch-and-release and other recreational angling practices to increase conservation.

D. Explore possibilities of increasing fish populations through stocking.

Recreational Access and Use

The Recreational Use Assessment identified certain areas of the Bay where better management would increase recreational enjoyment, improve safety and protect Bay resources such as marine mammals, birds and habitats.

Management Options: Recreational Access and Use

1. Improve management of recreational uses in the Bay. Particular areas to be addressed include Palma Sola Causeway, the Intracoastal Waterway (ICW) dogleg in northern Sarasota Bay, Longboat Pass, Big Pass, ICW near Phillippi Creek, Venice Inlet.

2. Reduce user impacts on resources including marine mammals, birds, seagrasses and natural shorelines.

3. Increase managed access to the Bay.
A. Improve existing access points.
B. Provide additional access in publicly owned areas.
C. Create new recreational opportunities or destinations.

Impacts of Sea-Level Rise

At current observed rates of sea-level rise, higher high tides experienced in the Sarasota Bay area will be 2.2 inches higher in the year 2020 and 9.8 inches higher in 2115 than at present. Accelerated rates of sea-level rise based on the best, most recent estimates of global warming indicate that higher high tides could be 5.8 inches higher in 2020 and 25.2 inches higher in 2115 than present levels. Higher water levels would impact natural systems, infrastructure and archaeological sites.

Management Options: Impacts of Sea Level Rise

1. Local comprehensive plans should address current rates of sea-level rise, particularly relating to development patterns.

2. Permitting processes should ensure that intrastructure will be functional throughout its estimated lifespan, given current rates of sea-level rise.

3. Impacts of current rates of sea-level rise should be addressed in beach-renourishment projects and wetlands protection.

Beach and Inlet Management

Numerous beach-renourishment and inlet-maintenance projects are planned or under way throughout the Sarasota Bay region. A regional approach to planning and permitting these projects could reduce impacts to Bay resources and increase efficient management of maintenance processes.

Management Options: Beach and Inlet Management

1. Develop a beach and inlet management plan for the Sarasota Bay region.

Additional Data Collection, Analysis and Monitoring

The Sarasota Bay Program's work to characterize the environmental quality of Bay resources provides a foundation for developing long-term data collection, analysis and monitoring priorities. This will be essential to measuring the effectiveness of Bay improvement strategies and adjusting those strategies for maximum benefits. Potential data needs are described by principal investigators within technical chapters in the *Framework for Action.*

Management Options: Data Collection, Analysis and Monitoring

1. Develop a long-term plan for data collection, analysis and monitoring in the Sarasota Bay watershed. Data collection, analysis and monitoring priorities will be developed in coming months by the Technical and Citizen Advisory Committees of the Sarasota Bay Program. This effort will be coordinated with related local, regional, state and federal programs, as Bay improvement options and related data needs are refined.

Citizen Involvement

Many people express concern for the Bay's health but are not certain what they can do to help the Bay. For people to be motivated to help improve Sarasota Bay, we must understand the Bay's problems, be convinced of our part in creating the problems, and understand how we can help solve the problems. Then we will be ready to act. To accelerate the public's involvement in restoring Sarasota Bay, the Program's Citizen Advisory Committee has recommended a strategy that:

1. Targets specific Bay problems and educates the public to help solve the problems;
2. Targets segments of the community who are most closely associated with the various problems; and
3. Tailors education and involvement programs to most effectively reach those people.

The ultimate goal of providing education about the Bay to the community is to promote citizen actions to improve and protect the Bay. The citizen's role should be threefold:

1. To advocate appropriate decisions by government;
2. To make lifestyle changes necessary to protect the Bay; and
3. When possible, participate in Bay education and improvement projects to involve other people in improving the Bay.

Options for citizen involvement will be developed during the coming months as Bay management options are refined. The Citizen Advisory Committee will be instrumental in helping citizens throughout the

community participate in Bay restoration. The CAC, by motivating groups its members represent and using personal networks to advocate change, would be the nucleus of an effective advocacy organization for pursuing Bay improvement strategies.

Bay Management

During the winter of 1991-92, the Sarasota Bay National Estuary Program – through a special grant from the U.S. Environmental Protection Agency, Office of Watersheds Oceans and Wetlands – conducted a series of interviews with senior environmental managers and personnel from around the region. In general, the study found that:

1. The Sarasota Bay National Estuary Program has been successful in focusing attention among the multitude of local jurisdictions on the environmental conditions and problems of Sarasota Bay.
2. Strong general support exists to develop and implement a comprehensive restoration plan for Sarasota Bay.
3. Those interviewed by the Governance Study stressed the need to continue a formal institutional structure for the Program beyond the five-year planning phase to assure coherent implementation of the recommended action program and to recruit funding for long-term restoration and remediation activities.
4. At the end of the planning phase, the role of the Sarasota Bay Program could change to recruiting funds, providing technical assistance to implementing agencies, focusing public attention on key issues and coordinating the review process for major, multi-jurisdiction public and private development proposals that would impact the Bay.

Four important organizational roles must be fulfilled for the future management of Sarasota Bay:

- Coordinating Bay restoration among the multitude of jurisdictions having responsibilities for implementing policies set forth in the comprehensive Bay management plan;
- Recruiting and combining funds to execute priority Bay-restoration activities;
- Maintaining the unique environmental "knowledge base" that has been assembled for the planning phase, including the mapping of conditions and trends in the Bay;
- Evaluating, managing and planning for the unique identity and needs of the Bay.

Given these needs, a number of alternative organizational forms were considered for coordinating Bay restoration after the *Comprehensive Conservation and Management Plan* is completed in 1994. Bay management options were developed from the interviews and through discussions among citizen and technical advisors to the Sarasota Bay Program. Relative merits and demerits of these and other options for Bay management will be analyzed by the Sarasota Bay Management Conference in coming months.

