BAYWIDE ENVIRONMENTAL MONITORING REPORT
1993-1998

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TAMPA BAY, FLORIDA

Tampa Bay Estuary Program, July 1999
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Editors

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Pinellas County Department of Environmental Management
Southwest Florida Water Management District Surface Water Improvement and Management (SWIM) Program

Cover Photograph: **Courtesy** of **Anne Meylan, FMRI**

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COMPREHENSIVE CONSERVATION AND MANAGEMENT PLAN

In 1996, the Tampa Bay National Estuary Program completed development of a Comprehensive Conservation and Management Plan to protect and restore the Bay's living resources. From initiation of the program in 1991, TBNEP participants have recognized that implementation of actions in the final Comprehensive Plan will primarily be the responsibility of local governments - the counties of Hillsborough, Pinellas, and Manatee and the cities of Clearwater, St. Petersburg, and Tampa. As part of the Implementing Agreement signed by the participants, a new name was adopted: the Tampa Bay Estuary Program (TBEP).

These governments and the three regulatory agencies participating in TBEP (US Environmental Protection Agency, Florida Department of Environmental Protection, and the Southwest Florida Water Management District) are working together to reach common long-term goals, including water quality conditions needed to support restoration of seagrass to acreage observed in 1950.

A critical element of the Comprehensive Plan for Tampa Bay is the establishment and maintenance of a monitoring program capable of measuring status and trends of environmental variables which may be affected by actions designated in the Plan. Local governments implementing actions need the ability to evaluate whether funds and effort spent on pollution abatement in the watershed is reflected in improvements in bay quality. An effective monitoring program can provide data to assess the effectiveness of current management strategies and indicate when goals have been met, if actions should continue, or whether more stringent efforts are warranted.

One of the first elements of the Estuary Program in Tampa, therefore, was to initiate a multi-year effort, in cooperation with local governments and agencies, to establish a coordinated monitoring program capable of reliably measuring changes in bay quality. The bay-wide monitoring plan builds on a significant foundation of existing water quality and fisheries monitoring programs. Existing programs have been standardized and expanded in some areas and new components - to measure bay sediment quality, atmospheric deposition and benthic organisms - have been added. Mammals, turtles and birds are also being monitored. Each of the monitoring components is summarized in following chapters.

IMPLEMENTING A COORDINATED PROGRAM

The Tampa Bay Monitoring Program is unique among estuaries and coastal areas across the country in that implementation is being accomplished by many individual governments and agencies, rather than one centralized agency. Successful implementation of the program will require strong commitment for continued coordination from the participating entities.

The Tampa Bay Estuary Program has initiated several avenues for continuing coordination, including the following:

- Regularly scheduled standardized quality assurance checks between participants conducting water quality and benthic community analyses.
- Development of a coordinated sampling design and procedures. TBEP participants have joined other county governments from Tampa Bay to Charlotte Harbor and the Sarasota Bay NEP to form the Florida West Coast Regional Ambient Monitoring Program, to implement standardized procedures.
- Reporting and integration of monitoring results in a regularly compiled Environmental Monitoring Report.

This report, the second edition of the Tampa Bay Environmental Monitoring Report, is intended for use by resource managers and scientists working in Tampa Bay. Its authors are those scientists responsible for conducting the extensive monitoring efforts ongoing in the bay. This document is intended to provide timely access to information critical for successful restoration and protection of Tampa Bay's living resources.

H. Greening (Tampa Bay Estuary Program)

INTRODUCTION

Charting The Course, the Comprehensive Conservation and Management Plan for Tampa Bay, lists 1l goals and 41 specific actions for bay improvement in five priority areas of concern:

- water and sediment quality;
- bay habitats;
- fish and wildlife;
- spill prevention and response; and
- dredging and dredged material management.

Charting The Course was adopted by the Tampa Bay Estuary Program's local government and regulatory partners in April 1997. An Interlocal Agreement adopting the goals and signifying the firm resolve of TBEP partners to implement the management plan was signed in February 1998.

One of the management plan's chief goals is to prevent increased nitrogen loadings to the bay to encourage the regrowth of more than 12,000 acres of seagrasses. Seagrasses were chosen as the benchmark by which to measure the program's success because of their importance to the bay ecosystem and their sensitivity to changes in water quality. Other priority goals identified in the action plan seek to:

- restore the historic balance of low-salinity tidal marshes in Tampa Bay by restoring a minimum of 100 acres every five years, for a total increase over time of 1,800 acres;

o better understand the role atmospheric deposition plays in the bay's water quality, and identify and address the sources of this air pollution;

o establish and maintain minimum seasonal freshwater from area rivers impounded by dams;

o install a state-of-the-art vessel traffic information system (VTIS) to reduce the risk of petroleum or chemical spills from ships traversing the bay's narrow shipping channel;

o develop a long-range, coordinated dredged material management plan for the bay that minimizes environmental impacts and maximizes beneficial uses of dredge spoil; and

o improve the on-water enforcement of fishing and environmental regulations.

A summary of progress towards reaching these goals is included in the following tables. "Action Indicators" indicate the actions taken or commitments made by local government, regulatory agencies and other partners of TBEP to achieve the key goals of the CCMP, while "Environmental Indicators" show the net ecological benefits resulting from those actions, expressed in measurable parameters such as increased seagrass coverage or lower chlorophyll levels. These tables are intended to provide a concise yet comprehensive summary of the status of the CCMP for Tampa Bay, and establish a clear connection between the actions undertaken by TBEP and its partners and the bottom-line environmental benefits of those actions.

Environmental Results and Trends

As indicated in the following graphics, Tampa Bay is currently showing good progress toward goals for nitrogen management, acres of seagrass, and restoration/creation of oligohaline habitats. Chlorophyll-a concentrations have fluctuated above and below the bay segment-specific targets, which indicates that particular attention to ensuring that proposed nitrogen management actions are fully implemented is critical to maintain steady progress toward long-term seagrass restoration goals.

Results from the ongoing sediment and benthic quality monitoring program, coupled with the results of the ongoing sediment quality targets definition project, will be used to generate progress towards sediment quality goals within the next year. In addition, development of public health indicators and action indicators for spill prevention and response will be initiated in 1999.

Measuring Progress Toward CCMP Goals: A Summary of Monitoring Programs supporting the CCMP in Tampa Bay

Effective monitoring is essential to a successful bay restoration effort by allowing communities to measure return on investment, assess progress, and fine-tune priorities as needed. The baywide monitoring program, initiated through a TBEP effort and based on EPA's EMAP statistical design, is implemented by several of the TBEP partners and builds upon existing monitoring data to more clearly assess progress in the bay's recovery. Rather than emphasizing compliance with rigid laboratory standards for water quality, the monitoring program for Tampa Bay seeks to measure instead the health and diversity of bay habitats and the animals that inhabit them.

The baywide environmental monitoring program addresses five components: water quality; benthos, sediment chemistry and composition; atmospheric deposition; bay habitats; and bay fisheries and wildlife. Within those components are four general objectives, which are to:

- estimate the areal extent of the bay that does not provide adequate water quality conditions to support seagrasses and other living resources;
- assess the abundance and health of bay fish populations over time;
- estimate the areal extent of degraded benthic habitat in the bay and within each bay segment; and
- estimate the areal extent and quality of seagrasses.

The baywide monitoring program is not run by one agency, but is a combined effort of Manatee and Pinellas counties, Hillsborough County EPC, the City of Tampa, FDEP, FMRI, and SWFWMD. Continuous coordination between the various local governments and agencies participating in this combined effort is therefore essential. Coordination for the water and sediment/benthic quality element of the program is accomplished through the Regional Ambient Monitoring Program (RAMP), which was initiated by TBNEP in 1992, but is now coordinated by the local governments who run the monitoring programs. RAMP meets quarterly to collect water samples from a common container. Each program has its own laboratory run the samples for a core group of parameters (TN, nitrate+nitrate, ammonia, TSS, TP, orthophosphate, color, turbidity, and chlorophyll-a), and the RAMP participants compare the results at a following meeting. To date, the RAMP participants have worked out differences between laboratories for several critical parameters (chlorophyll, TN, TP, TSS) and continues to work on others (color, for example).

This successful coordination effort has recently been joined by Charlotte, Sarasota, Lee and Polk counties' monitoring programs, and has been recognized by the State of Florida as a core group for inclusion in the developing statewide program.

The RAMP participants also bring updated methods and techniques to the group for discussion and testing among the partners, and will be examining "the new STORET" as a method to more effectively share data. Data collected by each agency is currently stored at that agency and/or is submitted to "the old STORET", and data sharing occurs when requested by other partners. To date, this informal system has been adequate for data sharing and reporting, but all partners agree that a user-friendly, effective data management system which will not require significant additional time from their already-overloaded monitoring staff should be a priority over the next several years. The TBEP partners are hopeful that "the new STORET" will serve this purpose.

The Tampa Bay region is fortunate to have FDEP's Florida Marine Research Institute located in this area, which conducts monthly adult and juvenile fish monitoring at approximately 60 stations throughout the bay. This program, which includes both random and fixed station design elements, provides excellent information on status and trends of fish populations in Tampa Bay, and the statistical design is compatible with the EMAP-based design of the water quality and benthos elements. FMRI supports an extensive statewide data base which **is** available upon request, and also reports status and trends of important fish species in the Tampa Bay Estuary Program's Baywide Environmental Monitoring Report.

The Southwest Florida Water Management District is continuing aerial photography and GIS mapping of seagrass extent every two years, which provides the basis for measuring progress toward the TBEP long-term seagrass restoration goal. SWFWMD develops Arc-Info GIS coverages for all bay segments, which are distributed to TBEP, FMRI, and other partners as requested. Status and trends of seagrass acreage in Tampa Bay are reported in the Tampa Bay Estuary Program's Baywide Environmental Monitoring Report.

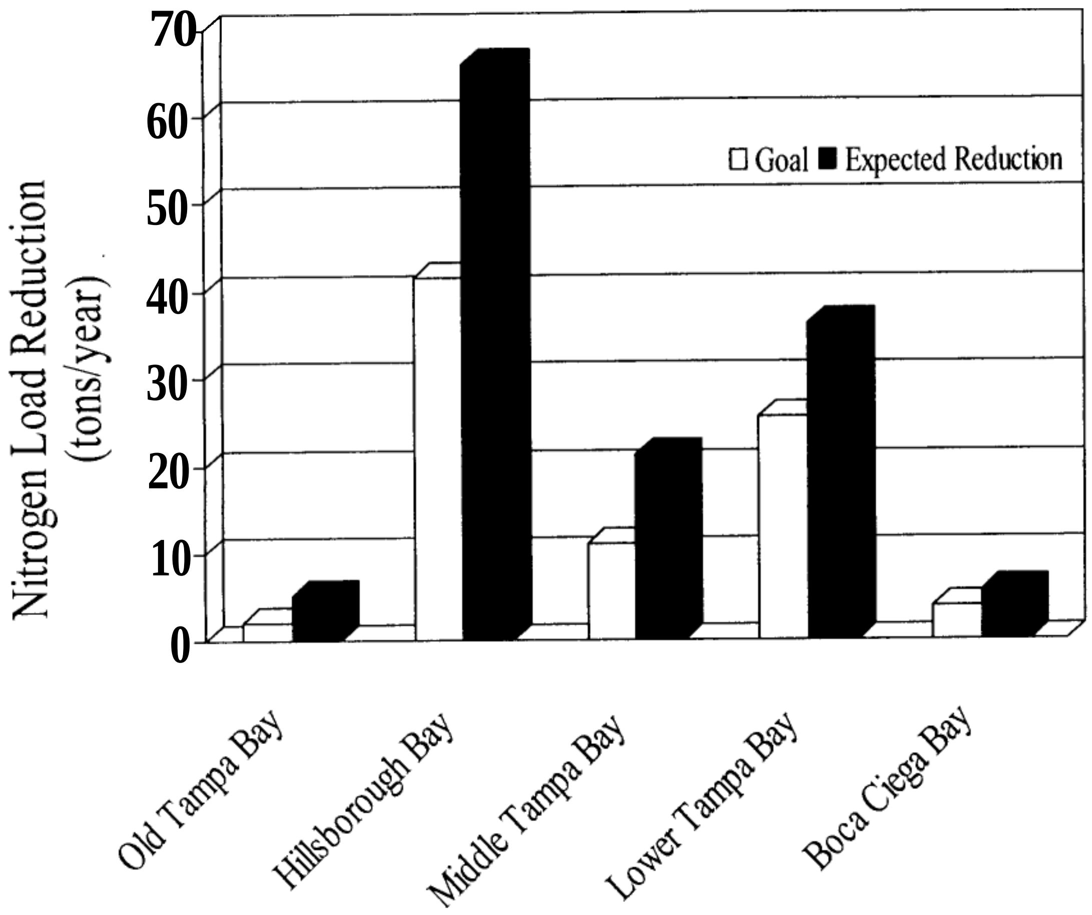
The atmospheric deposition monitoring program is coordinated by TBEP and FDEP as an element of the Tampa Bay Atmospheric Deposition Study (TBADS), and sample collection is conducted by EPC of Hillsborough County and Pinellas County. The TBADS intensive site (wet deposition measurements) has recently been included in the NADP network, using NADP sample analyses QA/QC procedures and techniques. Core parameters include ambient air (sulfate, nitrate-N, and ammonium-N) and wet deposition measurements for sulfate, nitrite, chloride, ammonium, phosphate, calcium, magnesium, sodium, and potassium. A companion meteorological station located in the center of the bay collects wind speed and direction, relative humidity, and water and air temperature for input into a "buoy model" developed by NOAA for TBADS to estimate dry deposition from ambient air and meteorological conditions. Data are currently being delivered to NADP (wet only) in addition to being available from the TBEP Data Library. The wet deposition data from the Tampa Bay site are available on the NAPD website. The first 24 months of data and initial interpretation are included in an Interim Data Report available from the TBEP Technical Publications library.

The Baywide Benthic Monitoring Program, initiated in 1993, is based on EMAP design and sampling protocols, and is being implemented in Tampa Bay by EPC of Hillsborough County, Pinellas County, and Manatee County, with taxonomic assistance from FMRI and some funding support from TBEP. Over 100 stations are collected using the EMAP stratified random hexagonal design once a year in September-October. Sediment quality parameters (metals, PAHs, PCBs, organic pesticides, and grain size fractions), benthic community structure (taxonomic sorting to species) and water quality measurements (24-hour *in-situ* dissolved oxygen, salinity, conductivity, pH, and temperature) are included in the sampling protocols. Results of the program are compiled and interpreted by EPC and distributed as TBEP technical publications. Data are stored in the TBEP Data Library and distributed to the participating programs and others as requested.

Key results of the monitoring program are highlighted in the Baywide Environmental Monitoring Report (BEMR) compiled every several years by TBEP. In addition to the core baywide monitoring program results, status and trends on manatees, dolphins, sea turtles, and wading birds in Tampa Bay are included in the BEMR. The first BEMR was produced in 1996; this document is the second.

Tampa Bay Estuary Program

Nitrogen Management Goals and Expected Reductions: 1995-1999

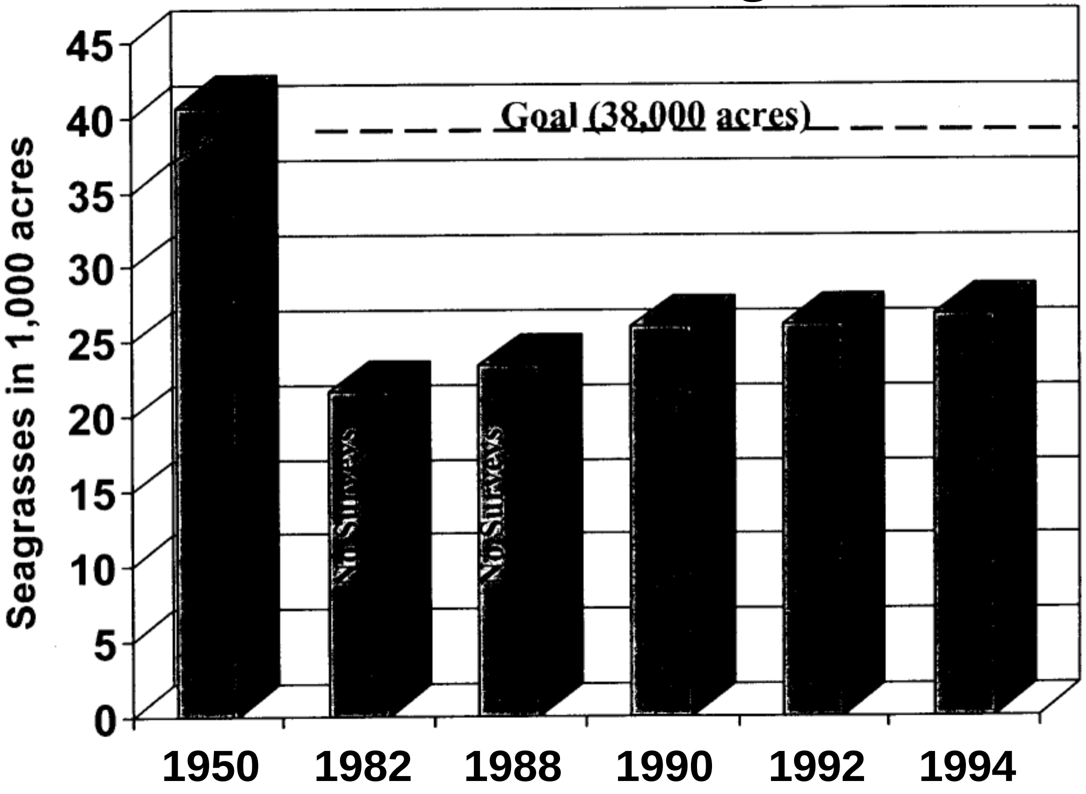


GOAL: "Hold the line" at nitrogen loading estimated for 1992-1994. To compensate for expected growth, reduce or preclude additional nitrogen loading by 17 tons per year (beginning in 1995).

STATUS: 1995-1999 reduction goals for all bay segments are expected to be met by the end of 1999.

Source Tampa Bay Nitrogen Management Consortium Action Plan

Tampa Bay Estuary Program
Acres of Seagrasses: 1988 - 1994

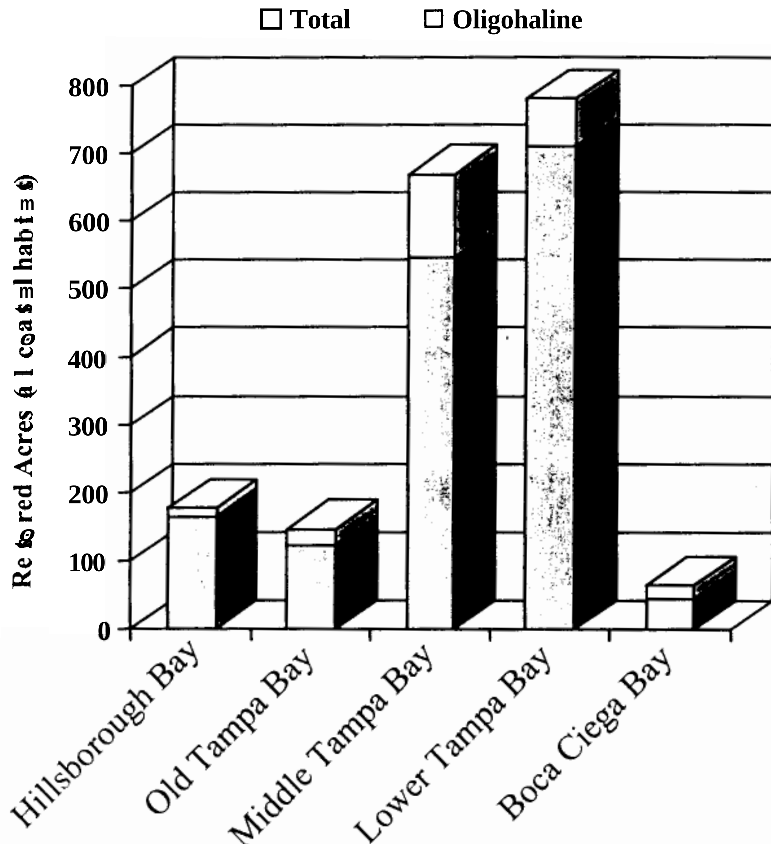


GOAL: Recover an additional 12,350 acres of seagrass over 1992 levels, while preserving the bay's existing 25,600 acres.