Management Options: Bay Management

1. Determine the best organizational structure for implementing restoration activities.

A. Continue the Sarasota Bay Program in its current form.

B. Administer Bay improvement strategies through existing entities of government (state, regional and local).

C. Establish an elected body with a special taxing district, such as a "Sarasota Bay Water Quality Authority."

D. Organize a Bay-restoration initiative as an affiliate of a Regional Planning Council.

E. Organize a Bay-restoration initiative as an affiliate of the West Coast Inland Navigation District (WCIND).

F. Establish a voluntary, interlocal council of governments through state statute.

2. Provide for administrative supervision of Bay-restoration activities. The analysis of future governance options for Sarasota Bay restoration did not investigate options for administrative supervision. However, the investigators observed that the existing arrangement (the Southwest Florida Water Management District [SWFWMD] providing administrative support to the Sarasota Bay National Estuary Program) seems to work well. If a future management arrangement calls for a small core staff to coordinate restoration efforts, a similar form of "outsourcing" for basic administrative functions would be advisable, according to the investigators.

3. Develop financing strategies to pay for Bay restoration. Financing Sarasota Bay restoration would be easy if resources were unlimited, but they are not, and decision makers must constantly balance different needs of the community and available resources. Restoring Sarasota Bay will rely upon the community's desire to take decisive action and creativity in matching appropriate finance options to restoration and protection activities. In coming months, as Bay improvement options are further defined, the Sarasota Bay Program will work with public and private sectors in the community to devise workable financing plans for Bay restoration.

Citizen Involvement in Sarasota Bay

Citizen Involvement in Sarasota Bay

by Heidi Smith
Sarasota Bay National Estuary Program

Executive Summary

It is fitting that the plan to save Sarasota Bay should culminate with the public's role in restoration. After all, the first voices raised in defense of the Bay were those of people whose livelihoods and lifestyles depend on a healthy Bay. From fisherfolk to families with generations of Baywatchers in their past, people noticed the Bay's decline and spoke out. Growing public sentiment, government support and the best efforts of science have brought the Sarasota Bay community closer than ever before to solving some of the area's most pressing environmental problems.

Some solutions to the Bay's problems will require action by elected officials and their appointed staffs. But all the solutions will require support from or action by the public, either through advocating the best options for government decisions or through changing individual actions to improve or protect the Bay.

To be motivated to help restore Sarasota Bay, we must understand the Bay's problems, be convinced of our part in creating those problems and understand how we can help solve them. Then we will be ready to act.

Understanding the Bay's Problems

A public-opinion survey conducted for the Sarasota Bay Program in 1990 showed that although people were concerned about the Bay's health, they did not fully understand the Bay's problems (Florida Atlantic University, 1990). For example, while nearly 74 percent of the people surveyed were "very concerned" about the loss of native habitat and its effects on fishing and shellfishing, less than 45 percent were "very concerned" about the effects of stormwater runoff. Clearly, the impact of stormwater pollution on fishing and shellfishing was not understood.

Recognizing that people cannot be part of solutions if they don't understand the problems, the Sarasota Bay Program's Citizen Advisory Committee (CAC) focused the Program's outreach on helping the public understand Bay problems. The Sarasota Bay Program staff made numerous presentations to community groups, highlighting what were emerging as the Bay's three major problems: stormwater runoff, wastewater discharge and habitat loss.

In discussions following these presentations, many misconceptions about Bay issues were evident. For example, many people said they believed the City of Sarasota's treated-wastewater discharge to Whitaker Bayou is the major source of pollution to Sarasota Bay. Many incorrectly assumed the discharge was "raw sewage," and that the city was making little headway in improving treatment levels or removing the discharge from the Bay. However, the city has upgraded the plant to advanced wastewater treatment, and water quality has improved in the area.

In addition, people were generally surprised to learn that stormwater is the major polluter Baywide, and that residential areas in the watershed are significant sources of stormwater pollution.

Another example of general misunderstanding among members of the public became apparent during workshops on the state's mangrove-pruning regulation. As part of the CAC's first Action Plan in 1990-91, two workshops were held by the Sarasota Bay Program and Florida Sea Grant College, with support from the Tri-County Chapter of the Landscape Maintenance Assn. Many citizens who attended the workshops generally had little knowledge of the ecological necessity of mangroves, and were unaware of scientific information on the negative impacts of pruning.

Whose Problem Is It?

The public's relationship to Sarasota Bay may be described by four basic categories:

- People who live next to the Bay.
- People who use the Bay for work or recreation.
- People who don't use the Bay, but like knowing it's there.
- People who don't think about the Bay at all.

According to the Program's public-opinion survey, the final category includes only about two percent of the Manatee-Sarasota community. That means just about everyone has a stake in Sarasota Bay.

Many people might say that those who benefit the most from a healthy Bay – waterfront-property owners and Bay users – also have the greatest potential for harming the Bay. In some ways, that may be true.

For example, owners of waterfront property depend on Sarasota Bay for the view and water access that enhance quality of life and increase property values. Yet stormwater runoff from waterfront properties could have an immediate impact on the Bay's water quality, and improper mangrove pruning damages an important part of the Bay's ecology.

Boaters rely on the Bay for recreation, yet unwary boaters can damage seagrass beds by running aground in its shallow waters, and pumping contaminated bilge water into the Bay is outright pollution.

Scientific work by the Sarasota Bay Program shows, however, that wherever we live, work or recreate in the watershed, each of us contributes to the Bay's problems. Stormwater runs off from roads, parking lots, yards and farms. That means anyone who drives a car or fertilizes a yard may be

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contributing to Bay pollution.

Wastewater pollution is another significant problem, particularly in the southern reaches of Sarasota Bay. Septic systems near tributaries and Bay waters, as well as some package-treatment plants, are polluting the Bay in southern Sarasota County. Residents of the City of Sarasota still contribute to Bay pollution, as well. Although the city has greatly improved the treatment level of the effluent and is expanding reuse operations, discharge to the Bay continues. Relying on existing wastewater-treatment operations means that residents of Sarasota County or the City of Sarasota who flush a toilet or take a shower also contribute to the Bay's problems.

So Bay pollution is everyone's problem. Fortunately, the majority of Sarasota Bay-area residents care what happens to the Bay. More than 80 percent of people surveyed in Manatee and Sarasota counties were "very" or "fairly" concerned about local Bay waters. And most (nearly 65 percent) were even willing to pay more in taxes to restore Sarasota Bay.

Who is "the Public," Anyway?

The Sarasota Bay area is home to about 500,000 people in two counties (Manatee and Sarasota) and nine incorporated cities or towns. Approximately 400,000 residents are of voting age, but only about half those are registered and actually vote. Three-quarters of the total population are over the age of 35, and more than one-third are over age 65 (Florida State University, 1991).

Estimates of the percentage of seasonal residents vary from 10-25 percent of the total population, depending on the source. On the barrier islands, such as Siesta Key and Longboat Key, the percentage of winter-season residents is probably much higher, around 70-90 percent (Florida State University, 1991). And then there are seasonal renters and tourists, whose impact on the economy and the Bay is significant, but difficult to quantify.

The makeup of the community, with so many part-time residents and newcomers, presents a challenge to environmental education and protection efforts. While these population groups may be some of the most intensive users of Sarasota Bay, they might not think of the Bay area as home, and may therefore have less of a stake in protecting Bay resources. Certainly, their understanding of threats to the Bay's fragile ecology is likely to be even less than that of year-round residents, whose incomplete knowledge of Bay issues has been documented by the Program.

To the benefit of Bay outreach programs, the Sarasota Bay area is replete with clubs, civic organizations and conservation groups whose memberships expand considerably during the winter season. These groups provide forums for reaching larger numbers of people with Bay education and action programs. Some areas have close-knit neighborhood associations that provide an excellent way to reach people who have a strong sense of community. The commitment and participation of these organizations also will be essential in changing public attitudes and actions related to the Bay.

The children of the Sarasota Bay area are some of the most ardent supporters of the Bay. More than 55,000 children are enrolled in Manatee and Sarasota public schools, and both school districts have been strongly supportive of improving Bay education. The Program has provided funding to both school districts for teacher training and curriculum development (see summaries of public-school programs in this chapter). Instructional programs stress understanding how Sarasota Bay's natural system is supposed to work, how people have damaged that system and how they can help repair it. Students take the messages to heart, and to their homes, sharing the Bay-protection message with parents and friends.

How the Public Can Help

Encouraging signs for Sarasota Bay's future are the number and diversity of people already active in promoting and protecting the Bay. Environmental organizations, teachers and students, trade associations, private foundations, civic clubs, church groups and neighborhood associations are participating in Bay-improvement projects. This core of commitment is expanding, but the pace must be accelerated to make significant strides in restoring the Bay.

To accelerate the public's involvement in restoring Sarasota Bay, the Program's Citizen Advisory Committee has been developing a strategy that:

1. Targets specific Bay problems and educates the public to help solve the problems.
2. Targets segments of the community that are most closely associated with the various problems.
3. Tailors education and involvement programs to most effectively reach those people.

Solving Sarasota Bay's problems will be a long-term process; therefore, people will need to be strongly motivated to maintain their commitment to restoring and protect-

ing the Bay. To forge that commitment, people need to be involved in hands-on activities that promote personal interaction with the Bay. People learn best when they *do*. A personal experience with the Bay, such as planting marsh grass, cleaning a shoreline or monitoring grass flats, is much more likely to influence a person's actions than reading a brochure.

Educating people about the Bay's problems and involving them in solutions can be accomplished in a variety of ways. To investigate ways to expand the pace of educating the public on Bay issues, the Program contracted with Florida State University's Conservatory in Motion Picture, Television & Recording Arts to develop a plan for the use of broadcast media and videos. Graduate students researched the local television and radio market, and conducted telephone interviews with most major clubs, neighborhood associations and civic groups in Manatee and Sarasota counties. Their research produced three primary methods for disseminating information about the Bay: 1) promoting activities worthy of news coverage; 2) providing videos and related instructional materials to schools; and 3) making personal presentations to community groups.

The Program has pursued all three avenues. News coverage of Program activities, and subsequent examination of Sarasota Bay's problems, averages two stories per month through local media sources. The Program's Speaker's Bureau includes citizen volunteers who use the Program's 15-minute video on Bay problems in making group presentations. Copies of the video are provided to each school in Manatee and Sarasota counties, and teachers in both counties are incorporating the video in instructional programs.

Public outreach by the Program began by producing a Bay reference called *The State of the Bay Report, 1990.* The illustrated volume presented what the community knew about Sarasota Bay at that time. The Program also participated with Sarasota County in producing the *Bay Repair Kit*, an award-winning guide to Bay-friendly living. After the original printing of 3,000 copies was distributed in about 30 days, the Program participated with the American Littoral Society, William & Marie Selby Foundation, NCNB Community Foundation and Sarasota County in reprinting the publication. Approximately 20,000 of 30,000 copies were mailed to residents living near Sarasota Bay; the remainder are distributed by mail upon request or at community events. A classroom set was provided to each public school in both Manatee and Sarasota counties.