STATUS: Since 1988, seagrass acreage is increasing at about 500 acres per year. At this rate, the goal will be reached in 25 years.

Source: *SWFWMD*

Tampa Bay Estuary Program
Estimated Estuarine Restoration Acres: 1995 - 1999



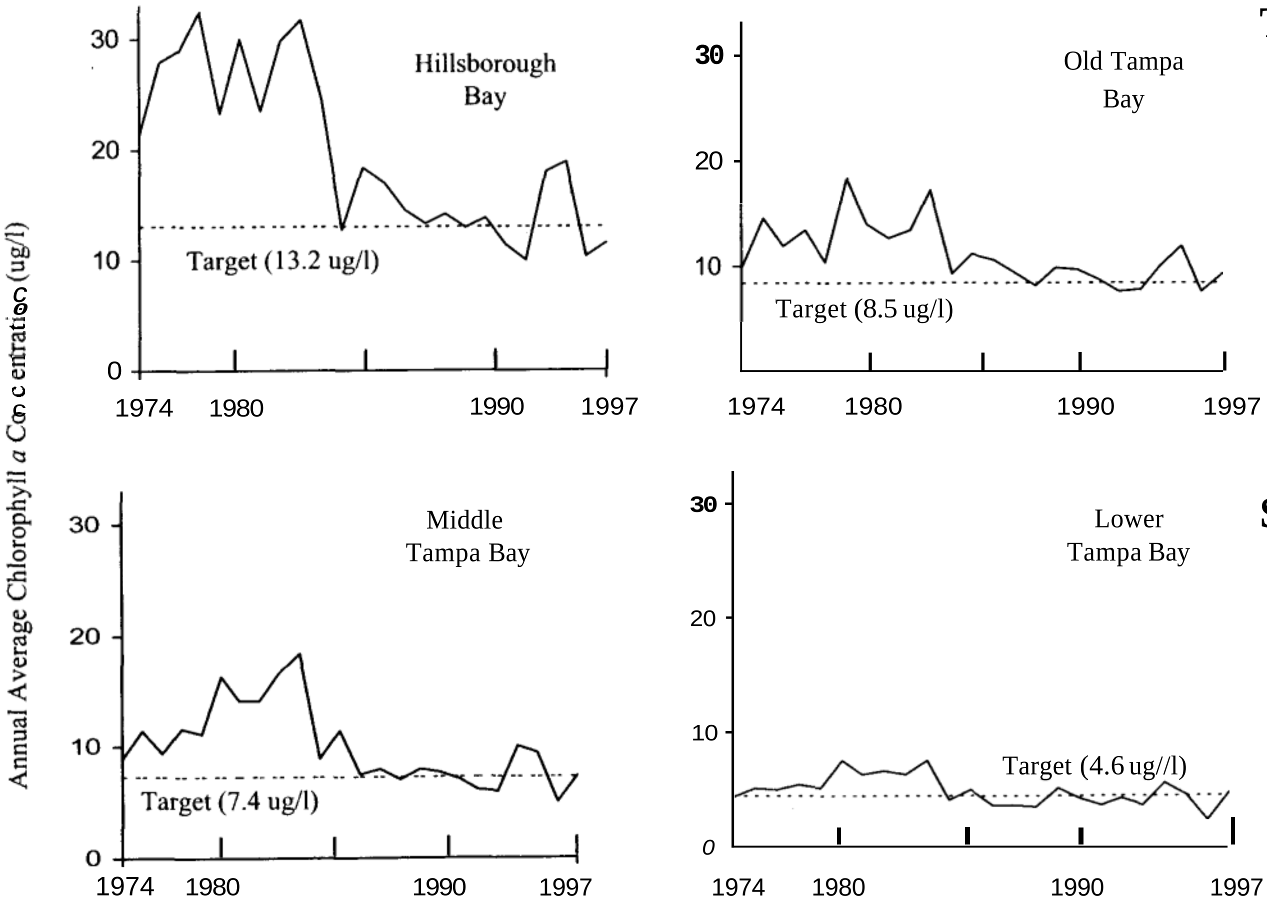
Source: SWFWMD

- Expected oligohaline habitat: 250 acres.
- Expected total estuarine restoration: 1589 acres.

GOAL: Restore historic balance of coastal wetland habitats in Tampa Bay by restoring at least 100 acres of oligohaline habitat every five years, for a total increase of 1800 acres.

STATUS: A total of 250 acres of oligohaline habitat will be restored in all bay segments, exceeding the goal by 150 acres.

Tampa Bay Estuary Program
Chlorophyll *a* Concentration Trends



TARGET: Maintain segment-specific chlorophyll a concentration equal to the lowest of either the annual average of 1992-1994 or the concentration that supports the seagrass

STATUS: Average annual chlorophyll a levels for each bay segment have fluctuated above and below the targets since 1994. No obvious trends over time are apparent.

Source: EPC Hillsborough County

Goals at a Glance: Water & Sediment Quality

GOAL	STATUS	
	ACTION INDICATORS	**ENVIRONMENTAL INDICATORS**
Prevent increases to the bay's nitrogen loadings by 'holding the line' at 1992-1994 levels to provide water clarity suitable for the recovery of 12,350 acres of seagrass. To compensate for expected growth, reduce or preclude additional nitrogen loadings by 17 tons per year.	1995-1999 reduction goals for all bay segments are expected to be met by the end of 1999, through implementation of projects specified by public and private partners in the Tampa Bay Nitrogen Management Consortium Action Plan *Partners for Progress*	Nitrogen loadings to the bay are scheduled to be updated with 1995-1999 data in the year 2000.
Interim target: Maintain segment-specific chlorophyll-a concentrations equal to the lowest of either the annual average of 1992-1994 or the concentration that supports the seagrass restoration goal.		Average annual chlorophyll-a levels for each bay segment have fluctuated above and below specific targets since 1994. No obvious trends over time are evident.
Reduce the amount of toxic chemicals in contaminated bay sediments and protect relatively clean areas of the bay from contamination.	Baywide annual sediment quality monitoring initiated in 1993. Specific numeric targets for concentrations of Tampa Bay Contaminants of Concern are scheduled to be developed by March 1999. Action plans to address "hot spots" and to protect relatively clean are under development.	"Hot spots" of contaminated sediments occur in relatively concentrated areas around large marinas, ports and urban stormwater outfalls. To date, no trends in sediment quality since monitoring was initiated in 1993 have been observed.
Gain a better understanding of the role that atmospheric deposition plays in the bay's water quality, and identify and address the sources of air pollution.	Ten research and monitoring projects addressing atmospheric deposition in the Tampa Bay area are ongoing.	
Reduce bacterial contamination now present in the bay to levels safe for swimming and shellfish harvesting.	Identification of appropriate indicators for human health concerns in Tampa Bay will be initiated in fall 1998. Coordination between local health units to standardize "beach closure" conditions is underway.	Number of beach closures and percent shellfish beds open (not yet compiled for Tampa Bay)

GOAL	STATUS	
	ACTION INDICATORS	ENVIRONMENTAL INDICATORS
Recover an additional 12,350 acres of seagrass over 1992 levels, while also preserving the bay's existing 25,600 acres and reducing propellor scarring of seagrasses.	Nitrogen management goals are being met (see Water & Sediment Status). Channels through seagrasses have been marked in heavily scarred areas. Aerial photos and mapping occurs every 2 years, and biannual seagrass conditions monitoring is being initiated in fall 1998.	Since 1992, seagrass acreage is increasing at about 500 acres per year. At this rate, the goal will be reached in 25 years.
"Restore the historic balance" of coastal wetland habitats in Tampa Bay by restoring at least 100 acres of low-salinity (oligohaline) tidal marsh every five years, for a total increase over time of 1,800 acres.	Twenty habitat restoration projects which include the creation or restoration of oligohaline habitat are ongoing or are scheduled to be complete by 2000.	Approximately 250 acres of oligohaline habitat will be restored by 2000, exceeding the 1995-1999 goal by 150 acres. Oligohaline restoration will occur in all bay segments.
Preserve and enhance the bay's 18,800 acres of existing mangrove/salt marsh habitats, including the 28 coastal habitat sites designated as priorities for protection, either through public purchase or methods such as conservation easements.	All 28 priority sites identified in the TBEP Habitat Masterplan have been given the highest priority for the State's Save Our Rivers or P2000 land acquisition programs by the Southwest Florida Water Management District.	A total of 1,833 acres of the 13,434 acres identified as the "Tampa Bay Estuarine Ecosystem" have been acquired for preservation and restoration between 1995-1997.
Establish and maintain adequate freshwater flows to Tampa Bay and its tributaries to increase crucial low-salinity habitat	Developed consensus-based salinity regime and dissolved oxygen criteria for the Hillsborough River below the dam, based on needs of estuarine-dependent species. These criteria are being considered in the determination of minimum flows by SWFWMD (not yet finalized).	

Goals at a Glance: Fish & Wildlife

GOAL	STATUS	
	ACTION INDICATORS	**ENVIRONMENTAL INDICATORS**
Improve the on-water enforcement of fishing and environmental regulations	In 1997-1998, a Manatee Protection Task Force developed recommendations for a manatee protection strategy in Tampa Bay, which included 1) seasonal "no-entry'' restrictions in manatee congregation and calfing areas; 2) voluntary "go slow" areas throughout the shallow seagrasses of the bay; and 3) "safe speed" marked access channels through the grass flats. The Manatee Awareness Coalition (MAC) has been formed to train volunteer on-water bay stewards to distribute "MAC pacs", a manatee awareness package to promote the voluntary "go slow" areas to boaters.	The MAC is currently developing specific environmental indicators to test the effectiveness of the voluntary "go slow" areas. Possible indicators may included 1) manatee scarring rates and mortality (probably not effective for measuring Tampa Bay-specific management strategy, since the manatees move up and down the coast); 2) monitoring how many boaters are aware of the manatee protection strategy, including the "go slow" areas; 3) on-water surveys of how many boats slow down upon entering a voluntary "go slow" area; and 4) presence or absence of manatee education materials at area marinas, boat dealersh

Goals at a Glance: Spill Prevention and Response

GOAL	STATUS	
	ACTION INDICATORS	**ENVIRONMENTAL INDICATORS**
Install a state-of-the-art vessel traffic and information system (VTIS) to improve coordination of' ship movements along the bay's shipping channel	A real-time tide and weather information (PORTS) system is operational and funded through 2000. Elements of the Vessel Traffic Advisory System are being implemented in Fall 1998. Remaining elements are ongoing.	A specific environmental indicator for this goal has not been defined. One possible indicator is the number of ship groundings and spills in Tampa Bay.

Goals at a Glance: Dredging and Dredged Material Management

GOAL	STATUS	
	ACTION INDICATORS	ENVIRONMENTAL INDICATORS
Develop a long-range dredged material management plan for the bay that will minimize environmental impacts and maximize beneficial uses of the dredged material	The U.S. Army Corps of Engineers and TBEP have entered into an agreement to develop a long-term dredged material management plan for Tampa Bay, which will include the three major ports on the bay. The year-long plan development is scheduled to begin in fall 1998.	Specific environmental indicators have not been developed for this goal.

A.P. Squires (Pinellas County Dept. of Environmental Management)

WHY MONITOR?

The environmental monitoring of Tampa Bay's waters is important to a wide range of interests, from recreational boaters, fisherman, and swimmers, to commercial fisherman, government environmental managers, scientists, and politicians. Monitoring information can provide information:

- to evaluate pollution abatement actions;
- to serve as an early warning system, to obviate higher-cost solutions to environmental problems;
- to help answer simple questions, for example, about the safety of swimming or consumption of fish and shellfish;
- for support of environmental quality standards developed by environmental managers and regulators; and
- to determine compliance with permit conditions.

TBEP MONITORING PROGRAMS

In recognition of the importance of monitoring for the above listed reasons and for the successful implementation of the Comprehensive Conservation and Management Plan (CCMP), the TBEP funded two projects aimed at designing a basinwide monitoring program for Tampa Bay. The first project encompassed two reports, the *Compendium of Current Monitoring Programs in Tampa Bay and its Watershed* (TBNEP Tech. Publ. #02-92), and the *Design of a Basinwide Monitoring Program for Tampa Bay* (TBNEP Tech. Publ. #09-92). The second project, documented in a report entitled *A Monitoring Program to Assess Environmental Changes in Tampa Bay, Florida* (TBNEP Tech. Publ. #02-93), developed recommendations to local governments for specific monitoring designs.

The primary developments from the first project were the establishment of overall monitoring program goals and the definition of specific monitoring program objectives. This first project laid the groundwork for subsequent monitoring designs by 1) identifying existing monitoring programs in Tampa Bay and its watershed, 2) defining monitoring program goals and objectives, 3) identifying indicators and a sampling design appropriate to those objectives, and 4) identifying how existing Tampa Bay monitoring programs can be incorporated and modified to meet the agreed upon monitoring objectives. The program was not intended to replace any existing monitoring programs, but instead provided a framework upon which existing monitoring programs could be built and identified important gaps in the existing monitoring network.

Existing Monitoring Programs

In the report on the compendium of monitoring programs, 36 existing (1992) programs were grouped into three components: water quality, habitat, and living resources. In addition to these programs, an atmospheric deposition monitoring program began gathering data in 1996. Many of the existing water quality programs are municipal or county programs implemented to comply with point source permit requirements. Habitat and living resource components are primarily

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TAMPA BAY WATER HBMP

In 1998, Tampa Bay Water, a new regional water supply utility, was established. To alleviate impacts due to ground water withdrawals in northern Hillsborough County and southern Pasco County, a new water plan was approved. This plan includes surface water withdrawals from the Tampa Bypass Canal, the Hillsborough River, and the Alafia River, and construction of a 25 MGD desalination facility at the Tampa Electric Company Big Bend power plant site on the shores of Hillsborough Bay. As part of the permitting process for these withdrawals, Hydrobiological Monitoring Programs (HBMPs) will be developed in 1999.

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addressed through state and regional monitoring programs.

The most noteworthy water quality programs are the continuous ongoing surface water monitoring programs conducted by the Environmental Protection Commission (EPC) of Hillsborough County, Pinellas County, Manatee County, and the City of Tampa. Ambient water quality monitoring by EPC has been conducted since 1972 at 54 stations covering the Old Tampa Bay, Hillsborough Bay, Middle Tampa Bay, and Lower Tampa Bay segments. Pinellas County and Manatee County have implemented surface water quality monitoring programs in Boca Ciega Bay and the Manatee River/Terra Ceia Bay region, respectively. In addition to these county programs, the City of Tampa has been conducting long-term surface water quality monitoring primarily in Hillsborough Bay and Middle Tampa Bay since 1976. Finally, some water quality sampling programs were conducted by the USGS associated with special projects.

The Tampa Bay Atmospheric Deposition Study (TBADS), after approval by the EPA Great Waters Program, was begun in the spring of 1995, and resulted in data collection beginning in August 1996. Data collection is continuing through the present, with plans for sampling through August 2000. Analyses of these data have provided estimates of wet nitrogen and phosphorus deposition and dry nitrogen deposition to the surface of the bay, and have been utilized in a study of rainfall nutrient contributions to stormwater runoff nutrient loads. Additionally, bulk atmospheric deposition of nutrients to the bay has been estimated.

Habitat programs are conducted by federal, state, regional, and local government agencies. Habitat programs include monitoring of shoreline vegetative habitats via satellite imagery by the Florida Marine Research Institute (FMRI) of FDEP and the National Oceanic and Atmospheric Administration (NOAA), seagrass mapping by SWFWMD SWIM using aerial photo-interpretation, sediment toxicity studies by NOAA, and watershed characterization studies by Pinellas County. Sediment chemistry, grain size, and benthos have been monitored annually by EPC and Manatee and Pinellas counties.

Living resources are monitored by the FMRI, NOAA, and the local chapter of the National Audubon Society. The FMRI conducts numerous programs that assess marine mammals, fisheries, and sea turtle nesting activity. NOAA has conducted special projects under their Mussel Watch and Oyster projects. Finally, Audubon's Coastal Island Sanctuaries program counts bird populations in the Tampa Bay area.

Monitoring Goals and Objectives

In the report documenting the basinwide monitoring program for Tampa Bay, two monitoring goals were selected for the TBEP:

- to measure the effectiveness of management actions and programs implemented under the CCMP, and
- to provide information that can be used to redirect and refocus the management plan over time.

Four monitoring objectives were developed after considerable discussion among members of the TBEP Technical Advisory Committee, and include:

- estimation of the areal extent and temporal trend in areal extent of habitat and water quality conditions in Tampa Bay that do not meet living resource requirements;
- assessment of the relative abundance and condition of fish populations of Tampa Bay over time;
- estimation of the areal extent and quality of seagrass, mangroves, and coastal marshes in Tampa Bay over time; and
- estimation of the areal extent and trends in areal extent of oligohaline habitat in Tampa Bay and its tributaries.

Monitoring Programs for Tampa Bay

In the second TBEP monitoring project, monitoring designs were developed to address benthic quality, scallop abundance, water quality, seagrass coverage and quality, and fish abundance. Recommended designs were developed to be consistent with the goals and objectives previously agreed upon for Tampa Bay. An important aspect incorporated into these monitoring programs was the use of a probability-based sampling design. This type of sampling design allows for unbiased estimates of abundance and areal extent of key indicator components.

The benthic quality and scallop abundance monitoring designs represent two newly implemented programs. The benthic quality program was the most important design since it filled a gap in the existing monitoring network. No long-term comprehensive program to assess the status and trends in benthic quality existed or had been undertaken in Tampa Bay. The scallop monitoring design filled the need to assess adult scallop abundance in a scientifically acceptable manner, and provided a mechanism for citizen volunteers to see Tampa Bay first-hand by assisting in evaluating population levels. The benthic monitoring program is currently in its seventh year of sampling.

The remaining three program elements were ongoing and include water quality monitoring by local county and municipal governments, seagrass monitoring by the SWFWMD and the City of Tampa, and fisheries monitoring by the FMRI. Recommendations were made to modify and/or augment these programs in order to address the TBEP monitoring objectives.

THE BAYWIDE ENVIRONMENTAL MONITORING REPORT

The purpose of the Baywide Environmental Monitoring Report is to summarize the results of key monitoring programs that have been implemented in the Tampa Bay region. The report is intended to be updated every few years, so that each new edition will include long-term trends while emphasizing changes during the reporting period. As an essential element of the TBEP approach, well-designed monitoring programs provide information needed to assess resource status and to ascertain any trend response from implemented management actions. Therefore, technically sound monitoring programs are critical to objectively assess the effectiveness of management decisions, and evaluate the return on the investments allocated to protect and enhance bay resources. As the completion of the CCMP approaches, the need to maintain a vehicle to inform the Tampa Bay community of the status of key bay resources was identified. The report herein marks the second installment of that vehicle, the Baywide Environmental Monitoring Report.