The Program also began producing a newsletter several times a year, providing news of the Program's activities in the context of defining and solving Bay problems. The *Bay Monitor* also is the vehicle for awarding the Program's "Bay Hooray!" award, which recognizes groups and individuals who work to restore and protect Sarasota Bay (see related story in this chapter). Recognizing exemplary stewards of the Bay helps encourage others to participate, and describes model projects that other organizations could adapt.

As Sarasota Bay's problems became better defined through the Program's technical work, more specific messages were developed based on major issues. The Citizen Advisory Committee produced Citizen Action Plans in 1991 and 1992, targeting education efforts to specific Bay problems and target audiences.

For example, loss of mangrove habitat was one focus of the 1991 plan. The Program capitalized on the community's interest in a controversial mangrove-pruning regulation implemented by the State of Florida in 1991. Workshops to explain the complex rules were held, and the importance of mangroves to Sarasota Bay's ecology was strongly emphasized. Promotion for the workshops targeted waterfront areas, landscape-maintenance professionals, utilities' maintenance supervisors and local government employees who are involved in mangrove regulation or shoreline maintenance. Approximately 200 people attended the workshops, and many more requested explanatory literature developed by Florida Sea Grant College. The strong interest in the topic has prompted Sea Grant and the Sarasota Bay Program to develop a more comprehensive approach to educating target groups on mangrove protection.

The public learned more about habitat loss and restoration through the Program's Early Action Demonstration Projects (see Early Action Demonstration Projects chapter). Thorough media coverage of projects at various stages allowed the Program to deliver strong messages about the extent of habitat loss and the need for restoration strategies.

Stormwater was another topic included in the 1991 Citizen Action Plan. The Program worked with stormwater managers in Sarasota and Manatee counties to develop a stormdrain-stenciling program called "Paint the Way to a Better Bay." The counties coordinate and supply a citizen-volunteer program in which clubs, schools and other organizations stencil a pollution-prevention message on catch basins in neighborhoods. By Spring 1992, nearly 100 people in Manatee and Sarasota counties had painted more than 800 drains since the program was launched in Fall 1991. The ongoing program continues to be supported by the counties' stormwater-management departments.

Another stormwater-related project involved developing coloring-book pages for a booklet produced by the Soil Conservation Service. Coloring books were distributed to school students in Sarasota County, and the coloring pages were distributed separately at community events and to teachers.

Additional topics in the 1991 plan included an assessment for mediating issues on Little Sarasota Bay, a door-to-door personal-interview process and projects related to shoreline-protection alternatives.

The 1992 Citizen Action Plan, implemented beginning in late 1992, builds on its predecessor. The 1992 plan looks to expand volunteer activities related to the Bay with a community grants program designed to encourage citizen groups to develop projects that educate and involve the public in Bay protection and restoration. The Program also plans to investigate opportunities for involving citizens in scientifically monitoring the health of Sarasota Bay.

The focus on habitat loss continues with plans for researching ownership of critical wetlands to help local governments plan acquisition strategies. Protecting seagrass habitats is also included in the 1992 plan, and the Program plans to expand boater-education programs.

The emphasis on preventing stormwater pollution is continued with resources for developing the Florida Yard Program, which will motivate area residents to improve yard design and maintenance to conserve water and protect the Bay.

Increasing the number of environmentally appropriate landscapes in the Sarasota Bay watershed is the goal of the Florida Yard Program, coordinated by the Sarasota Bay National Estuary Program, Cooperative Extension Services of Manatee and Sarasota counties, and the Florida Sea Grant College. The Florida Yard Program provides information and on-site advice to homeowners who want to conserve water, reduce fertilizer and pesticide use, and increase wildlife habitat in their yards.

When the program is available in 1993, Manatee and Sarasota county homeowners will be able to receive yard-calls from Florida Yard Advisors, who are Extension Service Master Gardeners with additional training. The advisors will help homeowners plan improvements in landscape design and maintenance that will help reduce stormwater runoff and increase habitat opportunities for wildlife.

Shoreline protection, mangrove care and proper waste disposal are among other issues homeowners can learn more about through the Florida Yard Program.

Other participants in the Florida Yard Program include the Southwest Florida Water Management District, Florida Dept. of Environmental Regulation, U.S. Environmental Protection Agency, Institute of Food and Agricultural Sciences (University of Florida), Soil Conservation Service, Landscape Maintenance Assn. Tri-County Chapter, Florida Nurserymen and Growers Assn., Florida Sod Growers Assn., Turfgrass Producers Assn., Native Plant Society, Garden Clubs, Mote Marine Laboratory and the John G. and Marie Selby Botanical Gardens.

Volunteers stencil this message near stormdrains to help prevent stormwater pollution.

Ready to Act

Developing outreach projects has helped the Program better refine what types of citizen activities are most effective. Those lessons will be applied in developing a strategy for involving citizens in implement-

ing the Bay restoration plan.

The citizen's role in restoring Sarasota Bay is threefold:

- To advocate appropriate decisions by government.
- To make lifestyle changes necessary to protect the Bay.
- When possible, to participate in Bay education and improvement projects to involve other people in restoring the Bay.

While there is much government must do to alter Bay policies and improve management activities, the will of the people ultimately drives the decisions of elected officials. Therefore, part of the public's role in restoration is supporting and encouraging government's movement toward better Bay policies and management. This support may range from advocacy on specific issues to financial commitments, such as bonds, fees or taxes that will pay for improving the Bay.

To restore and protect Sarasota Bay, the public's commitment to improving habits of daily living also is required. Research by the Sarasota Bay Program documents what many have long believed: individual lifestyles have an impact on the Bay. Many of our daily activities – yard maintenance, waste disposal and so on – can be improved to better preserve Sarasota Bay.

For people with time, interest and energy, participating in Bay education or improvement projects will help spread the word and the work throughout the community. Clubs, schools and government agencies can help make projects and programs available to citizens eager to do their part.

The most effective opportunities for citizen involvement in restoring Sarasota Bay will be closely tied to recommendations for improving the Bay. During the next year or more, the Program's participants and other members of the community will be discussing and refining Bay-restoration options. As that process evolves, so too will the citizen's role in applying solutions to the Bay's problems. That role will be described in the final *Sarasota Bay Comprehensive Conservation & Management Plan*, scheduled for release in June 1994.

Public Outreach Programs for Sarasota Bay

Since 1989, the Sarasota Bay Program has investigated numerous ways to educate and involve citizens in restoring the Bay. Programs for public schools, action projects, exhibits at community events, opportunities for volunteers, workshops and publications are some examples. These activities are summarized below.

More than 15,000 school students have toured the Sarasota BayWalk habitat-restoration project on City Island.

Public School Education

The Program, with considerable assistance from Citizen Advisory Committee members, developed several projects in conjunction with the public-school districts in Manatee and Sarasota counties. Projects include teacher training, curriculum enhancement, literature distribution, field trips, an educational display and other activities.

Elementary Classroom Activities: In Fall 1990, the Program worked with Manatee County fifth-grade teachers to develop *Sarasota BayBook, Vol. I*, a collection of classroom activities for use in conjunction with an existing curriculum on estuarine ecology. The booklet was used in classrooms during Spring 1991, and in-service training sessions were provided to fifth-grade teachers in Fall 1991. The booklet was used in classrooms during the 1991-92 school year and revised in Summer 1992 based on teacher evaluations.

BayWalk Habitat Tours: The Program worked with Mote Marine Laboratory in Spring 1991 to provide guided tours of the Sarasota BayWalk tidal habitat, an Early Action Demonstration Project restoration site on City Island, for 3,000 school children from Manatee, Sarasota and other counties. Tours were provided by high-school students, citizen advisors and other area residents.

In the 1991-92 school year, the Program worked with Sarasota County teachers to develop printed student field guides for use in the BayWalk. Different guides were designed for elementary, middle- and high-school students. The guides, which empha-

size observation and critical thinking, provide information on Bay issues highlighted in BayWalk signage. They also include a worksheet to encourage student interaction.

Environmental Educators' Workshop: The Program hosted a workshop for environmental educators from each school in Manatee and Sarasota counties in Fall 1991. Teachers learned about Bay issues and collected information on available programs from various agencies and organizations. They also toured the Mote Marine Aquarium, Sarasota BayWalk and the Pelican Man's Bird Sanctuary.

Bay Reference Material: The Program provided classroom sets of the *State of the Bay Report, 1990* and the *Bay Repair Kit* to each school in Manatee and Sarasota counties in Fall 1991.

Bay Display: The Program developed a display representing Bay issues and the community's efforts to solve Sarasota Bay's problems. The display is rotated among schools and other public facilities in Manatee and Sarasota counties.

Manatee County Middle-School Curriculum: The Program, in a joint effort with the Tampa Bay National Estuary Program, provided funds to the Manatee County School Board to develop a middle school curriculum on the Bay. A pilot program was developed in the 1991-92 school year, with each school designing unique activities and field exercises for the grade level of choice. The program will be expanded to additional grades at each school in the 1992-93 school year.

Sarasota County Middle-School Science: The Program participated with the Selby Foundation, Mote Marine Laboratory, Selby Botanical Gardens and the Sarasota County School Board in providing training for middle-school science teachers in Spring 1992. The Program provided funding and instruction for part of a marine-science college-credit course for teachers. The Program also purchased aquaria for sixth-grade classrooms in Sarasota County and sponsored a workshop to provide instruction on tank set-up and maintenance to teachers.

Stormwater Coloring Pages: The Program provided artwork to the Soil Conservation Service in Sarasota County for a coloring book for elementary-school students. The artwork features a manatee and other Bay animals to focus on stormwater runoff and how children can help protect Sarasota Bay from pollution; it also is distributed separately to teachers, who reproduce the pages for classroom use. The Program also distributes stormwater coloring books, provided by the Santa Monica Bay Restoration Project, featuring the "Teenage Mutant Ninja Turtles."

Classroom Presentations: Program staff and citizen advisors provided presentations to students and teacher organizations on Sarasota Bay's problems and the Program's efforts to develop solutions. Beginning in Spring 1992, presentations included the use of a 15-minute video, "Sarasota Bay: Reclaiming Paradise," and a "Check Your Bay-Q" worksheet for use in discussions following the video.

Bay Monitor Newsletter

The Program released the first issue of its *Bay Monitor* newsletter in February 1991. The publication relates Bay issues in a lively, readable manner. It includes features on the Program's technical projects, Early Action Projects and public-outreach activities. Direct-mail circulation is 5,000-10,000 copies per issue, depending on distribution needs.

The newsletter is the vehicle for promoting the "Bay Hooray!" award, which the Program uses to recognize groups or individuals whose efforts benefit Sarasota Bay.

Media Plan and Productions

In 1991, the Program contracted with Florida State University's Film & Motion Picture Conservatory at the Asolo Center in Sarasota to research and develop a plan for video productions and the use of broadcast media. The CAC provided oversight for the development of the plan, and the Citizen Advisory, Management and Policy committees participated in review of a script and storyboards for a 15-minute Speakers' Bureau video on Sarasota Bay's problems and the Program's role in developing solutions.