Report Contents

This report includes a synopsis of Tampa Bay and its watershed. The background information provided in the opening three chapters, including progress toward goals of the Tampa Bay CCMP, will be followed by more specific material depicting temporal and geographical trends of important ecological components. Components addressed include:

- freshwater flow and nutrient loadings;
- atmospheric deposition;
- water quality;
- seagrass coverage;
- sediment quality;
- benthic quality;
- fisheries;
- marine mammals;
- bird populations; and
- sea turtles.

The final chapter includes the synthesis and conclusions of monitoring information previously presented.

R. Pribble (Janicki Environmental, Inc.)

NITROGEN LIMITED ALGAE GROWTH

The growth and production of Tampa Bay's algae populations depend upon the available nutrients (primarily nitrogen and phosphorus) in the water column. The bay's algal forms include phytoplankton (measured by chlorophyll-a) and attached and drifi mucroalgae (such as Ulva and Gracilaria). Since phosphorus levels are very high in the bay's waters due to naturally occurring phosphorus deposits in the watershed, water column phosphorus supply for algal growth is seldom lacking. Conversely, the amount of nitrogen in the water column, especially in inorganic form, generally limits algal growth. Consequently, excess contributions of nitrogen-containing substances into Tampa Bay can result in algal blooms of nuisance species. These events often lead to eutrophic conditions characterized by poor water clarity and bottom waters devoid of dissolved oxygen.

INTRODUCTION

This chapter discusses the various influences on the ecological health of the Tampa Bay estuarine system, The status of the ecosystem is determined by physical and chemical factors. Meteorological conditions in the area influence the amount of water draining to the bay from its watershed, and the distribution and flow patterns of water masses in the bay. Characteristics of the watershed are in part responsible for both the quality and quantity of freshwater entering the estuary, and the physical characteristics of the bay determine the movement of water in the bay.

Associated with the water masses in Tampa Bay are physical and chemical characteristics which impact the range and health, both in time and space, of habitats within the ecosystem. Drainage from the watershed carries nutrient, suspended sediment, and toxic loads, as determined by various characteristics of the watershed. Saltwater from the Gulf of Mexico also contains chemicals and sediments, and the combination of the loads carried by the saltwater and freshwater masses determines the types of biological communities in the ecosystem. Circulation patterns, flushing and exchange rates, temperature, nutrient, and salinity distributions, and sedimentation are all related to the physical structure of Tampa Bay, and the locations of biological communities are influenced by some or all of these.

Water column communities are adapted to certain ranges of nutrients, salinity, temperature, dissolved oxygen, and light conditions. The health of submerged aquatic vegetation depends on the light environment and conditions on the bottom of the bay. The health of benthic ecosystems depends on sediment conditions, food supply, and oxygen availability. All of these are determined by the interactions of the physical/chemical properties in water masses and the movement of these water masses, which are ultimately determined by the characteristics of the watershed and the bay's physical structure.

PHYSICAL SETTING

Tampa Bay is on the west central coast of Florida between 27.5° and 28°N latitude (Figure 3-1). The land surrounding the bay is relatively flat, and the subtropical climate is mild. The average annual temperature is around 22°C (72°F). The low topography allows an unimpeded path for winds and rains to move across the area. The proximity of the Gulf of Mexico tends to moderate temperatures, with the water acting as a heat sink in the summer and a heat source in the winter.

The Tampa Bay area receives an average of 140 cm (55 inches) of precipitation each year, with approximately 30% of this falling during November through April. Approximately 60% of the annual rainfall occurs during June through September as the result of thunderstorms. These thunderstorms are caused by differences in heating rates between the land and nearby water. Local variations in precipitation can be very high, as these thunderstorm systems are not large. This wet-season rainfall results in higher freshwater input to the bay during the summer months.

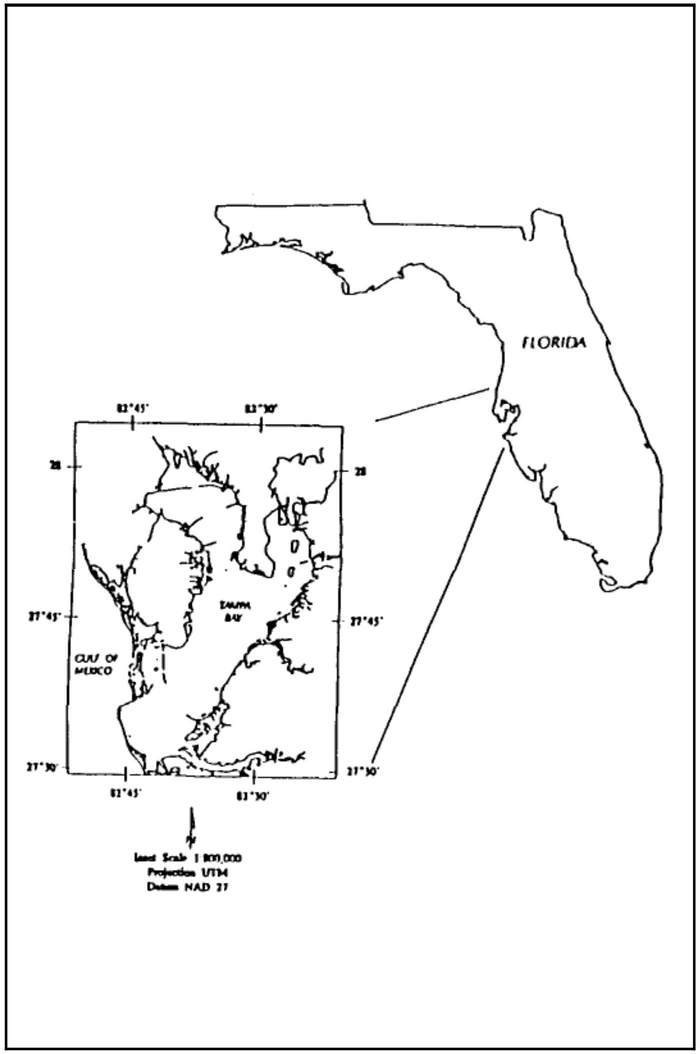

Figure 3-1. Location of the Tampa Bay estuarine system.

Wind characteristics arc dctcrmincd by the interaction of long- and short-term wind patterns. Long-term wind patterns result from large-scale atmospheric features, such as the Atlantic high-pressure system which drives winds from the south and southeast over the Tampa Bay watershed in the summer months. During the wet season, sea breeze convective winds interact with the winds from the south produced by the high-pressure system. Wind speeds associated with the sea breeze convection are normally strongest along the coast and weaker inland, with short-term wind speeds of 22-31 mph resulting from a thunderstorm. Wind speeds resulting from the sea breeze convection increase during the day, peak in late afternoon, and decrease in the evening.

During the dry season (November-April), sea breeze convection lessens as less heating occurs. Wind patterns during these months are influenced by frontal systems moving through the area, bringing colder air with them. Winter cold fronts normally affect the Tampa Bay area about once a week, with winds over the duration rotating through 360 degrees. Maximum wind speeds at the leading edgc of the front arc from the southwest, and may be as high as 45-58 mph, although generally these maximum wind speeds are about 18 mph.

Winds affect the general circulation of the Tampa Bay estuary, as well as the magnitude of the tides. Winds from the northeast associated with the passage of frontal systems over the fall-winter period result in a lowering of mean sea level by several inches, as well as lower water temperatures in the bay. Winds blowing into the bay along the bay's axis (from the south/southwest) result in an increase of mean sea level, and produce non-tidal currents from the middle to the bottom of the water column directed out of the bay within the deep channel, with return flow nearer the surface and along the sides. When winds blow in the opposite direction, the converse occurs.

Temperatures in the Tampa Bay watershed are affected by the previously mentioned frontal passages, thunderstorms, and solar radiation. Coastal areas show smaller daily variations in temperatures than do inland areas, as the nearness of the water tends to moderate extremes, and the inland areas warm and cool more quickly. Sharp drops in temperatures are caused by the passage of frontal systems in the winter, with temperature differences of 3-8°C (5-14°F) found from the shore to a few kilometers inland. A similar gradient may exist between high, dry land and nearby moist lowlands, and temperature gradients develop between urban and rural areas.

Severe freezes occur about once every 20 years, and relatively non-destructive freezcs occur about once or twice a year. Severe freezes are more likely inland, where the distance from the waters of the gulf and bay results in less protection than for coastal areas.

During the summcrtimc (wet season), air temperaturcs rise to 35-37°C (mid- to upper-90s °F) in the area of developing thunderstorms, then drop rapidly by 5-17°C (9-31°F) just prior to a downpour. In the Tampa Bay region, especially inland, temperatures of 32°C (90°F) or greater occur an average of 100 days each year.

Tropical storms and hurricanes introduce unique climatic characteristics and conditions affecting local ecosystems. The Tampa Bay watershed is most likely to be hit by a tropical storm/hurricane in September and October. Associated with these systems is a storm surge, the result of high winds and low barometric pressure. The highest storm tide recorded in Tampa Bay was 4.5 m (15 feet) in 1848. Rainfall from these systems is normally 12-25 cm (5-10 inches) over the period of storm passage, with more than 30 cm (12 inches) of rain in 24 hours in 1960 as Hurricane Brenda struck the bay area.

WATERSHED DESCRIPTION

The Tampa Bay watershed, or drainage basin, covers approximately 5,950 km^2 (2,300 mi^2) (Figure 3-2). The watershed includes all or parts of Pasco, Pinellas, Hillsborough, Polk, Manatee, and Sarasota counties. Approximately five percent of the watershed is internally drained, and does not contribute to runoff except in rare instances. For the purposes of better delineating runoff sources, the watershed is divided into ten major basins. These major basins correspond to the drainage areas of thc four major rivers (Hillsborough, Alafia, Little Manatee, and Manatee and the six ungaged drainage basins (Old Tampa Bay, Hillsborough Bay, Middle Tampa Bay, Lower Tampa Bay, Boca Ciega Bay, and Terra Ceia Bay).

The ten major drainage basins provide freshwater inflow to seven Tampa Bay segments. Two of these seven major segments' watersheds are made up of more than one drainage basin. The watershed of the Hillsborough Bay segment is composed of the Coastal Hillsborough Bay basin (7% of the entire Tampa Bay drainage basin), the Hillsborough River basin (26% of the entire watershed), and the Alafia River basin (14% of the entire watershed). Similarly, the Middle Tampa Bay segment watershed is made up of the Coastal Middle Tampa Bay basin (7% of the entire watershed) and the Little Manatee River basin (9% of the entire watershed). Even further subdivision of the watershed into 435 subbasins has been made by the TBEP, building on earlier work by the USGS.

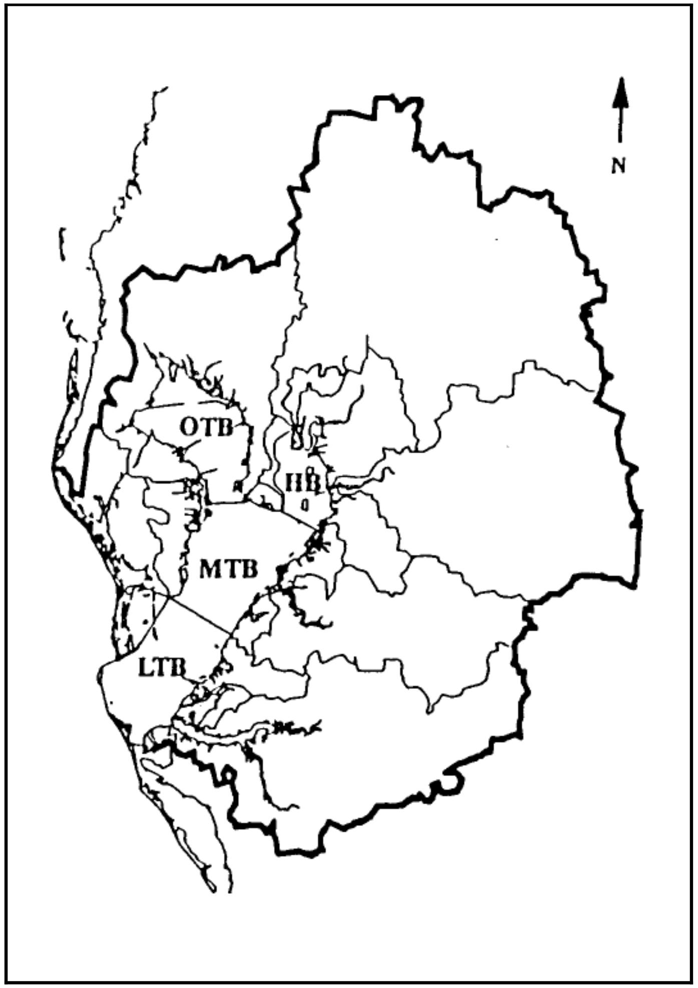

Figure 3-2. The Tampa Bay estuary and the ten major drainage basins of the watershed. (OTB=Old Tampa Bay, HB=Hillsborough Bay, MTB=Middle Tampa Bay, LTB=Lower Tampa Bay)

The watershed contains various sources of runoff which deliver freshwater and the associated nutrients and pollutants to the Tampa Bay estuarine system. These sources are divided into nonpoint sources, atmospheric deposition (directly to the open water of the estuary), point sources (domestic, industrial, and springs), groundwater, and septic tank leachate and wastewater residual solids.

Nonpoint sources include stormwater runoff, base flow, and direct overland flow. The Little Manatee, Hillsborough, Alafia, and Manatee rivers, as well as the Lake Tarpon Outfall and the Tampa Bypass Canal, are all nonpoint sources of freshwater inflow. Wetlands may also contribute, depending on the season.

Also contributing as a source of freshwater, nutrients, and pollutants is rainfall directly on the various bay segments. Dry deposition of nutrients and pollutants may occur in the absence of rainfall. Atmospheric nutrients are mainly supplied by industries and automobiles, with natural sources of atmospheric nutrients believed to be less significant.

Point sources are comprised of domestic, industrial, and spring discharges. Point sources contribute discharge through either direct surface discharge, to surface water bodies such as streams, creeks, rivers, or bay waters, or through application to land, as in discharge to a settling pond or to an irrigation system. Important springs in the Tampa Bay watershed are Crystal Springs, Sulphur Springs, Buckhorn Springs, and Lithia Springs.

Groundwater inflows occur from the water table, intermediate, and Floridan aquifers, and may enter the bay from the shoreline or bay bottom. Septic tank leachate and wastewater residual solids are of special concern as nutrient and pollutant sources in areas with high concentrations of septic tank systems near bay waters.

The Tampa Bay watershed's four major tributaries, in conjunction with more than 40 creeks and coastal streams, strongly influence the Tampa Bay estuary, providing freshwater to mix with the saline waters of the bay. This mixing of freshwater and saltwater influences both physical and biological aspects of the Tampa Bay estuarine system.

Runoff from the Tampa Bay watershed is affected by various factors, including topography, soils distribution, hydrogeology, land use, and rainfall. The main factor impacting runoff patterns is land use. As urbanization increases, activities that affect surface hydrology occur: canals are dug, tributaries are straightened, reservoirs are built, and land surface is paved over.

For estimating nonpoint source flows and pollutant loads, land use in the Tampa Bay watershed was divided into four major categories: urban, agricultural, wetlands, and other undeveloped lands. In 1993, urban lands accounted for approximately 25% of the watershed area, with agricultural, wetlands, and other undeveloped lands making up approximately 35%, 13%, and 27%, respectively, of the drainage basin lands. Each land use category has different drainage and retention characteristics.

BAY DESCRIPTION

Physical Structure

Tampa Bay covers an area of about 1,030 km^2, or 398 mi^2 (Table 3-1). It extends approximately 35 miles (56 km) inland from the Gulf of Mexico, and is 5 to 10 miles (8-16 km) wide along the majority of its length. It is crossed by four major causeways, and has 42 nautical miles of dredged channels with designed mean low water depths of 6 to 13 m (20 to 43 feet). The major shipping channel has been dredged from the mouth of the bay to the upper reaches of the Middle Tampa Bay segment, where it splits to the north into the Old Tampa Bay segment and to the northeast into the Hillsborough Bay segment. The average depth of the bay is approximately 4 m (13 feet), with the maximum natural depth of 27 m (89 feet) found in a small area at the mouth of the bay in the Egmont Channel.

Tampa Bay is subdivided into seven segments (Figure 3-3). The Lower Tampa Bay segment connects the mouth of the bay to the Gulf of Mexico. The Lower Tampa Bay segment is joined on the southeast by the Manatee River and

Table 3-1. Parameters for four main Tampa Bay segments and Tampa Bay as a whole.

Bay Segment	Surface Area km^2 (mi^2)	Volume million m^3 (million ft^3)	Average Depth m (ft)	Watershed Drainage Area km^2 (mi^2)
Tampa Bay	1030 (398)	3,300 (116,000)	4 (13)	5,950 (2,300)
Lower Tampa Bay	247 (95)	1,200 (42,100)	4 (13)	298 (115)
Middle Tampa Bay	310 (120)	1,166 (40,900)	4 (13)	952 (368)
Hillsborough Bay	105 (41)	306 (10,700)	3 (10)	2,797 (1,081)
Old Tampa Bay	200 (77)	548 (19,200)	3 (10)	774 (299)
Manatee River	55 (21)	-	-	833 (322)
Boca Ciega Bay	93 (36)	-	-	238 (92)
Terra Ceia Bay	21 (8)	-	-	35.7 (13.8)

Terra Ceia Bay segments, with the Boca Ciega Bay segment adjacent to the north.

The next segment up the bay is Middle Tampa Bay, with the Hillsborough Bay segment connecting to the northeast and the Old Tampa Bay segment adjoining to the north. The southern boundary of the Hillsborough Bay segment crosses from the southernmost point of the Interbay Peninsula southeast to Hillsborough County. For the Old Tampa Bay segment, the southern boundary links the closest points of the Pinellas and Interbay Peninsulas.

Water Movement

Water movements in Tampa Bay are controlled by tidal processes, winds, the physical structure of the bay, and freshwater inflow. Tidal forcing is primarily mixed lunar semi-diurnal and solar diurnal, resulting in two unequal high and two unequal low tides daily, with an average tidal range of about 0.7 m (2.3 ft). Meteorological influences on water movement were discussed previously in this chapter. The physical structure of the bay, including human-made changes, defines the location of some circulation gyres, as well as the path of water exchange between bay segments and the Gulf of Mexico. Freshwater inflow to the bay, and especially Hillsborough Bay, is essential to maintain flushing.

Tidal action results in currents of approximately 1.8 m/s (5.9 ft/s) on ebb tides and approximately 1.2 m/s (3.9 ft/s) on flood tide at the mouth of Tampa Bay. The flood tide follows the main navigational channel as it propagates into the bay, and splits into Old Tampa Bay and Hillsborough Bay where the channel diverges. Current speeds are decreased by about 90% by the time the tidal influence reaches Hillsborough Bay. It takes the flood tide 3.5 hours to propagate from the mouth to the upper reaches of the bay, with shorter duration for the ebb cycle.