The video, "Sarasota Bay: Reclaiming Paradise," was completed in Spring 1992 and distributed to schools in Fall 1992. The video is used in speaking engagements by Program staff, and will be used by the Program's Speakers' Bureau. Additional productions are planned.

CAC Action Plan

The CAC developed Action Plans for fiscal years 1991 and 1992, focusing on major Bay issues. The 1991 Action Plan targeted mangrove protection and restoration, seawalls, stormwater, septic systems and a mediation assessment on Little Sarasota Bay issues. The 1992 plan included seagrass protection, boater education, the Florida Yard program, newcomer and tourist

education, wetlands, volunteerism/citizen monitoring and a community grants program.

Additional Outreach Activities

Bay Reference Material: The Program published a brochure describing Bay issues and the Sarasota Bay Program's role in restoring the Bay.

The *State of the Bay Report, 1990* describes Sarasota Bay's problems as they were understood in 1990, before the Program began its technical work. The *Report* was reprinted in 1991 and distributed to schools and citizens.

In 1989, the Program participated with Sarasota County in publishing the *Bay Repair Kit*, a homeowner's guide to Bay-friendly living. The *Kit* won a national award in 1990, and was reprinted in 1991 in a joint effort of the American Littoral Society, the Selby Foundation, NCNB Community Foundation, Sarasota County and the Program. The reprint was mailed to 20,000 homeowners in close proximity to the Bay and was distributed to other citizens and schools.

Boater Education: To support ongoing boater education related to the Seagrass Signage Early Action Project, the Program reprinted a brochure educating boaters on seagrass flats in an effort to reduce propeller scarring of these vital habitats. The brochure is distributed at community events and through boat registration offices in Manatee and Sarasota counties.

***Carefree Learner* Brochure:** The Program participated in producing a brochure to promote the general public's use of the *Carefree Learner* floating classroom, a non-profit educational effort of Sarasota High School.

Bay Display: The Program developed a tabletop display for use at conferences, meetings and workshops. The display represents Sarasota Bay's problems and the Program's role in developing solutions.

Community Events: The Program participates in a host of community events, such as Earth Day celebrations, the *Bradenton Herald* Fishing College, the Cortez Fishing Festival and Mote Marine Laboratory's annual open house.

In 1991, the Program sponsored Coastweeks activities, including a photography exhibit with local camera clubs and Sarasota Bay Day. Bay Day included free tours of the Sarasota BayWalk habitat and boat tours of the Bay's underwater habitats provided by Sarasota High School's *Carefree Learner*. The Program also helped promote Coastal Cleanup and participated in the cleanup at the Leffis Key restoration site.

Adopt-A-Shore: The Program supported the establishment of Adopt-A-Shore programs in Manatee and Sarasota counties in 1991-92.

"Bay Hooray!" Recognizes Citizen Action

The Sarasota Bay Program began awarding the "Bay Hooray!" in 1991 to promote the efforts of groups and individuals who are helping to protect and restore the Bay. Winners receive an engraved award, plus a feature in the Program's newsletter.

Following are brief descriptions of past winners of the "Bay Hooray!":

Junior League of Sarasota

The Junior League of Sarasota, the first winner of the "Bay Hooray!," earned the award by helping Sarasota County adopt an environmental pest-management policy for public lands.

Junior League members spent several months researching and developing the pest-management program with government staff members and lawn-care professionals. When county commissioners adopted the policy in April 1991, Sarasota County became the first municipality in the nation to institute such a program.

The policy requires the county to use integrated pest-management practices that emphasize using minimal amounts of chemicals and using less-toxic products. Organic substances also may be substituted, while pest-resistant plantings are encouraged.

Limiting the amount of chemicals used for landscape maintenance helps protect the Bay environment. Fewer chemicals applied means that fewer chemicals will reach Sarasota Bay through groundwater and stormwater runoff.

Junior League of Sarasota

Rick Meyers

Rick Meyers, Environmental Educator, Manatee County Schools

During the past seven years, Rick Meyers has introduced the mysteries of beach and Bay life to more than 25,000 students through coordinating environmental-education programs in Manatee County schools. An equal number of fourth-graders have followed Meyers to the county landfill and Lake Manatee to contrast how humans and nature dispose of waste.

Meyers encourages students to draw their own conclusions about how humans can hurt and help the environment. In addition to teaching, he is an active volunteer with the Manatee County chapters of the Audubon Society, Florida Conservation Assn. and Science Teachers' Assn. Meyers received the "Bay Hooray!" for his innovative Bay-education programs for students and his active participation in community groups helping to conserve Bay resources.

Sarasota High School's *Carefree Learner* Floating Classroom

Wonder, awe and new-found concern for Sarasota Bay are typical reactions to a trip aboard the *Carefree Learner* floating classroom. In a short cruise, passengers learn important basics about water quality and Bay habitats, while actually seeing and touching creatures pulled from the Bay. Shrimp, crabs and fish often are taken back to classroom aquaria for additional study, then returned to the Bay. Classroom instructional materials help students gain understanding of the Bay's ecosystem before and after their cruise.

The *Carefree Learner* program, based at Sarasota High School, provides one of the best hands-on learning experiences available on any estuary. As a true community-based project helping people understand and care about our Bay, the *Carefree Learner* program was a natural choice for a "Bay Hooray!"

Honorable Mentions

"Bay Hooray!" Honorable Mentions have gone to Kristin Jamerson and her Tidy Island neighbors, as well as to Larry Smith with Wildlife Rescue Service of Florida, Inc.

Kristin Jamerson and her neighbors in the Manatee County community of Tidy Island approached shoreline erosion the natural way. They planted smooth cordgrass along the shore of their neighborhood to reduce erosion and provide habitat for marine life.