Tidal forcing leads to water exchange between segments and with the Gulf of Mexico. Lower Tampa Bay interacts with the Gulf of Mexico, Boca Ciega Bay, Terra Ceia Bay, and Middle Tampa Bay, and tidally exchanges approximately 6.5% of its total volume each day. Middle Tampa Bay has a daily tidal exchange of approximately 4.6% of its total volume, and interacts with Old Tampa Bay, Hillsborough Bay,

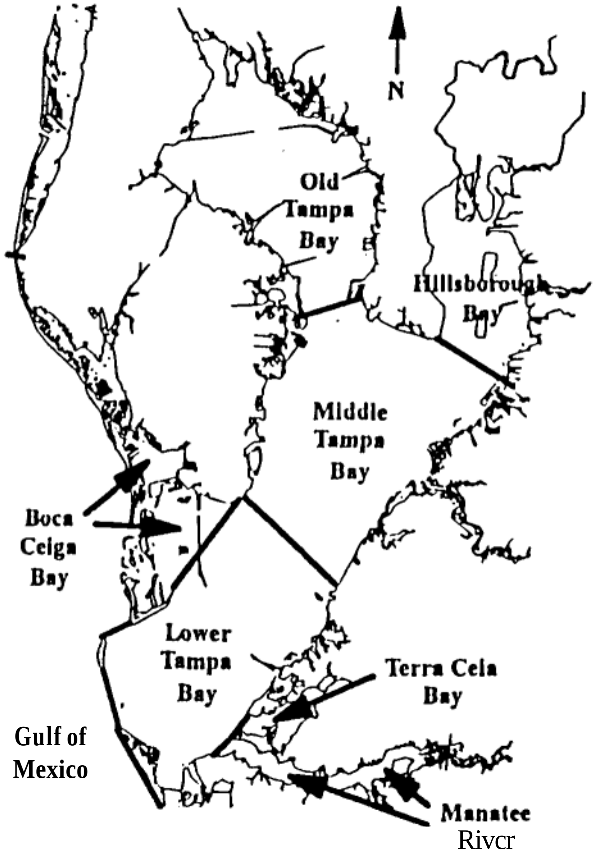

Figure 3-3. The seven segments of the Tampa Bay estuary.

and Lower Tampa Bay. Old Tampa Bay also has a daily tidal exchange rate of approximately 4.6% of its volume, and interacts on its southern boundary with Middle Tampa Bay. Hillsborough Bay has the least tidal exchange of any of the major segments, with only approximately 1.4% of its volume exchanged daily.

The physical structure of the bay also affects circulation and flushing. Besides the previously mentioned tidal flow following the dredged main channel of the bay, other circulation features are associated with human-made causeways of the four main bridges spanning the bay. A series of tidal gyres is present in the bay. and it has been hypothesized that the creation of thcsc circular tide-inducced features is aided by the causeway structures. The gyres can be from one to six miles in diameter, and may decrease the exchange of water, as well as the nutrient and pollutant loads associated with it, in the northern portions of the bay.

Freshwater inflow to Tampa Bay is about 63 m^3/s, or about 2 billion m^3 (525 billion gallons) on an annual basis, with the four major rivers contributing about 70%-85% of this. The Hillsborough and Alafia rivers, contributing approximately 44% of the total freshwater inflow to Tampa Bay, discharge to the Hillsborough Bay segment. The Little Manatee River discharges to Middle Tampa Bay on the eastern shore, and Lower Tampa Bay receives freshwater input from the Manatee River in the southeast.

Even though Tampa Bay is considered to be a vertically well-mixed estuary (little vertical change in salinity/density), the freshwater inflow results in horizontal salinity gradients important in the circulation and flushing of Tampa Bay, especially along the eastern shore where most of the freshwater inflow occurs. Despite the fact that freshwater inflow is only 63 m^3/s, compared to the averagc tidal flow at halftide of 25,500 m^3/s, these horizontal salinity gradients may dominate the residual (not tidal-induced) circulation of Tampa Bay. Observational data to support this hypothesis arc lacking, although model results indicate that fresher water exits the bay along its banks and near the surface, while saltier water enters the bay along its axis and nearer the bottom.

Salinity and Temperature Patterns

Salinity patterns in Tampa Bay are as expected, with higher salinities in areas which interact strongly with the Gulf of Mexico, and lower salinities in regions affected by freshwater inflow and regions farthest away from the Gulf. Surface salinities are normally 1-2 ppt (parts per thousand) less than those near the bottom. Minimum salinities occur in September of each year, with maximum salinities in June.

Variability between years of 6-10 ppt at the surface and 5-6 ppt near the bottom occurs, with a pronounced salinity gradient along the axis of the bay in both wet and dry years. This horizontal salinity gradient between Hillsborough Bay and the mouth of Tampa Bay is about 10 ppt throughout the year. Physical alterations to the bay, especially the shipping channel network, strongly influence bay salinities, with a tongue of high salinity extending up the center of the bay along the main channel.

Salinity values are affected by precipitation, evaporation, freshwater input, and interaction with the Gulf of Mexico. The highest salinities are found in late spring and early summer, following the low rainfall and runoff of the dry season. The lowest salinities, in September, are related to high rainfall and runoff. Local effects of riverine inputs are obvious during the wet season.

Salinity in Lower Tampa Bay, nearest the mouth of the bay, generally ranges over 25-38 ppt, with salinity in the north portion of Lower Tampa Bay rarely below 30 ppt. Middle Tampa Bay, serving as a transitional area between the northern and southern regions of the bay, has salinities of 25-35 ppt, and the southern portion of this segment, like the northern portion of Lower Tampa Bay which joins it, very seldom has salinities less than 30 ppt. Old Tampa Bay, in the northern part of Tampa Bay, receives runoff from urban areas within its watershed, and has a higher range of salinities than do the more southem regions of the bay, with salinities normally varying over 18-32 ppt. Hillsborough Bay, by virtue of the relatively large volume of freshwater discharge it receives from rivers and the surrounding urban area, has the lowest salinities in the bay, with a salinity range of 15-30 ppt.

Temperature patterns in the waters of Tampa Bay, like salinity patterns, show little vertical variation. Variations in annual average water temperature between the surface and the bottom are only up to 1°C (1.8°F). Maximum water temperatures of 28-30°C (82-86°F) are found in June through August, with minimum temperatures of 15-18°C (59-64°F) in December through February. As expected, temperatures follow a smooth seasonal pattern, with similar seasonal temperature patterns throughout the bay.

Sedimentology

Tampa Bay has its geologic origins in a drowned river valley system which was flooded over a period beginning 6000-8000 years ago and ending between 3000 and 5000 years ago. Prior to this flooding, with sea level 100 m lower than present and land extending 160 km farther west, streams carried quartz sand that had eroded from the Tertiary terrace deposits in central Florida, which were formed during a period of high sea level. This quartz sand was deposited directly into Tampa Bay after the most recent sea level rise, and joined other deposits of muds, peats, and oyster bars to make up the sediment within the bay. There are up to 20 m of unconsolidated sediments in Tampa Bay, with surface sediments consisting of a mixture of quartz sands, shell material, and muds high in organic matter.

Sediments are classified as being land-derived or marine-derived. Land-derived sediments are predominantly quartz sands and silt, with some fine-grained organic materials and clay minerals mixed in. Quartz sand-sized sediments originated during the early period of bay flooding, and are found throughout the bay. Marine-derived sediments are coarse-grained calcium carbonate from marine shells. Various factors play a role in the distributions of the different types of sediments, including grain size and depositional environment.

The distribution of old quartz sands within Tampa Bay is controlled by physical processes, with limited input of new quartz sands via exchange with the Gulf of Mexico. High energy events, such as storms and strong tides, serve to redistribute these quartz sands, which predominate in open portions of the central and lower bay, mainly because of the lack of modem sediment deposition.

Most current additions of land-derived sediments are fine-grained muds with high quartz and organic matter components, with which contaminants are associated. Mud-sized (fine-grained) sediments tend to collect in depressions in the floor of the bay and in dead-end canals, where low-energy zones exist. Fine-grained sediments high in organic matter (muck) occupy 15-20% of the Hillsborough Bay bottom, normally where the bay floor is more than 4 m

(13 feet) deep, and have been accumulating in these areas for about the last 5000 years. In less developed areas and near the mouth of the bay, where higher-energy zones (high rates of flushing and disturbance) are prevalent, mud-sized sediments are more scarce.

Controlling factors affecting the distribution of these fine-grained land-derived sediments are bathymetry (as described above), physical processes, and sediment origin. The physical processes in some areas of the bay are not highly energetic, and these are the areas nearest the source of the fine-grained land-derived sediments, so that these regions are most likely to accumulate fine-grained land-derived sediments.

The sediments with a marine source are almost entirely calcium carbonate from marine shells, and are larger, coarser-grained sediments. Muds are also created from the breakdown of algae within the bay. The larger-grained sediments may be produced within the bay or imported from the Gulf of Mexico via tidal currents. Calcium carbonate sediments generally increase as a proportion of total sediments with increasing nearness to the bay mouth, and within open portions of the bay. In some peripheral areas, these sediments may be layered within fine-grained, land-derived sediments, which may represent either local calcium carbonate production and sedimentation, or may be the result of storm events.

The distribution of these coarse-grained. marine-derived sediments is controlled by physical processes and the origin of the sediment. A combination of these factors explains the increase in these sediments as the mouth of the bay is approached, where stronger tidal action and more marine conditions prevail. Even when tidal energy is too low to move the coarse-grained sediments, it can still provide a means for removing fine-grained sediments and leaving deposits of predominantly coarse-grained sediments.

CONCLUSION

The Tampa Bay ecosystem is strongly influenced by the local meteorological conditions occurring over the watershed and bay, affecting freshwater inputs to the bay. The characteristics of the Tampa Bay watershed determine the quality and quantity of the fresh water inflow to the bay. This fresh water inflow, in combination with the physical structure of the bay and the associated water movements, is an important factor in producing patterns of salinity, temperature, and sedimentation which define the limits of biological communities.

CHAPTER 4 - FRESHWATER INFLOW AND NUTRIENT LOADINGS

J.O.R. Johansson (City of Tampa, Bay Study Group)

- CHAPTER HIGHLIGHTS -

- *Estimates of Tampa Bay freshwater inflow and estimated total nitrogen and total phosphorus loadings do not indicate any obvious trends over 1985-1998.*
- *Variability in total nitrogen loads between years appears to be greatly affected by rainfall.*
- *Total nitrogen loadings estimated by the dilution method ranged between 5,000 and 6,000 US tons during wet years and between 3,000 and 4,000 US tons during relatively dry years.*
- *Total phosphorus loadings do not reflect differences between wet and dry periods.*

INTRODUCTION

The flow of freshwater, nutrients and sediments to Tampa Bay from the surrounding land and atmosphere is a natural result of the hydrologic cycle and is essential for the maintenance of the bay ecosystem. However, industrial development and population growth in the watershed, and the increased use of fertilizers and fossil fuels, have all influenced the export of these materials to the bay. Specifically, the excessive loading of nutrients, primarily nitrogen, is of special concern because the enrichment of this nutrient to estuaries like Tampa Bay generally results in deteriorated water quality and an over-all loss of biological diversity and system productivity. Nutrient enrichment, or eutrophication, of Tampa Bay waters appears to have been most serious from the late 1960s to the early 1980s. Records of water quality and biological indicators, such as phytoplankton biomass and seagrass coverage, show that the severest degradation occurred in the upper portions of the bay, while areas closer to the Gulf of Mexico were less impacted.

Regulatory actions directed at several large point-sources, and voluntarily conducted improvements as well, greatly reduced the loading of nutrients and suspended solids to Tampa Bay during the late 1970s and early 1980s. Reductions of nitrogen are of particular interest because of the link between this nutrient and eutrophication. Large nitrogen reductions occurred in Hillsborough Bay as a result of the upgrade of treatment at the City of Tampa's domestic wastewater plant and pollution abatement actions at several agricultural fertilizer producing plants. These actions resulted in a more than 50% reduction of nitrogen loading to Hillsborough Bay and a substantial reduction to Tampa Bay as a whole. Additional decreases in nitrogen loading have occurred in other sections of the bay as other domestic wastewater plants either upgraded their treatment or terminated discharges to the bay. Efforts to reduce the impact of stormwater discharge have also been undertaken during the last decade. Phosphorus and suspended solids reductions resulting from these efforts may be substantial. However, with the exception of actions taken at several agricultural fertilizer facilities, nitrogen loading reduction as a result of stormwater management has, to this date, probably been minor in comparison to the reductions from the point-sources.

It is important to periodically estimate freshwater, nutrient, and solids loadings to Tampa Bay in order to document the progress of bay management and to help explain ambient bay conditions. This section of the Baywide Environmental Monitoring Report will primarily discuss annual loading estimates of freshwater inflow, total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) from five source categories for each of the seven major Tampa Bay segments. Loadings have been calculated for the ten year period, 1985 through 1994, for all parameters except TSS, which has not been estimated since 1991. The loadings were calculated by Coastal Environmental/PBS&J (under contract with TBEP) by using the traditional method of summing the loadings from major known sources. Updated loading estimates through 1998 are currently being conducted. In addition, the author of this section used an alternate approach to estimate historical and current TN and TP loadings to Tampa Bay. This method, called the dilution method, is based on the ambient Tampa Bay salinity and nutrient concentration relationship.

METHODS USED TO CALCULATE LOADINGS

Traditional:
Five categories of potential major sources of TN, TP, and TSS have been identified by the TBEP. These include nonpoint sources (stormwater runoff and base flow), point sources (domestic and industrial), atmospheric deposition (wetfall-rainfall and dryfall-dust, delivered to the open-water estuary), groundwater, and fertilizer material loss (unpermitted losses during handling and shipping of fertilizer products). Loads from these sources were estimated by Coastal Environmental/PBS&J by the use of Geographic Information System mapping and analytical techniques described in BEMR 1996. The contributions from the five source categories were then summed to yield individual bay segment loads and the total load to Tampa Bay.

Dilution:
The dilution approach of estimating Tampa Bay nutrient loadings is based on the salinity-nutrient concentration relationship of the bay water (GESAMP, 1987; Balls, 1994). This approach is less laborious than the traditional method; however, as applied here, it only yields total Tampa Bay loadings in contrast to the traditional method which has been used to estimate loadings of five source categories to each of the seven major bay segments. The purpose of estimating annual loadings by the dilution method, in addition to traditional estimates, is twofold. First, dilution estimated loadings can serve as a check on the total Tampa Bay traditional loading estimates. Secondly, dilution loadings can be calculated quickly at a low cost and can, therefore, provide a timely loading estimate. The dilution method assumes that once TN and TP has entered Tampa Bay from all sources, the nutrients are mixed conservatively with bay waters. Ambient nutrient concentrations, provided by the Hillsborough County Environmental Protection Commission (EPC), can then be expressed as a function of salinity. The nutrient concentrations at zero salinity, representing the nutrient concentrations of the freshwater entering the bay, are then calculated from the regression. The zero salinity nutrient concentrations are then multiplied by the freshwater input, estimated from US Geological Survey flow data and other flow information, to yield total annual Tampa Bay loadings of TN and TP.

Nutrient loadings to Tampa Bay calculated by the two methods may not always be comparable Results from the dilution method reflect the loadings from all known and unknown nutrient sources to the bay, including potential modifications to nutrients within the bay. In contrast, loadings estimated by the traditional procedure are generally limited to recognized external loadings. It should be noted that the traditional estimates for Tampa Bay do not include TN and TP inputs from documented major accidental fertilizer spills to the bay.

RESULTS AND DISCUSSION

Estimates of Tampa Bay freshwater inflow and traditionally estimated TN and TP loadings do not indicate any obvious trends over the 10 year period, 1985 through 1994 (Figs. 4-1,4-2, and 4-3). Also, a long-term trend is not apparent in the shorter TSS loading record (Fig. 4-4). The variation between years for all parameters appears to be affected, to a great extent, by the annual Tampa Bay rainfall amount (Fig. 4-5). For example, 1988 had the greatest amount of rainfall during the ten year period and this year also had the highest loadings for all parameters. Similarly, 1990 had the smallest amount of rainfall and the lowest loadings for all parameters.

Hillsborough Bay has, by far, the greatest watershed area of all bay segments, and also receives discharges from several large point sources (Figs. 4-6 to 4-9) and the major fraction of inputs from the fertilizer facilities located near Tampa Bay. Consequently, Hillsborough Bay has the greatest impact among the bay segments on total Tampa Bay loadings for all parameters, including 30% of freshwater inflow, 41% of TN loading, 56% of TP loading and 42% of TSS loading (Table 4-I). In contrast, Terra Ciea Bay, which has the smallest watershed area and which lacks inputs from large point sources, has the least impact on the bay and supplies less than two percent of any input parameter to Tampa Bay.

Table 4-1. Percentage contribution by each bay segment to the total Tampa Bay loading of freshwater inflow, TN, and TP for the period 1985-1994, and TSS for the period 1985-1991.

Bay Segment	Freshwater Inflow (percentage)	TN Loading (percentage)	TP Loading (percentage)	TSS Loading (percentage)
Old Tampa Bay	17.5	12.6	10.5	14.1
Hillsborough Bay	29.6	40.9	55.9	42.1
Middle Tampa Bay	22.5	19.0	13.8	14.7
Lower Tampa Bay	12.9	9.0	10.5	1.4
Boca Ciega Bay	6.4	5.6	3.6	12.3
Terra Ceia Bay	1.1	0.9	0.7	0.6
Manatee River	10.0	11.9	5.0	14.7

Atmospheric deposition apparently supplies a major fraction of TP inputs, and a substantial amount of TN inputs, to the three bay segments with large surface areas, Old Tampa Bay, Middle Tampa Bay, and Lower Tampa Bay (Appendix A). However, the smaller segments, Boca Ciega Bay and Terra Ciea Bay, also receive relatively large amounts of these nutrients from the atmosphere. About 28% of the TN loading to Tampa Bay is deposited from the atmosphere directly on the open water area of the bay. This value agrees with findings from other United States east coast estuaries.

Non-point sources supply the major amounts of TSS loading to all Tampa Bay segments except to the Manatee River (Appendix A). This segment also has, in addition to a large non-point source input, a substantial industrial point source loading of TSS. Loadings to the Manatee River are expected to decrease in the near future as a result of industrial discharge improvements.

The annual Tampa Bay TN loadings calculated by the traditional and the dilution method are quite similar for all years except 1985 (Fig. 4-10). The 1985 traditional estimate is considerably less than the dilution estimate. The difference could be related to a major industrial spill of ammonium nitrate to Hillsborough Bay. The loss, reported to be 1650 US tons of nitrogen, was not included in the 1985 traditional estimate. Adding the spilled amount to the 1985 traditional estimate reduces the difference; however, the dilution estimate is still substantially greater than the traditional estimate.

The annual TP loadings calculated by the traditional method are most often lower than the dilution estimate (Fig. 4-11). This discrepancy suggests that substantial amounts of phosphorous may be released from internal sources, such as the bay sediments, or that the dilution method accounts for external sources of TP which were not included, or only partly included, in the traditional estimate. It is interesting that the discrepancy is largest for the early years of the comparison and that the most recent estimates between the two methods are quite similar. The decreasing difference between the two estimates may imply that sediment phosphorous deposits, created during a documented period of high phosphorous loading prior to the 1980s (Fig. 4-11), are now being depleted.

TN loadings to Tampa Bay, estimated by the dilution method, increased during the relatively high rainfall periods, 1994, 1995, and the El Nino event in 1997 and 1998 (Fig. 4-10). The annual loading during these periods ranged between 5000 and 6000 US tons. TN loadings were considerably lower (3000 to 4000 US tons/yr) during the relatively low rainfall period 1989-1993. In contrast, the recent TP loadings estimated by the dilution method do not reflect distinct differences between wet and dry periods.