Larry Smith, executive director of Wildlife Rescue Service, coordinated an ambitious shoreline cleanup called Project Clean Coast. In 25 Saturday sessions in 1991, volunteers removed seven tons of trash from Manatee and Sarasota county coastal shores. The cleanup's aim was to protect wildlife from trash-related injuries, and Smith reports a dramatic drop in wildlife emergencies after the cleanup.

Carefree Learner

Glossary

Glossary of Terms

accretion - the build-up of land due to artificial or natural causes.

Aeromonas - a genus of bacteria in the family *Vibrionaceae;* most species are pathogenic to marine and estuarine life.

algae - a group of plants, one-celled, colonial or many-celled, and having no true root, stem or leaf.

algae bloom - heavy growth of algae in and on a body of water, caused by high concentrations of nutrients.

anoxic - without oxygen.

anthropogenic - resulting from human activities.

bathymetry - the science of measuring water depths to determine coastal or ocean bottom topography.

bayou - a small, sluggish secondary stream or lake.

beach/bay access - the ability to use or pass to and from a beach or bay; a location that allows such access.

beach renourishment - the process of pumping sand onto beaches from channels, inlets or offshore sources.

benthic - pertaining to the bottom, as in sediment swelling.

benthos - bottom-dwelling forms of marine life.

biological community - a collection of living organisms.

brackish - less salty than seawater, but more salty than fresh water.

brine - water with a high salt concentration.

bulkhead - to partition an area for protection against intrusion by water; a structure that provides such protection.

bulkhead line - the farthest offshore area to which a structure may be constructed without interfering with navigation.

carnivore - a flesh-eating animal.

commercial landing - a quantity of fish or shellfish brought ashore by commercial fishing operations.

coquina - a small marine clam; also, a coarse-grained, porous, easily crumbled variety of rock, principally of mollusk shells and coral fragments cemented together.

creek - a stream or channel, normally smaller than and often flowing into a river.

crustacean - one of a class of arthropods having crust-like shells; generally aquatic, including lobsters, crabs, barnacles, etc.

deep-well injection system - a process whereby liquid, usually either treated water or treated wastewater, is pumped underground.

detritus - loose organic material resulting from disintegration of vegetation; debris; any mass of disintegrated material.

dredge spoil - sand and/or mud removed from the bottom of a water course or body of water during dredging.

dredging - removing bottom material from a waterway.

ecosystem - a natural unit formed by the interaction of a community of organisms with their environment.

effluent - the liquid waste of sewage and industrial processing.

embayment - indention in a shoreline forming a bay.

entrainment - the movement of sediment by current flow.

epifauna - animals that live on the surface of the bottom or on the surface of any intertidal or subtidal surface.

epiphytes - for the seagrass habitat, taken to mean plants and/or animals that grow on seagrass blades.

erosion - the loosening, transporting and wearing away of the land, chiefly by water or wind.

estuarine habitat - the natural home or dwelling place of an organism that lives in an estuary.

estuary - a semi-enclosed body of water with free connection with the open sea, and within which seawater is measurably diluted by freshwater from land drainage.

eutrophic - a condition typified by high nutrient input, with periods of oxygen deficiency.

exotic species - a plant or animal species not native to an area.

fauna - animals; generally, in the sense of the report fauna refers to bottom-dwelling invertebrates.

fetch - the distance traversed by waves without obstruction.

fishery - place for harvesting fish; a coordinated activity for the capture of fish.

fish kill - the death of fish in measurable numbers.

flushing - the removal or reduction of contaminants in an estuary or harbor through the movement of water and consequent dilution.

groundwater - the water beneath the surface of the ground.

habitat - the natural or unnatural environment of a plant or animal.

Halodule wrightii (shoal grass) - thin (2 - 3 mm), flat leaves generally 4-10 centimeters in height. This species occupies the lower intertidal area and is the seagrass most commonly observed exposed on tidal flats. It is also common along the deeper fringes of *Thalassia testudinum* beds.

Halophila englemannii (star grass) - a seagrass characterized by a whorl of six to eight smooth, flat green leaves (to 3 centimeters in length) atop a slender stalk. The edges of the blades have fine teeth.

hardened shoreline/shore hardening - the artificial alteration of a shoreline, using seawalls, rubble or other means; replacement of vegetative or otherwise natural shoreline with man-made structures.

herbivore - a plant-eating animal.

herbivory - the consumption of plants.

hydrogen sulfide - a noxious, toxic gas with a characteristic "rotten-egg" smell, produced by the anaerobic bacterial decomposition of organic material.

hydroid - of or pertaining to a class of mostly marine coelenterates resembling the hydra; like a polyp.

hydrology - the science relating to the occurrence, circulation, distribution and properties of the waters of the earth, and their reaction with the environment.

hypoxia - a condition of low dissolved oxygen levels in the water, typically less than or equal to 2 mg. dissolved oxygen per liter.

infauna - animals that live within the substratum.

inlet - a short, narrow waterway connecting a bay or lagoon with the sea.

intertidal - the area of bay bottom that is alternately covered with water and then exposed due to the rise and fall of tide waters on a regular basis. Areas that are only occasionally exposed or covered due to extremely high or low tides are generally not considered to be *intertidal.*

invertebrate - animals without a backbone, encompassing many distinct groups that collectively comprise the largest group of organisms on earth. Examples of common invertebrates are shrimp, snails, oysters, worms, sponges, corals.

jetty - a barrier built out from shore to protect the land from sand erosion by currents or waves.

macrofauna - animals visible to the naked eye; in the technical sense of this report, animals that would be retained on a screen with apertures of 0.5 millimeters in any dimension.

macrophyte - macroscopic aquatic plant; generally algae or seagrass.

macroscopic - visible to the naked eye; opposed to microscopic.

mangrove - a salt-tolerant sub-tropical tree or shrub found near the shore, with leaves and bark that are rich in tannin.

marsh - a transitional land-water area covered at least part of the time by estuarine or marine waters.

mean depth - the average depth of water.

monotypic - consisting of only one species.

morphology - the structure and form of an object.

nekton - free-swimming aquatic animals, essentially independent of water movements.

nodule - a small, irregularly shaped area.

non-point source abatement - the halting of indirect discharge (i.e., not from a pipe or other specific source), either sewage or stormwater, into a system.

outcropping - an exposed layer of rock or other material at the earth's surface.

PAH - poly-cyclic aromatic hydrocarbons.

phytoplankton - free-floating or weakly motile microscopic plant life.

plankton - passively floating or weakly motile microscopic aquatic plants and animals.

pneumatophores - a root structure found on certain mangrove trees that act as a respiratory organ.

point source abatement - the halting of direct discharge (through a pipe or other specific source), either sewage or stormwater, into a system.

predacious mollusks - clams, snails, etc. that feed on other animals.

propagules - a reproductive structure.

prop scour - the resultant condition of sediments subject to chronic prop wash.

prop wash - the turbulent action of water ejected from a boat propeller.

protozoan - a microscopic organism consisting of a single cell, and reproducing typically by binary fission. They are largely aquatic, and include many parasitic forms.

regression relationship - statistically based analysis of the relationship between two or more variables.

reverse-osmosis water treatment - a technique for removing minerals from water in which pressure is applied to the water to be treated, purifying it as it passes through a membrane.

revetment - a hard structure used to protect an embankment from water or wind.

rip rap - a foundation or revetment in water or on soft ground, made of irregularly placed stones or pieces of boulders and used to protect the shore.

rookery - the breeding or nursery ground of animals or birds.

runoff - the portion of precipitation on the land that through surface flow reaches a body of water.

salinity - any concentration of salt in water, usually measured in parts per thousand.

saltern - an area where salt is precipitated out of seawater by evaporation.

saltern plant - a plant found in a saltern.

salt marsh - a marine habitat that is usually wet with saltwater and contains shrubby vegetation.

SAV - an abbreviation referring to submerged aquatic vegetation, which consists of seagrasses and algae. It does not include shoreline vegetation such as marsh plants and mangroves.

seagrass - flowering marine plants recognized for their extreme importance as productive nearshore habitat. Four common species of seagrasses grow within the Sarasota Bay system: *Thalassia testudinum* (turtle grass), *Syringodium filiforme* (manatee grass), *Halodule wrightii* (shoal grass) and *Ruppia maritima* (widgeon grass). Less common is *Halophila englemannii* (star grass).

seagrass bed - a mass or growth of flowering marine plants, generally found on the sea bottom in relatively shallow water.

sea level - the level of the surface of the ocean; especially, the mean level halfway between high and low tide used as a standard in reckoning land elevation or sea depths.

sea-level rise - a gradual rising of sea level.

seawall - a wall or embankment constructed along a shore to reduce wave erosion and encroachment by the sea.

sediment - organic or inorganic material that comprises bay bottoms; can be placed in suspension in the water by wave energy.

septic system - a system of tanks and porous pipes in which sewage is decomposed by anaerobic bacterial action and then filtered by soil.

sewage treatment - a process for purifying mixtures of human and other wastes by aerobic and/or anaerobic means.

shellfish - an aquatic invertebrate, such as a mollusk or crustacean, that has a shell or exoskeleton.

shell mound/midden - a refuse pile, in the Sarasota Bay region generally comprised of fossilized bivalve shellfish, produced by aboriginal peoples.

sinusoidal - having continuous periodic behavior; repeating at regular intervals.

sound - a body of water, wider than a strait or channel, usually connecting larger bodies of water.

spoil pile - accumulation of dredged materials.

stormwater runoff - water from rain, often carrying refuse liquids and waste.

subtidal - the area of the bay bottom that remains covered with water under all average tide conditions.

substratum - the bottom of the bay; the soils of the bay bottom. Can also refer to any surface that allows for the colonization of marine life.

Syringodium filiforme (manatee grass) - the only seagrass with cylindrical leaves that may exceed 50 centimeters in length. Common in higher-salinity grass-bed fringe areas (deeper water) near gulf passes.

tailwater recovery system - a process in which irrigation water is prevented from going off-site by capturing runoff and redelivering it to the original place of input.

Thalassia testudinum (turtle grass) - the most conspicuous subtidal grass, with thin flat blades 4-12 millimeters wide and up to 50 cm in length, although most Sarasota Bay specimens are considerably shorter.

tidal amplitude - one-half the difference between consecutive high and low tides; one-half the tide range.

tide - the periodic rising and falling of the oceans resulting from lunar and solar forces acting upon the rotating earth.

tributary - a body of water that supplies a larger body of water, such as a lake or estuary.

trophic status - the degree of organic enrichment of any particular water body.

turbidity - cloudy or hazy appearance in a liquid, caused by a suspension of fine solids.

uplands - terrestrial areas above the influence of tide waters.

Vibrios - anaerobic rod-shaped bacteria.

wastewater - water that has been used for industrial or domestic purposes.

watershed - an area that supplies water to a stream and its tributaries by either direct runoff or groundwater flow.

wetlands - areas with wet or spongy soil, such as swamps or tidal flats, characterized by plants adapted to living under often-wet conditions.

wet-sand area (of beach) - the area of beach generally seaward of the mean high-tide line.

zooplankton - microscopic animals that move passively in aquatic ecosystems.

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