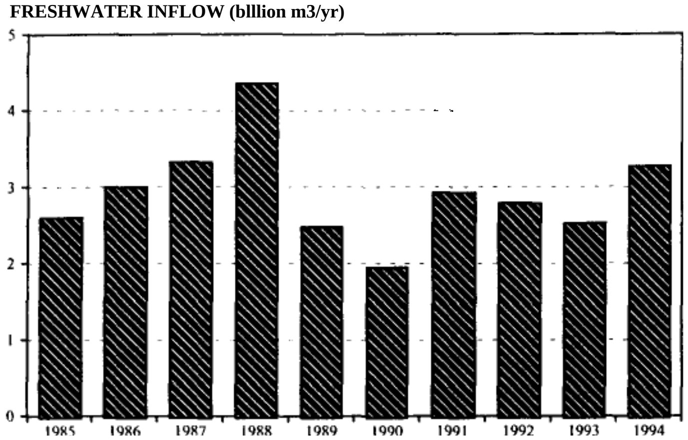

Figure 4-1. Annual freshwater inflow to Tampa Bay, 1985-1994.

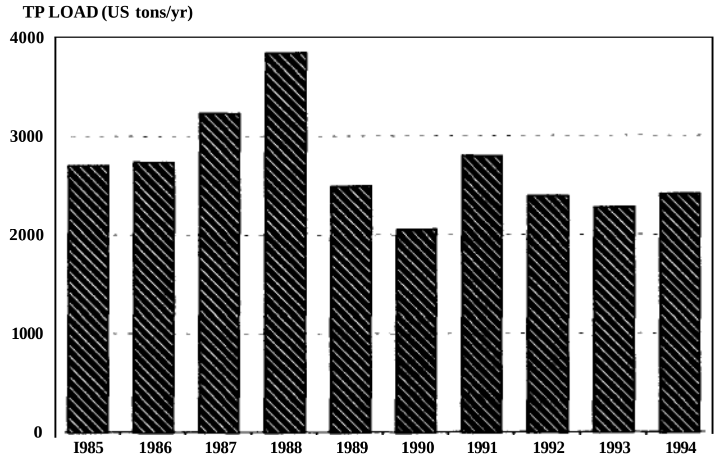

Figure 4-3. Annual TP loading to Tampa Bay, 1985-1994.

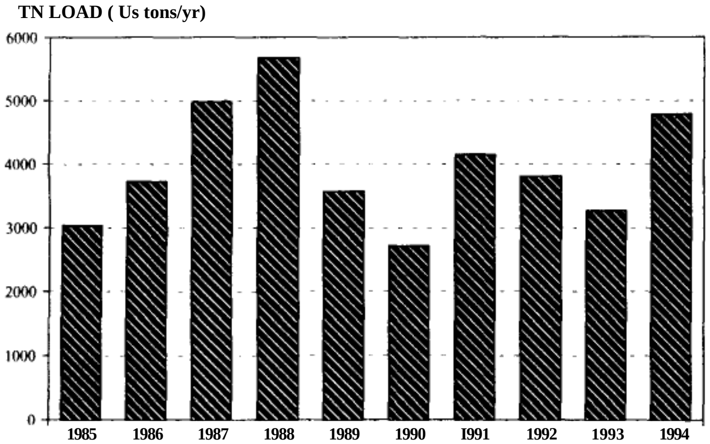

Figure 4-2. Annual TN loading to Tampa Bay, 1985-1994.

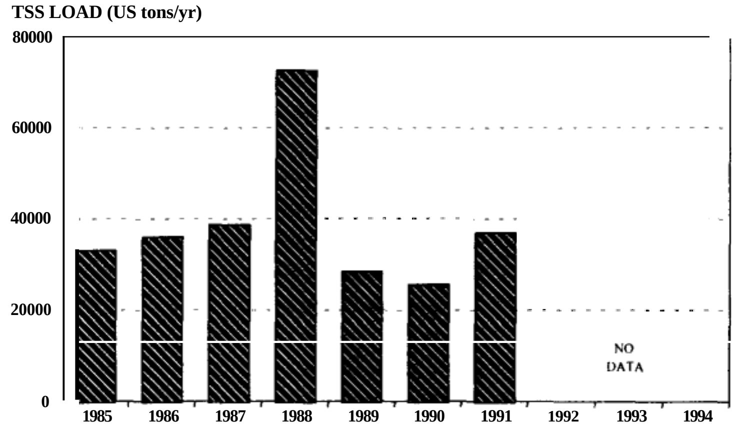

Figure 4-4. Annual TSS loading to Tampa Bay, 1985-1991.

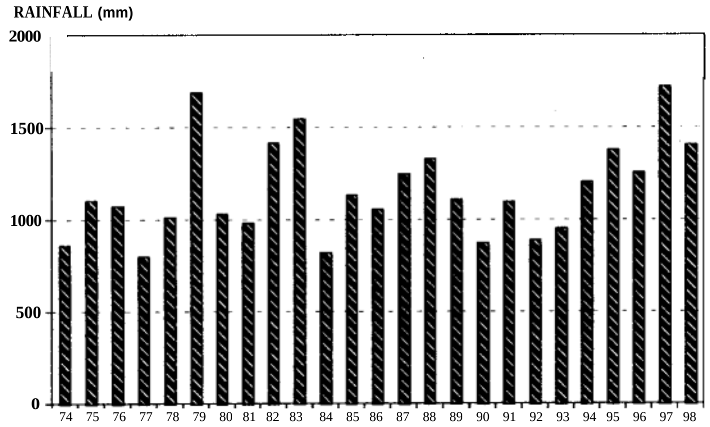

Figure 4-5. Annual rainfall at the Tampa International Airport, 1974-1998.

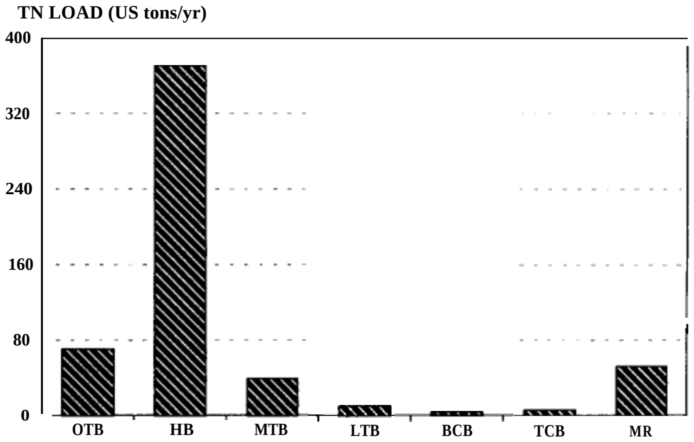

Figure 4-7. Average annual point source loading of TN to the seven Tampa Bay segments for the period 1985-1994.

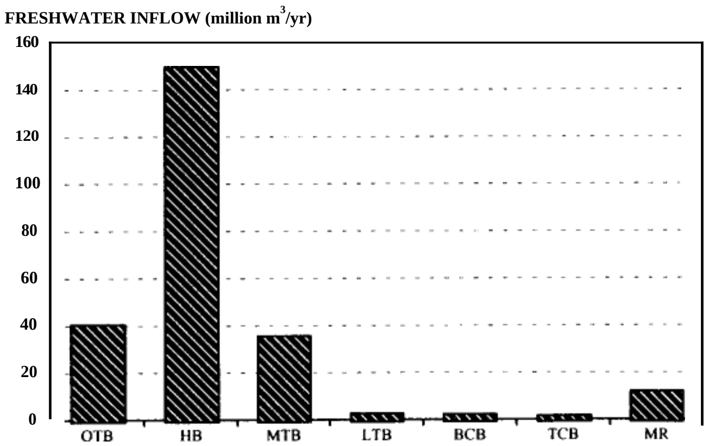

Figure 4-6. Average annual point source fresh water inflow to the seven Tampa Bay segments for the period 1985-1994.

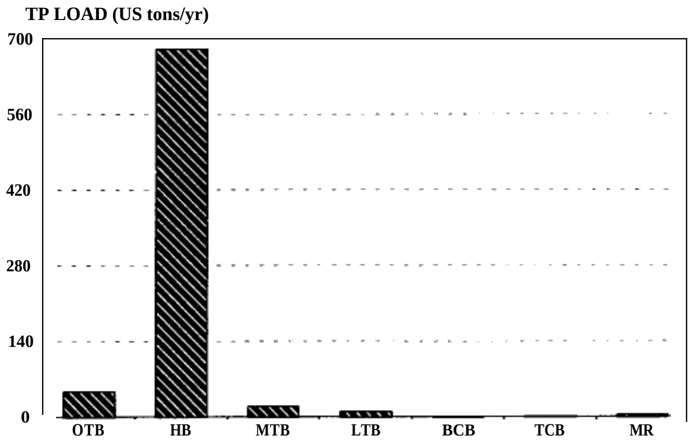

Figure 4-8. Average annual point source loading of TP to the seven Tampa Bay segments for the period 1985-1994.

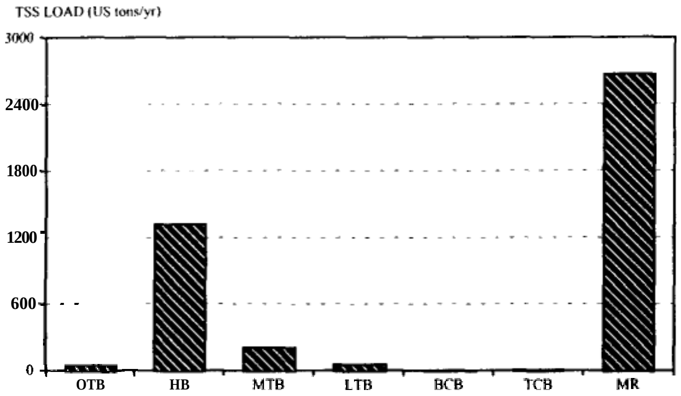

Figure 4-9. Average annual point source loading of TSS to the seven Tampa Bay segments for the period 1985-1991.

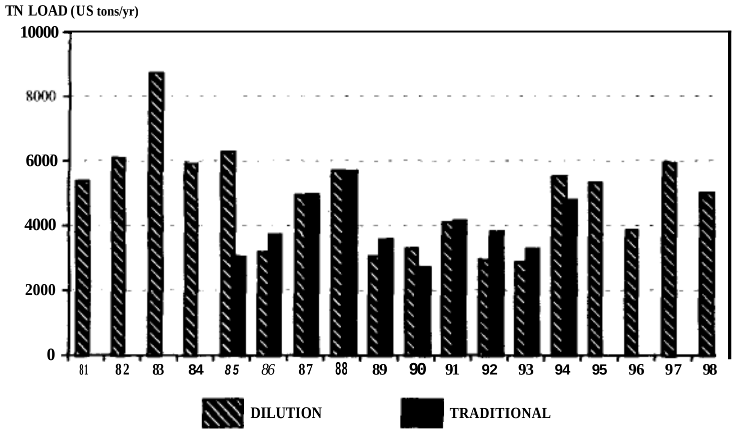

Figure 4-10. Annual loading of TN to Tampa Bay estimated by the traditional method (1985- 1994) and by the dilution method (1981-1998). Gauged freshwater flows needed for the 1997 and 1998 dilution loadings calculations were not available. Flows for these years were estimated from rainfall at Tampa International Airport.

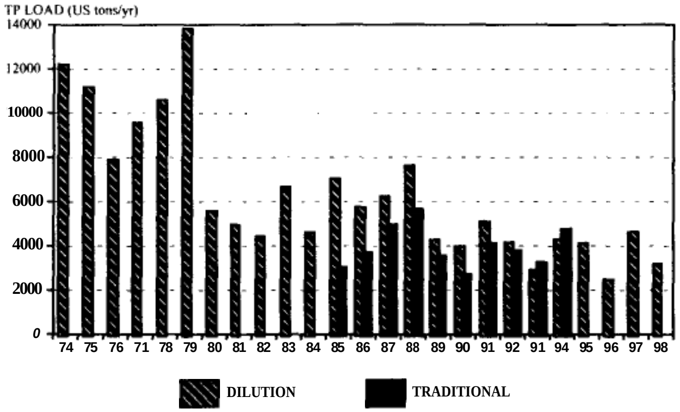

Figure 4-11. Annual loading of TP to Tampa Bay estimated by the traditional method (1985-1994) and by the dilution method (1974-1998). Gauged freshwater flows needed for the 1997 and 1998 dilution loadings calculations were not available. Flows for these years were estimated from rainfall at Tampa International Airport.

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R. Pribble (Janicki Environmental, Inc.)

- CHAPTER HIGHLIGHTS -

- ***Previous estimates suggested that atmospheric deposition provides about 29% of the total nitrogen load and about 31% of the total phosphorus load to the bay.***

- ***Recent studies have been performed concerning deposition directly to the bay surface, bulk deposition, and contributions of atmospheric deposition to stormwater runoff to the bay.***

- ***Total annual deposition, averaged over the period August 1996 through July 1998, to the surface of the bay was approximately 760 mg/m^2 (838 US tons to the bay's surface), or approximately 78% of the previous estimate for 1985-1991, and representing approximately 24% of the 1985-1991 total nitrogen loads to the bay.***

INTRODUCTION

Nitrogen and phosphorus loading estimates to Tampa Bay due to atmospheric deposition have been previously determined as part of the total estimated loadings to the bay for 1985-1991. These estimates determined that atmospheric deposition directly to the bay's surface may provide about 29% of the total nitrogen load and about 31% of the total phosphorus load to the bay (Zarbock et al., 1994). Given the relative importance of these loads in comparison to the total nutrient loads to the bay, it was determined that more accurate estimates of atmospheric deposition of nitrogen and phosphorus to the bay's surface were necessary. The TBEP, Hillsborough, Pinellas, and Manatee counties, and the Florida Department of Environmental Protection asked that the bay be included as an EPA Great Waters Program. The Tampa Bay Atmospheric Deposition Study (TBADS), after approval by the EPA Great Waters Program, was begun in the spring of 1995, and resulted in data collection beginning in August 1996, and continuing through the present, with plans for sampling through August 2000.

To determine the estimates of atmospheric nitrogen and phosphorus deposition to the bay, participants in the TBADS recommended a site on the eastern end of the Gandy Bridge, which was approved by the NOAA/Great Waters participants, at which samples are collected. Data collected from this site, in concert with meteorological data collected at a mid-bay site, are analyzed to derive the amount of nitrogen and phosphorus being directly deposited to the bay surface. These data are also being utilized to estimate contributions of atmospheric deposition to stormwater nutrient loadings to the bay.

Another part of the effort to ascertain the impacts of atmospheric deposition of nutrients to Tampa Bay was an assessment of bulk deposition to the Tampa Bay watershed at seven sites (Dixon et al., 1996). Samples were analyzed for metals, nitrogen, and phosphorus at all sites over a one year period, with samples from five of the seven sites analyzed for synthetic organics over a 12 week period, Results of the analyses showed that nitrogen loading to the bay from direct atmospheric loadings is 32% of the total nitrogen load to the bay.

This project was followed by an investigation of the relationship between bulk atmospheric deposition and stormwater quality, sponsored by the Florida Department of Transportation (Dixon et al., 1998). The goals of this project were to examine spatial variability in bulk deposition and determine any relationships between bulk atmospheric deposition and stormwater loadings. Samples were collected at ten sites within the bay's watershed. Sample analyses showed that approximately 1.5 times as much nitrogen was found in stormwater than was provided by the bulk atmospheric deposition, indicating that sources other than bulk atmospheric nitrogen contributed to the stormwater. runoff nitrogen load.

Additionally, TBEP recently funded a study with the goal of estimating the contribution of atmospheric deposition of nitrogen to stormwater loading from small urban watersheds. Utilizing two small watersheds in Tampa just east of the wet and dry deposition sampling Candy Bridge site, stormwater samples were analyzed for nitrogen. Utilizing nitrogen concentrations from rainfall events at the Candy Bridge site and rainfall amounts from the small urban watersheds, a relationship was derived relating nitrogen in stormwater to the nitrogen deposited by rainfall events. Results showed that approximately the same amount of nitrogen left the watersheds in stormwater runoff as was deposited to the watersheds via rainfall from July-December 1997 (BCI and PBS&J, 1999).

The following provides the methods and results of the estimates of atmospheric nutrients to the bay's surface utilizing the data obtained at the intensive site through July 1998 (Pribble and Janicki, 1999).

METHODS

Data collection at the Gandy site and the meteorological station commenced in August 1996, with the first measurements of atmospheric nitrogen species and meteorological data on August 7, 1996. Collection of wet deposition data for both nitrogen and phosphorus began on August 13, 1996. This analysis included data from August 1996 through July 1998.

To determine the wet deposition of nutrient species to the surface of the bay, the concentrations of various nitrogen species are determined, and the total mass flux to the bay due to wetfall is the product of the chemical concentration in the rainfall, the rainfall depth, and the surface area of the bay. Determination of dry deposition is not such a straightforward calculation. Concentrations of various nitrogen species in the atmosphere above the bay are determined, and deposition velocities for the various nutrient components to the bay are determined utilizing a buoy model developed by NOAA. The NOAA model uses as input meteorological data collected near the intensive deposition sampling site.

Wet deposition sampling is done following the protocols developed by the National Atmospheric Deposition Program (NADP) Atmospheric Integrated Research Monitoring Network (NADP/AIRMoN). A wet bucket collects rainfall samples, and samples of greater than 10 ml are sent to the Central Analytical Laboratory (CAL) of the Illinois State Water Survey, where the samples are analyzed utilizing the same methods as those used by the NADP/AIRMoN program. Results are given for ammonium, chloride, sulfate, potassium, magnesium, specific conductance, orthophosphate, nitrate, sodium, calcium, and pH. In addition to the wetfall samples, rainfall amounts are taken from an on-site rain gauge. Wetfall samples were collected at least once weekly, and often more frequently. For samples which span several days, the measured wet deposition is evenly distributed over the days for deposition calculation.

For calculation of the dry deposition of nutrient species to the bay, the meteorological site in Tampa Bay provides data for input to the NOAA buoy model to determine deposition velocities of particulates from 1-2 μm and for nitric acid (gaseous). Meteorological data is averaged over 30-minute intervals, from data collected every second. The relevant physical parameters are wind speed, air temperature, water temperature, and relative humidity. The dry deposition sampling apparatus consists of a dual flow-through system containing annular denuders, for gaseous components measurement, and a nylon filter system, for collection of particulates. Sampling is done for a 24-hour period every six days, with the denuders and filter packs sent to Environmental Science and Engineering for analysis. The samples are analyzed for gaseous and particulate nitrate, sulfate, and ammonia. The concentrations of the various chemical species in the atmosphere are then multiplied by the appropriate deposition velocity, the surface area of the bay, and the time period over which the deposition velocity is calculated, to determine the total flux of each nutrient species to the bay.

The sum of the wet mass flux and the dry mass flux of the nitrogen species to the bay represents the deposition of nitrogen due only to those nitrogen species converted by the annular denuders to nitrate and ammonium, in addition to the particulate forms of nitrogen collected by the nylon filter pack and the nitrate and ammonium from the wet deposition. Similarly, the phosphorus mass flux to the bay is only represented by the orthophosphate as collected by the wet deposition sampling.

RESULTS

Nitrogen and Phosphorus Wet Deposition

The relationship between rainfall and wet nitrogen deposition is linearly fit with a line by the equation

N-flux (mg/m^2)= Rainfall (m) x 1.29 + 258.4,

with a coefficient of determination (r^2) of 0.45. The relationship between rainfall and wet phosphorus deposition is not as clearly defined as that between rainfall and nitrogen, with a coefficient of determination of only 0.01.

Wet deposition totals for the first year of data, August 1996 through July 1997, were 340.2 mg/m^2 for nitrogen, and 4.91 mg/m^2 for phosphorus. Wet deposition totals for the second year of data, August 1997 through July 1998, were 419.3 mg/m^2 for nitrogen, and 6.83 mg/m^2 for phosphorus. Variability within the same month from year to year may be high, as may be expected given the variability in rainfall for the same months. It should be noted that the month of maximum wet nitrogen deposition, July 1997, is not the same as that for maximum wet phosphorus deposition, September 1997. It is also important to note that approximately 59% of the first year's total wet nitrogen deposition occurred in April and July, while approximately 33% of the second year's total wet nitrogen deposition occurred in June and July.

Extrapolation of the total annual direct wet nitrogen (380 mg/m^2) and phosphorus (5.87 mg/m^2) deposition to Tampa Bay, containing approximately lx l0^9 m^2, leads to approximately 3.8x10^5 kg N (419 US tons) being deposited directly to the bay's surface annually for August 1996 through July 1998, and approximately 5.9x10^3 kg P (6.5 US tons) annually. An estimate of annual total atmospheric deposition of nitrogen (sum of wet and dry) for the period 1985-1991 (Zarbock et al., 1994) was 9.7x105 kg (1,069 US tons), or approximately 2.6 times the annual wet deposition calculated from the Candy intensive site. For the period 1985-1991, the ratio of total nitrogen deposition to wet nitrogen deposition was taken to be 3.04:1 (Zarback et al., 1994).

As mentioned previously, the estimates for 1985-1991 utilized precipitation and nutrient concentration data collected at the National Atmospheric Deposition Program site at Verna Wellfield, and dry deposition estimates were determined by multiplying wetfall estimates by a regionally-derived ratio determined by the Florida Acid Deposition Study.

Nitrogen Dry Deposition

Atmospheric concentrations of nitrogen species in ambient air were determined from data collected every six days at the Candy site for August 1996 through July 1998. Meteorologic data were collected for the same time period. The meteorological data are run throuhg the NOAA buoy model to determine gaseous and particulate nitrogen deposition velocities, which are multiplied with particulate and gaseous nitrogen concentrations to yield dry nitrogen deposition fluxes to the surface of the bay.

Dry deposition velocities are calculated for every 30 minutes for which meteorological data exist, and multiplication of the deposition velocities with the atmospheric nitrogen concentrations over the 6-day periods results in the daily total dry nitrogen deposition.

For the first year of data, collected from August 1996 through July 1997, the total dry deposition of nitrogen was 342 mg/m^2,and for the second year, from August 1997 through July 1998, the total dry deposition of nitrogen was 419 mg/m^2. It should be noted that the month of maximum dry nitrogen deposition, October 1997, accounted for approximately 22% of the total dry nitrogen deposition for August 1997-July 1998, and the next highest deposition of approximately 16% of the total for the same period occurred in September 1997. The average annual dry deposition of nitrogen for the two-year period was 381 mg/m^2, or approximately the same as the wet deposition of nitrogen over the same time period.

Extrapolation of the total direct dry nitrogen deposition to the surface of Tampa Bay, containing approximately 1x109 m^2, leads to approximately 3.8xl0^5 kg N/year. An estimate of annual total atmospheric deposition of nitrogen (sum of wet and dry) for the period 1985-1991 (Zarbock et al., 1994) was 9.7x10^5 kg, or approximately 2.6 times the annual dry deposition calculated for the August 1996-July 1998 period. As mentioned previously, the estimates for 1985-1991 utilized precipitation and nutrient concentration data collected at the National Atmospheric Deposition Program site at Verna Wellfield, and dry deposition estimates were determined by multiplying wetfall estimates

Table 5-1. Monthly wet, dry, and total deposition of nitrogen.

Year	Month	Wet N Deposition (mg/m^2/month)	Dry N Deposition (mg/m^2/month)	Dry/Wet Ratio	Total N Deposition (mg/m^2/month)
1996	8	23.6	35.4	1.50	59.0
1996	9	13.5	34.8	2.56	48.3
1996	10	12.0	14.5	1.21	26.5
1996	11	7.3	51.4	7.04	58.7
1996	12	6.9	37.2	5.39	44.1
1997	1	4.9	26.1	5.33	31.0
1997	2	6.4	22.0	3.44	28.4
1997	3	11.7	24.9	2.13	36.6
1997	4	80.2	24.1	0.30	104.3
1997	5	20.0	24.2	1.21	44.2
1997	6	31.5	33.4	1.06	64.9
1997	7	122.2	14.0	0.11	136.2
1997	8	39.2	8.8	0.22	48.0
1997	9	39.5	41.0	1.04	80.5
1997	10	26.4	91.3	3.46	117.7
1997	11	9.4	68.7	7.31	78.1
1997	12	29.5	23.7	0.80	53.2
1998	1	24.7	24.6	1.00	49.3
1998	2	54.2	16.0	0.30	70.2
1998	3	32.7	20.8	0.63	53.5
1998	4	4.0	33.2	8.3	37.2
1998	5	20.8	34.2	1.64	55.0
1998	6	67.4	31.5	0.47	98.9
I998	7	71.5	25.5	0.36	97.0

by a regionally-derived ratio determined by the Florida Acid Deposition Study.

Total Nitrogen Deposition

The total nitrogen reaching the surface of Tampa Bay due to atmospheric deposition is the sum of the wet and dry nitrogen fluxes. Table 5-1 shows the wet, dry, and total nitrogen deposition for each month from August 1996 through July 1998, as well as the ratio of dry to wet deposition. For August 1996 through July 1997, total nitrogen deposition to the surface of the bay was approximately 682 mg/m^2, with some of the dry deposition missing as noted before. For the second full year of data, August 1997 through July 1998, total nitrogen deposition to the bay's surface was approximately 839 mg/m^2. Given the average annual total nitrogen deposition of approximately 760 mg/m^2, approximately $7.6x10^5$ kg N (838 US tons) was deposited directly to the bay surface, or approximately 78% of the previous estimate for 1985-1991 (Zarbock et al., 1994).

The ratio of dry to wet deposition used for estimating total atmospheric deposition of nitrogen

Table 5-2a. Wet nitrogen deposition at Gandy site and other Florida NADP sites*: Concentrations (mg/L)

Concentration (mg/L)	Bradford Forest		Kennedy		Everglades		Quincy		Verna Well Field		Tampa Bay	
Month	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3
1	0.07	0.42	0.07	0.60	0.23	0.41	0.07	0.44	0.12	0.46	0.12	0.46
2	0.11	0.53	0.12	0.61	0.15	0.62	0.09	0.43	0.10	0.48	0.18	0.60
3	0.14	0.71	0.20	0.79	0.27	0.59	0.13	0.49	0.16	0.64	0.18	0.57
4	0.19	0.89	0.14	0.81	0.25	0.81	0.20	0.74	0.20	0.84	0.37	0.85
5	0.29	1.18	0.37	1.27	0.14	0.44	0.19	0.90	0.42	2.08	0.39	1.32
6	0.11	1.01	0.10	0.89	0.09	0.62	0.14	0.92	0.16	0.91	0.38	1.73
7	0.08	1.04	0.09	1.29	0.06	0.80	0.13	0.96	0.09	1.06	0.18	1.29
8	0.09	0.88	0.11	1.22	0.09	0.73	0.11	0.84	0.12	1.08	0.20	1.35
9	0.15	0.96	0.08	0.74	0.07	0.49	0.08	0.62	0.09	0.70	0.18	0.95
10	0.03	0.38	0.04	0.33	0.07	0.44	0.06	0.37	0.07	0.51	0.13	0.40
11	0.09	0.88	0.36	0.88	0.16	0.84	0.08	0.35	0.15	0.80	0.11	0.50
12	0.11	0.70	0.07	0.41	0.09	0.42	0.14	0.76	0.08	0.44	0.11	0.39
Annual Mean	0.12	0.80	0.15	0.82	0.14	0.60	0.12	0.65	0.15	0.83	0.20	0.88

* - From NADP electronic database, for 1990-1996 precipitation-weighted monthly means.

to the surface of the bay for the 1985-1991 time period (Zarbock et al., 1994) was 2.04:1. From the results of this study after the first two years, this ratio is approximately 1:1. The proportions of nitrogen deposition due to dry and wet fluxes for the August 1996 - July 1998 time period appear to be more nearly equal than previously estimated (Zarbock et al., 1994).

A comparison of nitrate and ammonium concentrations and wet deposition fluxes at the Gandy Site for the sampling period to concentrations and wet deposition fluxes measured at NADP sites in Florida over 1990-1996 is shown in Tables 5-2a and 5-2b below, compiled from information obtained from NADP electronically. The Bradford Forest site is in northeastern Florida, the Quincy site is in northwestern Florida, the Verna Wellfield site is in west-central Florida, the Kennedy site is at the Kennedy Space Center in the east-central part of the state, and the Everglades site is in south Florida.

Concentrations of ammonium in rainfall at the Tampa Bay site from the August 1996 through July 1998 sampling period (Table 5-2a) are in the middle to high range of values found at other NADP sites in Florida during the dry season (November-May), but are at the high portion of the statewide measurements during the remainder of the year. The precipitation-weighted mean annual ammonium concentration at the Tampa Bay site of 0.20 mg/L is one-third greater than the maximum annual precipitation-weighted mean ammonium concentration at the other NADP sites in Florida, which range from

Deposition (kg/ha)	Bradford Forest		Kennedy		Everglades		Quincy		Verna Well Field		Tampa Bay	
Month	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3
1	0.08	0.43	0.05	0.39	0.12	0.21	0.13	0.77	0.07	0.28	0.09	0.35
2	0.07	0.33	0.07	0.39	0.07	0.29	0.09	0.41	0.06	0.28	0.20	0.66
3	0.19	0.91	0.28	1.10	0.15	0.34	0.23	0.87	0.15	0.61	0.15	0.48
4	0.19	0.89	0.09	0.51	0.14	0.45	0.17	0.65	0.21	0.86	0.32	0.74
5	0.18	0.72	0.25	0.83	0.20	0.63	0.21	1.00	0.46	2.28	0.13	0.45
6	0.21	1.97	0.20	1.69	0.26	1.86	0.21	1.42	0.36	2.05	0.28	1.25
7	0.12	1.53	0.12	1.73	0.10	1.26	0.22	1.57	0.17	1.95	0.40	2.92
8	0.14	1.37	0.16	1.85	0.18	1.45	0.19	1.44	0.27	2.47	0.14	0.92
9	0.17	1.10	0.14	1.28	0.13	0.91	0.11	0.80	0.13	1.09	0.14	0.71
10	0.04	0.51	0.07	0.53	0.11	0.73	0.05	0.34	0.06	0.44	0.13	0.40
11	0.04	0.39	0.34	0.83	0.12	0.62	0.05	0.25	0.06	0.30	0.05	0.21
12	0.07	0.44	0.04	0.22	0.02	0.11	0.12	0.65	0.03	0.17	0.12	0.41
Annual Total	1.5	10.6	1.81	11.4	1.6	8.86	1.78	10.2	2.03	13	2.13	9.48

Wet deposition of ammonium and nitrate (Table 5-2b) in Tampa Bay has a variable relationship with deposition at the other Florida sites, with about twice as much ammonium and nitrate deposited in February than for the 1990-1996 February average for any other site. Annual average ammonium deposition at the Gandy site is 1.05 times that at the Vernal Well Field site, whereas annual average nitrate deposition at the Gandy site is approximately three-fourths that at the Vernal Well Field site. The comparison between the Florida NADP sites for 1990-1996 and the Tampa Bay site for August 1996-July 1998 is preliminary at best, with the relatively short time period of the Gandy Site measurements making relationships only tentative. As more data become available from NADP, additional comparisons will be made between the wet nutrient fluxes at the Gandy site and those at the Verna Wellfield NADP site.

CONCLUSIONS

From these data, it is estimated that the total annual deposition to the surface of the bay was approximately 760 mg/m^2 for the August 1996 - July 1998 time period (Pribble and Janicki, 1999). This corresponds to approximately 7.6×10^5 kg N/yr (838 US tons/yr) being deposited directly to the entire bay surface, or approximately 78% of the previous annual estimate for 1985-1991 (Zarbock et al., 1994). This represents approximately 24% of the average annual 1985-1991 total nitrogen loads to the bay. Updated estimates for the period 1995-1998 for other sources are currently being conducted.

The ratio of dry to wet deposition used for estimating total atmospheric deposition of nitrogen to the surface of the bay for the 1985-1991 time period (Zarbock et al., 1994) was 2.04:1. From the August 1996 through July 1998 results, this ratio averages approximately 1:1. The proportions of nitrogen deposition due to dry and wet fluxes for this two year period appear to be more nearly equal than previously estimated (Zarbock et al., 1994).

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T. Cardinale (Environmental Protection Commission of Hillsborough County)

- CHAPTER HIGHLIGHTS -

- ☞ *The large water quality improvements realized in the early to mid 1980s (water clarity, nutrients, chlorophyll-a) have been maintained through the 1990s.*

- ☞ *All segments of Tampa Bay have shown long-term improvement in chlorophyll-a concentrations.*

- ☞ *No long-term salinity trends are apparent in Tampa Bay since 1974.*

- ☞ *Dissolved oxygen conditions have maintained their improved level through the 1990s compared to conditions observed in the early 1980s.*

- ☞ *Hillsborough Bay continues to have the greatest number of sites and samples not meeting State water quality standards for dissolved oxygen.*

INTRODUCTION

The water quality of Tampa Bay is of utmost importance both ecologically and economically. Water quality influences which animals and plants can live and reproduce in the bay, their abundance, and where and when they can be found. In terms of economics, many commercial and recreational fish are dependent on the quality of the bay's water for survival. Furthermore, users of the bay want clean water for safe swimming and boating, as well as for its aesthetic benefits.

The periodic assessment of water quality can provide an early warning system of degraded water quality before conditions become critically degraded and key resources or uses of the bay are negatively impacted. Since no single measurement alone can adequately determine water quality, it is assessed through the measurement of several key indicators (or parameters). Tampa Bay's water quality is primarily monitored by local county and municipal programs.

This chapter first identifies and describes the importance of water quality indicators measured in Tampa Bay. Later in the chapter, the temporal and spatial trends of these key water quality indicators, as determined by the local government monitoring programs, are reviewed and discussed.

Water Quality Indicators

The water quality indicators reviewed include physical parameters (water temperature and salinity), water clarity parameters (Secchi disk depth and turbidity), dissolved oxygen concentration, nutrients concentrations (total phosphorus and total nitrogen), and phytoplankton biomass as estimated by chlorophyll-a concentration. Each indicator is briefly addressed below.

Temperature

Temperature changes can cause great variation in the properties of seawater. Temperature affects the solubility of both solids and gases in seawater. As water temperatures increase, a greater amount of solids, such as salts, and conversely a smaller quantity of gases, such as dissolved oxygen, can be dissolved in a given volume of water. Water temperature is affected by radiant energy, air temperature, heat absorbance and heat loss properties of a water mass, and the degree of mixing and flushing of a water mass. Other factors that may affect water temperatures include water column depth and point source inputs from power plants and wastewater treatment plants.

Temperature changes also greatly affect the living organisms that seawater supports. Most animals (the "cold blooded forms") and virtually all plants lack the ability to regulate their body temperature. Consequently, their body temperatures are largely controlled by water temperature. For example, the metabolic rate of many "cold blooded" animals is roughly doubled by a 10°C temperature increase.

Salinity

The total amount of dissolved solids (primarily salts) in seawater is referred to as salinity, which is measured in parts per thousand (ppt). The salt content in estuarine waters provides the chemical substances necessary for the growth and maintenance of plant and animal tissue. The distribution of living organisms inhabiting estuarine waters is often closely related to the salinity distribution of the estuary. The average ocean salinity is 35 ppt, while the salinity of freshwater is 0 ppt. Estuarine salinities, including those in Tampa Bay, range between values found in oceanic and freshwater environments.

Salinity is altered by processes that add or remove salts or water from the estuary. The primary mechanisms of salt and water addition and removal are evaporation, tidal exchange, rainfall, and freshwater inputs from tributaries and point sources such as wastewater treatment plants. The distribution of salinity in Tampa Bay, therefore, is affected by these primary mechanisms and the hydrodynamic characteristics of the bay itself that control the circulation of water throughout the estuarine system. Salinity distribution, at least on a localized level, could also be affected by the discharge of saline "concentrate" to Tampa Ray from a desalination plant currently being planned for the Tampa Bay area within the next few years.

Water Clarity

The degree of transparency of water, or water clarity, is one of its most important attributes. Water transparency allows the penetration of light, which supports life through the photosynthetic process. The degree of water transparency has a direct impact on seagrass bed growth and distribution in Tampa Bay. Water transparency also allows organisms with visual organs to see in order to search for food and shelter. Water transparency can be affected by water color, suspended organic and inorganic matter in the water column, and dissolved substances. Two indicators of water clarity reviewed in this chapter are Secchi disk depth and turbidity.

A simple method to determine the amount of light penetration in the water column is with a Secchi disk. A Secchi disk is a black and white disk, typically measuring 20 to 30 centimeters in diameter. A line is fastened at the center and the disk is lowered until it disappears from sight. This depth of disappearance is called the depth of visibility or Secchi disk depth.

Turbidity is the optical property of water which is related to the amount of light scattered and absorbed in the water column. The amount and size distribution of suspended particles, such as plankton, organic debris, silt, and clay, can greatly affect the degree of turbidity measured in the water column. In the data collected for this review, turbidity was measured as Nephelometric Turbidity Units (NTU) using a nephelometer.

Dissolved Oxygen

Dissolved oxygen in the form of 0_2 in estuarine water is necessary for the survival of most organisms with the exception of some species of anaerobic microorganisms. The abundance or lack of 0_2 in water strongly influences the distribution of marine life. The transfer of oxygen from the atmosphere to the water at the water surface, the production of oxygen from marine plants by photosynthesis, and the introduction of oxygenated waters from landward (e.g., tributaries) or seaward (e.g., Gulf of Mexico) sources are the only methods of adding oxygen into estuarine waters. In estuaries, low bottom water dissolved oxygen concentrations (e.g., < 2.0 mg/l) may cause stress or death to marine animals. Low dissolved oxygen conditions in bottom waters of an estuary may often result from eutrophication, the overenrichment of aquatic systems by excess inputs of nutrients. Eutrophic conditions that cause an accumulation of planktonic algae near the surface of the water may also result in elevated dissolved oxygen concentration in surface waters from photosynthetic activity by the algae. In addition to low dissolved oxygen in bottom waters, and high dissolved oxygen in surface waters, eutrophic conditions may also cause fish kills and benthic fauna mortality if widespread dissolved oxygen depletion in bottom waters occurs.

Nutrients

Phosphorus and nitrogen, commonly found in fertilizers, are important elements needed to support the growth of marine plants. These two nutrients, and their various chemical forms, are generally of greatest concern in marine systems.

The amount of nitrogen relative to phosphorus that is available to marine plants, including marine algae, is related to the potential productivity of marine plants in the estuary. Since marine plants are at the base of the "food chain," nutrients play a vital role in the overall health and production that occurs in estuaries. An excessive supply of these nutrients, in appropriate forms for uptake by marine plants, may result in eutrophic conditions. Eutrophic conditions are exemplified by an ecological imbalance resulting in large concentrations of algae, poor water clarity, and low bottom water dissolved oxygen conditions. Low dissolved oxygen levels, as previously discussed, can result in fish kills and other undesirable effects.

Phytoplankton Biomass

Water column chlorophyll-a concentrations are an indirect measure of the quantity or biomass of planktonic algae present in a body of water. Planktonic algae or phytoplankton are typically single celled organisms that live suspended in the water column. Their life cycles can respond quickly to changes in environmental conditions, such as changes in dissolved nutrient concentrations, available light, and water temperatures. Phytoplankton are one of several major forms of plants that exist in Tampa Bay and in most other estuaries. Other major estuarine plant types include submerged seagrass, macro-algae, and benthic micro-algae such as epiphytic algae that often attach to seagrass blades. These different plants can be viewed as being in competition with each other for required resources of light and nutrients. Eutrophic conditions brought about by excessive nutrient loadings into a system are often manifested in high phytoplankton and macro-algal biomass. High algal biomass can greatly reduce water clarity, which in turn often limits the growth and distribution of seagrass beds and can degrade the aesthetic quality of a body of water.

In 1989, the Tampa Bay Regional Planning Council's Agency on Bay Management, in recognition of the importance of chlorophyll-a as an indicator of water quality, established annual average chlorophyll-a target concentrations for four major segments of Tampa Bay. In 1996, modified chlorophyll-a targets were calculated from TBEP model predictions relating chlorophyll-a, water column light transparency, and seagrass depth distribution. These modified target concentrations are listed below.

Old Tampa Bay (OTB)	8.5 μg/l
Hillsborough Bay (HB)	13.2 μg/l
Middle Tampa Bay (MTB)	7.4 μg/l
Lower Tampa Bay (LTB)	4.6 μg/l

DATA SETS REPORTED

The water quality in the seven segments of Tampa Bay is routinely monitored by four local government agencies. These agencies include the Environmental Protection Commission of Hillsborough County (EPC), Pinellas County Department of Environmental Management (PCDEM), the Manatee County Environmental Management Department, and the City of Tampa.

EPC has been monitoring water quality monthly since the early 1970s at more than 50 stations throughout the Tampa Bay estuary, with most of the stations located within the OTB, HB, MTB, and LTB segments.

PCDEM has been monitoring water quality monthly in Boca Ciega Bay (BCB) since 1991. Water quality results reported were from about ten (depending on year) randomly selected sites within the defined TBEP boundaries of BCB.

Manatee County changed its sampling program from sampling a set of fixed stations monthly from 1992-1995, to sampling a set of 24 randomly selected stations each year beginning in 1996. A new set of 24 stations is randomly selected each year. The program now samples one-third (8) of all stations each month, thus allowing all 24 stations to be sampled one time every three month period.

The geographical boundaries sampled by Manatee County also changed in 1996. Fixed stations (1992-95) were located within the boundaries of Terra Ceia Bay (TCB) and the Manatee River (MR), with water quality results grouped by each bay segment. In the existing program, randomly selected stations (1996-97) were grouped into a single North Manatee County (NMC) segment, were located within the boundaries of TCB and the MR, and included lower Tampa Bay waters extending one nautical

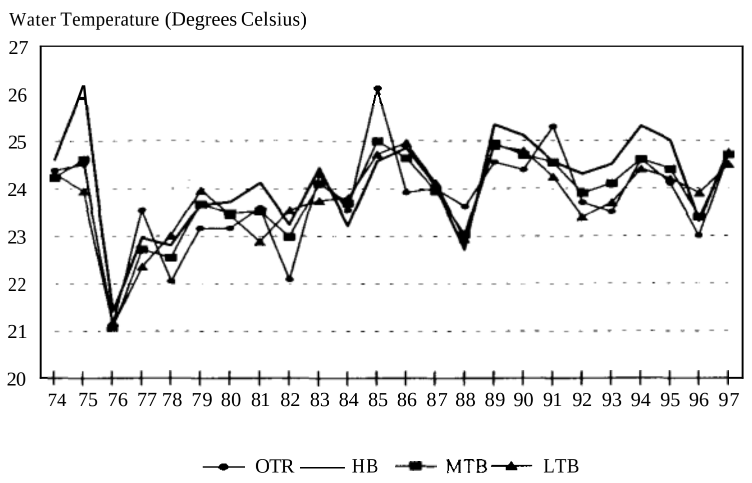

Figure 6-1. Mean annual water temperatures in Tampa Bay.

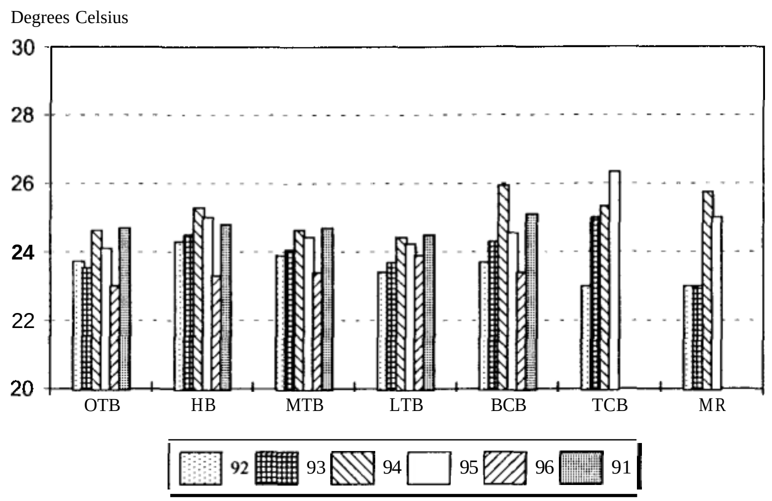

Figure 6-2. Mean annual temperatures in Tampa Bay during 1992-1997.

mile from shore between TCB and the MR (Figure 3-3). Since the waterbodies' geographical limits, the station locations, and sampling frequency changed, water quality trends for Manatee County are addressed separately for the two time periods.

Finally, the Bay Study Group of the City of Tampa has been monitoring water quality at several stations in HB and one station in MTB since the late 1970s.

Most of the data reviewed were collected on a monthly basis, but data collected in TCB and the MR during 1992 and 1993 were collected only quarterly. Data from more than 110 sites were used in this review, although about twice as many sites were actually monitored by the four programs.

Long-term (1974-1997) and recent (1992-1997) mean annual water quality data were examined. Long-term records were reviewed from data collected by EPC. Recent mean annual data were available for all seven bay segments and the newly defined North Manatee County segment which overlaps three previously defined bay segments (Lower Tampa Bay, MR, and TCB). The recent data sets essentially depict existing conditions in Tampa Bay and contain pooled data for each segment from the EPC program plus data from the three other monitoring programs, as available.

TEMPERATURE AND SALINITY

Temperature

Mean annual water temperatures among the four major bay segments from 1974 through 1997 varied from about 21°C to about 26°C, depending upon the year (Figure 6-1). The variability of mean annual temperatures among the four major bay segments during any given year typically were very small (+-0.5°C); only a few exceptions occurred in the more shallow bay segments (OTB and HB).

Mean annual water temperatures among bay segments from 1992 through 1997 are compared in Figure 6-2. Segment-specific temperature data were not available for TCB and MR. Mean

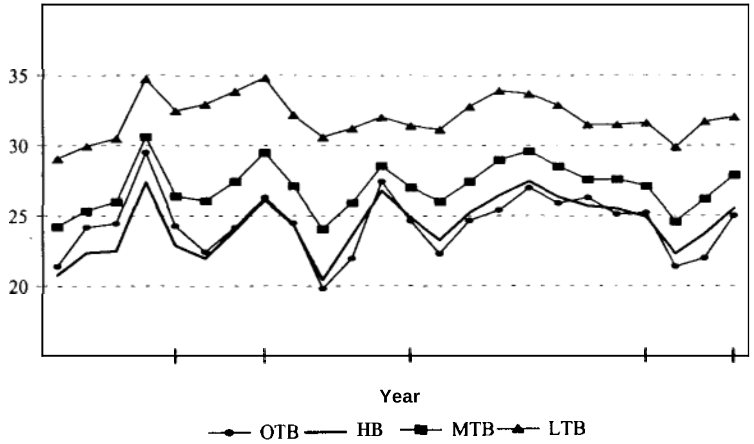

Figure 6-3. Mean annual salinities in Tampa Bay.

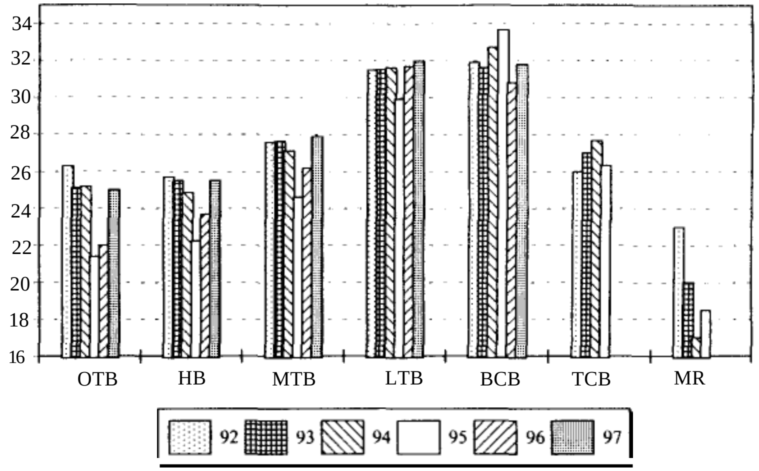

Figure 6-4. Mean annual salinities in Tampa Bay during 1992-1997.

annual temperatures ranged from a low of 23°C in the Manatee River (1992 and 1993) to a high of 26.3°C in TCB in 1995. In all bay segments, temperatures were greatest in 1994, 1995, and 1997.

Salinity

Mean annual salinities for the four major bay segments from 1974 through 1997 ranged from a low of about 20 ppt in OTB in 1983 to a high of nearly 35 ppt in LTB in 1977 and 1981 (Figure 6-3). During any given year, salinities among bay segments typically varied from 5 to 10 ppt from the bay segment with the lowest mean salinity to the bay segment with the highest mean salinity. Lowest salinities occurred in either HB or OTB (20 to 27 ppt), intermediate salinities occurred in MTB (24 to 31 ppt), and highest salinities were recorded in LTB (29 ppt to nearly 35 ppt). These long-term salinity trends by bay segment show a pattern of peaks (and troughs) about 4 or 5 years apart. These salinity oscillations may be related to changes in freshwater loads and/or changes in tidal prism; however, confirmation of such relationships has not occurred.

Mean annual salinities among all seven bay segments are shown in Figure 6-4. Available mean annual salinity data varied from 17 ppt in the MR in 1995 to about 34 ppt in BCB in 1995. In the four main bay segments, mean annual salinities were lowest in 1995 relative to other years. Overall highest mean annual salinities occurred in LTB and BCB, intermediate salinities occurred in OTB, HB, MTB, and TCB, and lowest salinities occurred in MR.

LONG-TERM TRENDS BY BAY SEGMENT

Long-term water quality trends from data collected by the EPC from 1974 through 1997 are examined for the four major bay segments of Tampa Bay in Figures 6-5 to 6-10. Water quality indicators examined for each bay segment include water clarity (Secchi disk depth, turbidity), dissolved oxygen, nutrients (total phosphorus, total nitrogen), and phytoplankton biomass (chlorophyll-a). The methodology for measuring nitrogen produced unreliable results until 1981; thus no total nitrogen concentrations prior to 1981 are shown.

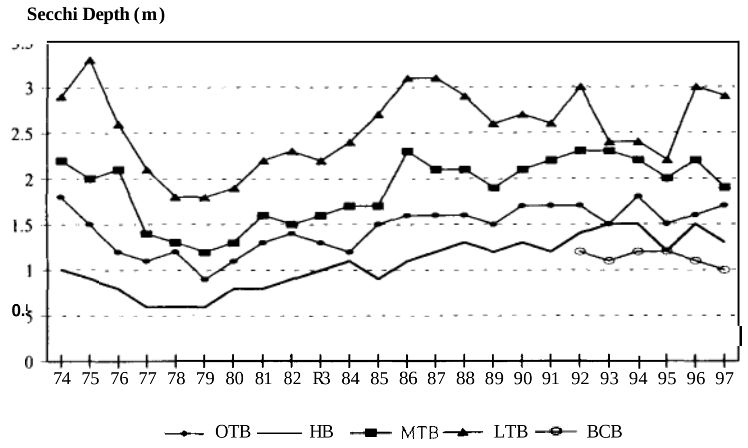

Figure 6-5. Mean annual Secchi disk depths in Tampa Bay.

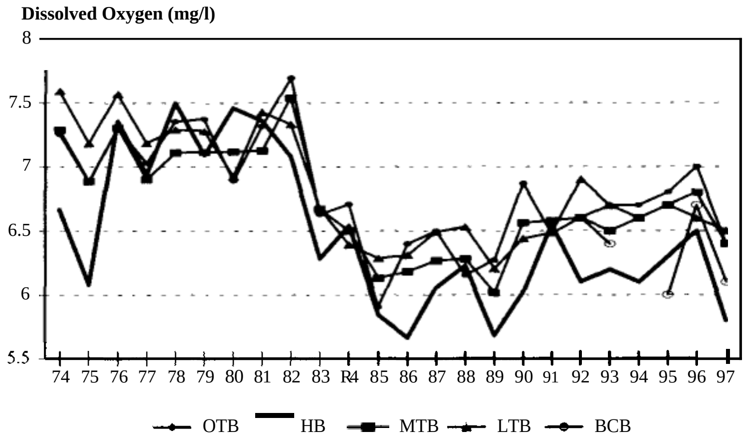

Figure 6-7. Mean annual dissolved oxygen concentrations in Tampa Bay.

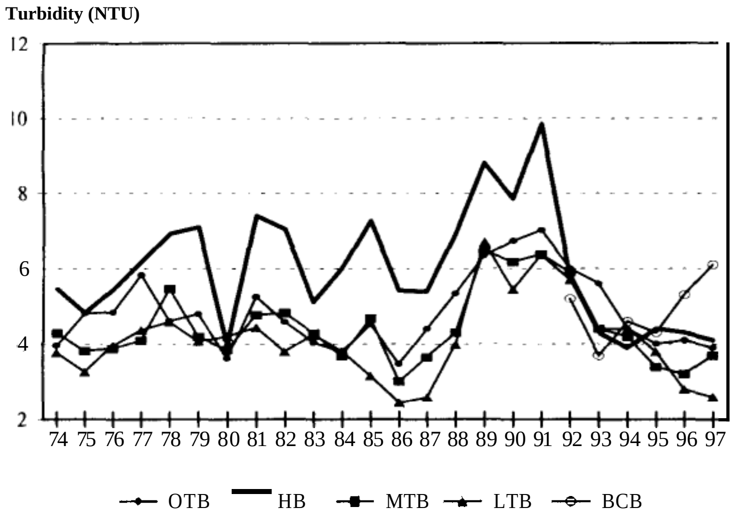

Figure 6-6. Mean annual turbidity values in Tampa Bay.

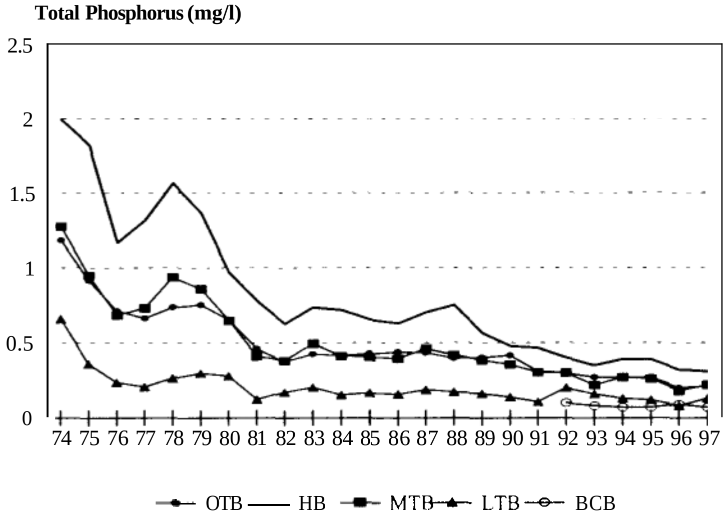

Figure 6-8. Mean annual total phosphorus concentrations in Tampa Bay.

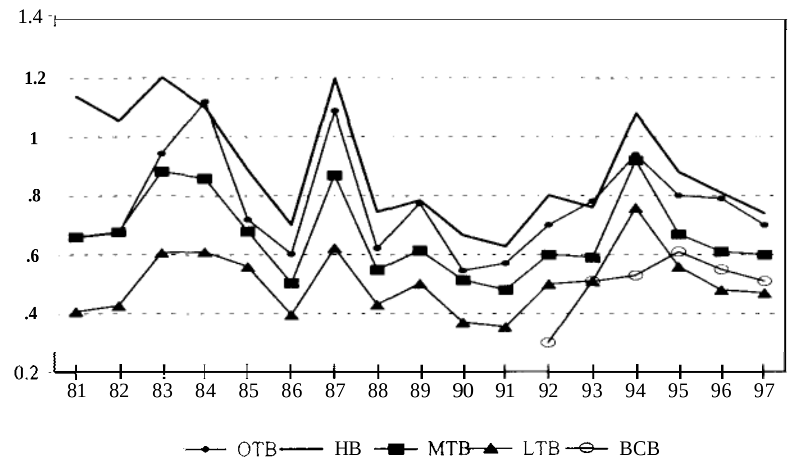

Figure 6-9. Mean annual total nitrogen concentrations in Tampa Bay.

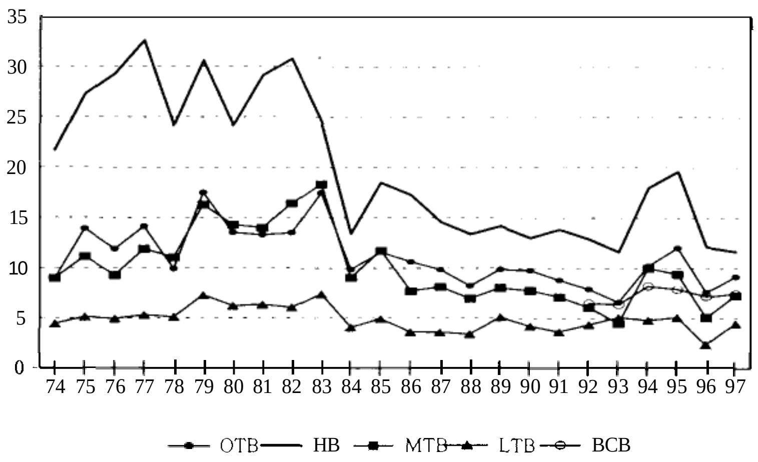

Figure 6-10. Mean annual chlorophyll-a concentrations in Tampa Bay.

Old Tampa Bay

Mean annual values of water quality indicators measured from OTB are plotted in Figures 6-5 to 6-10. These figures also include plots for the other three major bay segments and BCB to facilitate comparisons among segments. The comparison of water quality conditions among bay segments will be emphasized in a subsequent section of this chapter.

Water clarity was reviewed with respect to Secchi disk depths and turbidity. Water clarity in OTB as measured by mean annual Secchi disk depth was about 1.75 m in 1974, declined to about 0.75 m in 1979, and has maintained clarity at or above 1.5 m since 1985 (Figure 6-5). Turbidity shows a somewhat different trend, with most annual values, except those from 1989-1993, ranging between 4 and 5 NTU. Turbidities were higher from 1989-1993 (Figure 6-6).

Mean annual dissolved oxygen concentrations in OTB fluctuated around 7 mg/l from 1974 through 1982, then dropped to values ranging from about 6-7 mg/l since 1983 (Figure 6-7). The implications of this drop in dissolved oxygen concentration are discussed later.

Mean annual total phosphorus and total nitrogen concentrations were examined to assess ambient nutrient trends. Total phosphorus concentrations have shown a nearly steady decline during the last 24 years, from about 1.2 mg/l in 1974 to about 0.2 mg/l by 1997 (Figure 6-8). Mean annual total nitrogen concentrations have varied from about 0.65 mg/l to about 1.1 mg/l since 1981, when reliable data were first available (Figure 6-9). Total nitrogen values peaked in 1984, 1987, and 1994. The lowest concentration of about 0.55 mg/l was recorded in 1990. Since the 1994 peak of 1 mg/l, concentrations have fallen to a mean value of 0.7 mg/l in 1997.

Phytoplankton biomass, as estimated by chlorophyll-a, ranged between about 7 and 18 μg/l from 1974 to 1983, then dropped to values ranging from 7.5 to 11 μg/l since 1984 (Figure 6-10). The chlorophyll-a not-to-exceed target of 10.0 μg/l has been achieved every year since 1987, with the exception of 1995, according to data collected exclusively from EPC sites.

The water quality indicator parameters of Secchi disk depth, dissolved oxygen, total phosphorus, and chlorophyll-a concentration showed improving conditions in OTB between current conditions and those measured beginning in the late 1970s to early 1980s. Improving trends in light transparency began in 1980, a lower range of dissolved oxygen concentrations occurred after 1982, a large drop in total phosphorus concentrations occurred after 1978, and phytoplankton biomass dropped to lower levels after 1983.

Dissolved oxygen was measured at surface, middle, and bottom depths at each station. The mean of these three measurements was plotted for each year in Figure 6-7. The higher surface water dissolved oxygen concentrations observed from 1974 through 1982 compared to the period 1983 to 1997 are likely reflective of the higher levels of phytoplankton biomass present during the earlier period (Figure 6-10). Surface dissolved oxygen concentrations prior to 1983 were very high and often reached supersaturation levels at some locations. Greater phytoplankton biomass in the water column prior to 1983 may have caused the higher amounts of oxygen produced during daylight hours, the time period in which sampling occurred. Since photosynthetic activity by phytoplankton result in the production of oxygen, higher levels of phytoplankton biomass often produce greater amounts of oxygen. Prior to 1983, the mean surface dissolved oxygen concentration baywide was 7.7 mg/l. As water quality conditions improved during the 1980s, phytoplankton biomass declined, and likewise the amount of oxygen generated during the day by phytoplankton declined, resulting in lower water column dissolved oxygen concentrations.

Hillsborough Bay

HB has often been considered the most impacted segment of Tampa Bay as it has received the highest nutrient loads and has the greatest amount of industrial activity relative to other Tampa Bay segments. Mean annual values of water quality indicators measured from HB are also plotted in Figures 6-5 to 6-10.

Water clarity as measured by Secchi disk depths was poorest during the late 1970s (about 0.6 m), but has improved considerably since that time to values approaching 1.5 m since 1993 (Figure 6-5). Turbidity values (Figure 6-6) show interannual fluctuations ranging from 4 NTU (1980) to about 10 NTU (1992). Prior to 1992, most mean annual turbidity values in HB were higher than other bay segments. Since 1992, HB turbidities have fallen to ranges consistent with the other bay segments.

Long-term trends in dissolved oxygen concentration in HB are similar to the trend described for OTB, with consistently lower concentrations (5.7-6.5 mg/l) occurring after 1981 (Figure 6-8). The high pre-1982 phytoplankton biomass observed in HB (Figure 6-10) was probably associated with high rates of photosynthetic activity resulting in elevated dissolved oxygen levels. Mean annual dissolved oxygen values in HB, calculated from surface, middle, and bottom daytime measurements, were typically lower than in other bay segments after 1981. The sharp drop in HB phytoplankton biomass levels after 1981-1982 coincided with a marked reduction in mean annual water column dissolved oxygen levels.

Long-term trends in HB nutrient concentrations were similar to the trends in OTB. Since 1974, total phosphorus values have declined from 2 mg/l to about 0.3 mg/l in 1997 (Figure 6-8). Total nitrogen values were greatest from 1981 through 1984, in 1987, and in 1994 (Figure 6-9).

HB has shown considerable improvement in chlorophyll-a concentrations. Mean annual chlorophyll-a values were greatest from 1974 through 1983, ranging from about 22 μg/l to 33 μg/l (Figure 6-10). After 1983, concentrations have remained much lower, ranging from about 10 to 20 μg/l from 1984 through 1997, with most annual mean concentrations near or below the established target of 13.2 μg/l after 1986. Since 1984, the greatest exceedances of the target concentration occurred in 1994 (18.0 μg/l) and 1995 (19.6 μg/l).

As was the case with OTB, the water quality indicators of Secchi disk depth, dissolved oxygen, total phosphorus, and chlorophyll-a concentration in HB generally reflected improving conditions since the early 1980s.

Middle Tampa Bay and Lower Tampa Bay

Mean annual values of water quality indicators for MTB and LTB are also plotted in Figures 6-5 to 6-10. The long-term trends in MTB and LTB are very similar to the trends found in OTB for all parameters plotted.

Water clarity was generally better in MTB and LTB (higher Secchi disk depths and lower turbidity values) compared to OTB and HB. Secchi disk depths were lowest in 1979 (about 1.2 m in MTB, 1.75 m in LTB), and have improved to values ranging from about 2 to 2.3 m in MTB and 2.2 to 3 m in LTB from 1986 through 1997 (Figure 6-5). MTB and LTB turbidity values varied between about 2.5 and 6.5 NTU since 1974, with lowest values from 1986-1987 and 1995-1997, and highest values from 1989 to 1992 (Figure 6-6).

Long-term trends in dissolved oxygen concentrations were similar in MTB and LTB compared to other segments. Mean annual dissolved oxygen concentrations in MTB and LTB dropped sharply from values ranging from about 6.8 to 7.6 mg/l through 1982 to values ranging from about 6 to 6.8 mg/l after 1982 (Figure 6-7).

Nutrient concentrations were somewhat lower in MTB and LTB relative to OTB and HB. Long-term total phosphorus concentrations showed a decline from a high of about 1.3 mg/l in MTB and 0.7 mg/l in LTB in 1974, to a low of about 0.2 mg/l in MTB and 0.13 mg/l in LTB during 1997 (Figure 6-8). Total nitrogen concentrations in MTB and LTB followed the long-term trend found in OTB, but were slightly lower. Since 1981, mean annual total nitrogen concentrations in MTB and LTB have varied between 0.35 mg/l and 0.92 mg/l (Figure 6-9).

Chlorophyll-a trends in MTB and LTB (Figure 6-10) are also similar to trends observed in OTB. Values in MTB dropped from about 18 μg/l in 1983 to about 9 mg/l in 1984, and have varied between 6 and 10 μg/l since 1984. Mean annual MTB chlorophyll-a values were lower than the target concentration of 8 μg/l from 1986-1993, and 1996-1997. Values in LTB dropped from about 7.5 μg/l in 1983 to about 4 μg/l in 1984. Since 1984, LTB chlorophyll-a concentrations have varied between about 2.4 and 5.1 μg/l, a concentration that is generally consistent with the established target of 4.6 μg/l.

Boca Ciega Bay

Mean annual indicators of water quality in Boca Ciega Bay (BCB) from 1992 to 1997 are also plotted in Figures 6-5 to 6-10. Although located near the Gulf of Mexico, water quality, at least in terms of water clarity, was relatively poor, especially compared to Lower Tampa Bay. Conversely, BCB nutrient and chlorophyll-a concentrations indicate good water quality and were in the same nutrient and chlorophyll concentration ranges as observed in MTB and LTB for the same time period.

Secchi depths, turbidity, and dissolved oxygen measurements indicated poor water quality conditions in BCB when compared to other Tampa Bay segments. Secchi disk depths were the worst relative to the other four bay segments assessed (Figure 6-5). Mean annual Secchi disk depths (1992-1997) showed little variation and ranged from about 1-1.2 m. Turbidity values were in the same range as the other segments from 1992 through 1995, but exceeded all other segments in 1996 and 1997, suggesting worsening conditions of water clarity (Figure 6-6). Mean annual dissolved oxygen levels were lowest (Figure 6-7) compared to all other Tampa Bay segments in 1995 (6 mg/l) and 1997 (6.1 mg/l).

Nutrient and chlorophyll-a values from BCB are shown in Figures 6-8 to 6-10. With only six years of data collected, no distinct trends are apparent for TP, TN, and chlorophyll-a. BCB TP concentrations were lowest of all segments assessed ($\leq$0.1 mg/l), TN concentrations were similar to values observed in LTB (usually about 0.5-0.6 mg/l), and chlorophyll-a concentrations were in the same range found in MTB (about 6-7 μg/l).

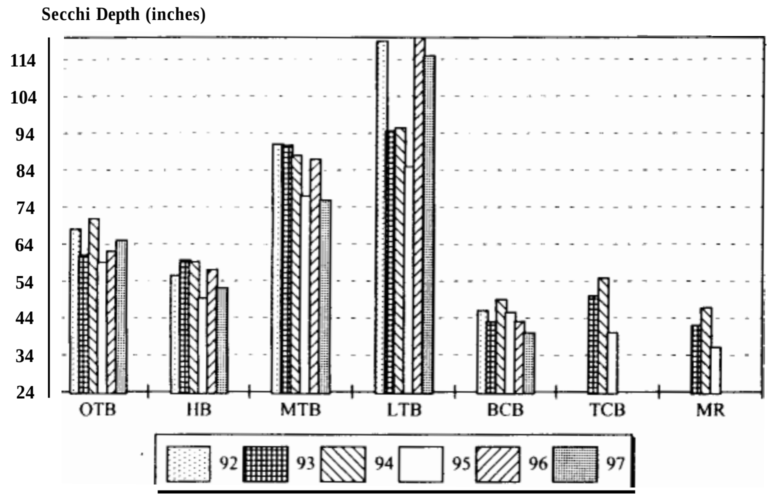

Figure 6-11. Mean annual Secchi disk depths in Tampa Bay.

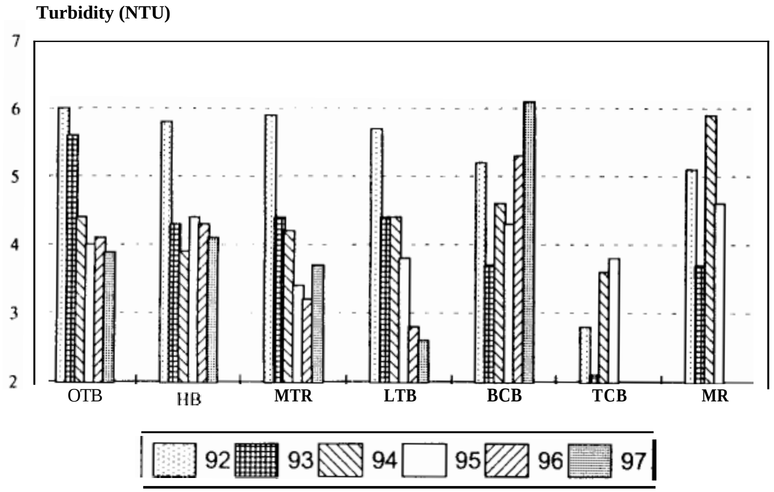

Figure 6-12. Mean annual turbidity values in Tampa Bay during 1992-1997.

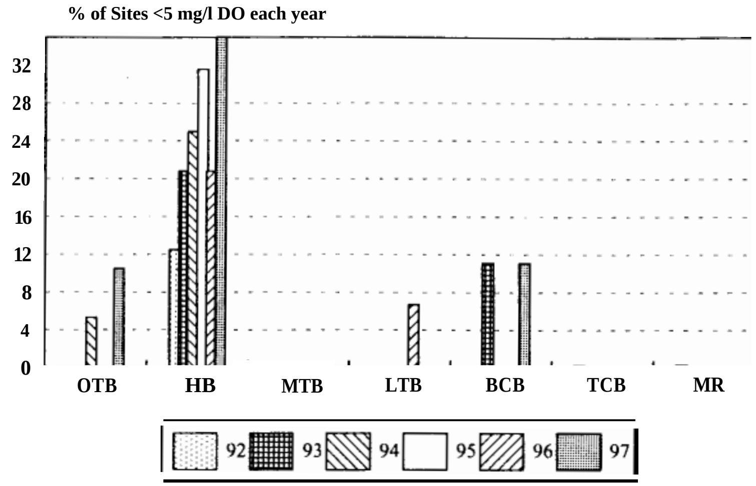

Figure 6-13. Comparison of measured dissolved oxygen concentrations to State water quality standards during 1992-1997: <5 mg/l.

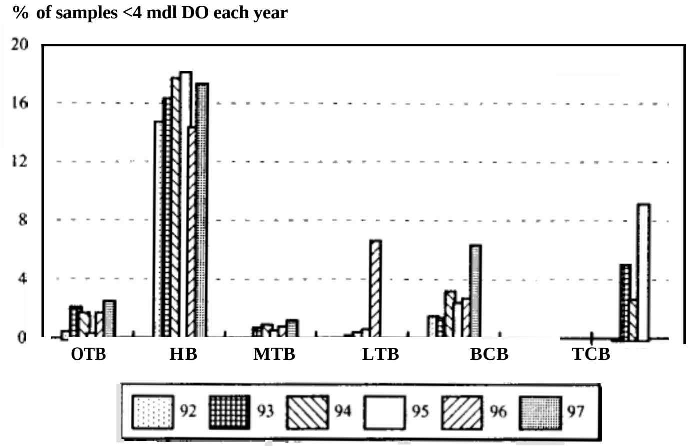

Figure 6-14. Comparison of measured dissolved oxygen concentrations to State water quality standards during 1992-1997: <4 mg/l.

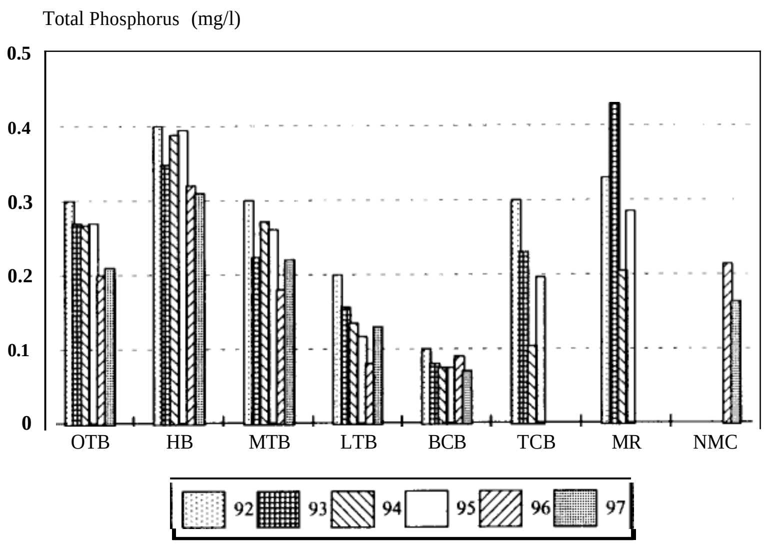

Figure 6-15. Mean annual total phosphorus concentrations in Tampa Bay during 1992-1997.

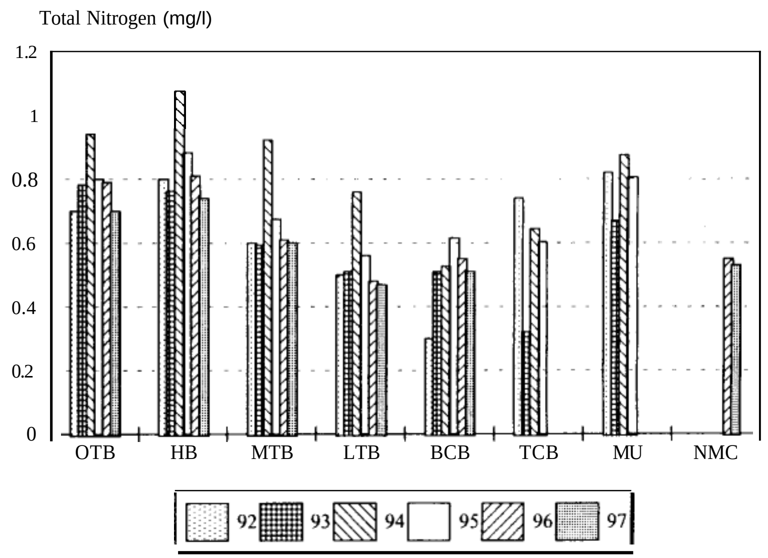

Figure 6-16. Mean annual total nitrogen concentrations in Tampa Bay during 1992-1997.

. COMPARISON OF BAY SEGMENTS

Long-term Trends

In general, Tampa Bay water quality conditions during any given year since 1974 improved as distance to the Gulf of Mexico decreased; thus LTB had better water quality than MTB, which in turn had better water quality than OTB. HB, being the most impacted segment, typically had the poorest water quality as best depicted in Secchi disk depth, total phosphorus concentrations, and chlorophyll-a values.

The time period of poorest water quality during the period of record (1974-1997) occurred during the late 1970s and early 1980s. As expected, water quality degradation was most pronounced in HB during this time period when mean annual Secchi disk depths were often less than 0.7 m, compared to values often exceeding 1 m in OTB and MTB (Figure 6-5). Also, mean annual chlorophyll-a concentrations in HB during that time period ranged from about 25 $\mu g/l$ to more than 32 $\mu g/l$, about twice the concentrations found in OTB and MTB (Figure 6-10).

The improvements in water quality after this time period are mostly attributed to decreased point source loadings from wastewater treatment plants, and in particular, the conversion of the City of Tampa's Hookers Point wastewater treatment plant (now known as the Howard F. Curren wastewater treatment plant) from primary to advanced treatment between 1979 and 1980. The relatively sharp decrease in total phosphorus concentrations from 1978 to 1982 represents the general slow-down in mining and fertilizer production activity of the phosphate industry. Since phosphorus is not considered limiting to phytoplankton growth in Tampa Bay, the decline in phosphorus levels should not have directly affected the eutrophic state or existing water quality conditions in Tampa Bay. The decline in the associated shipping and handling of fertilizer products in and adjacent to Tampa Bay, which included nitrogen as well as phosphorus containing fertilizers, may have reduced nitrogen loads into Tampa Bay, thus contributing to improved water quality conditions.

Unfortunately, nitrogen loading measurements into Tampa Bay were not performed during this period of changing conditions. It should also be recognized that, since nitrogen is a very reactive element, the amount of nitrogen loading to Tampa Bay in a given year is not necessarily reflected in total nitrogen concentrations measured in the water column. Furthermore, mean annual total nitrogen concentrations will not necessarily be related to the water quality and/or eutrophic state of the estuary as generally perceived by the local scientific community.

Since the early 1980s, all segments of Tampa Bay have shown considerable improvement in water quality. Assuming that Secchi disk depths and chlorophyll-a values most directly reflect perceived water quality conditions in Tampa Bay, these two parameters have shown continued good water clarity and relatively low phytoplankton biomass since the mid 1980s.

Existing (1992-1997) Conditions

Mean annual values of water quality indicators measured in 1992 through 1997 were examined (Figures 6-11 through 6-17) to compare the existing conditions among all Tampa Bay segments including NMC (see discussion below). Available data from all four government monitoring programs were used in these comparisons.

It should be recognized that data presented from the MR and TCB segments were only collected quarterly at fixed stations from 1992 to 1995 for some, but not all, parameters. The mean annual values from the MR and TCB segments may be subject to greater variability compared to other segments. In other segments mean annual values were derived from data collected monthly. Furthermore, the newly created North Manatee County (NMC) segment results for 1996 and 1997 were also included in this section as a separate segment (see Figure 3-3) for select parameters.

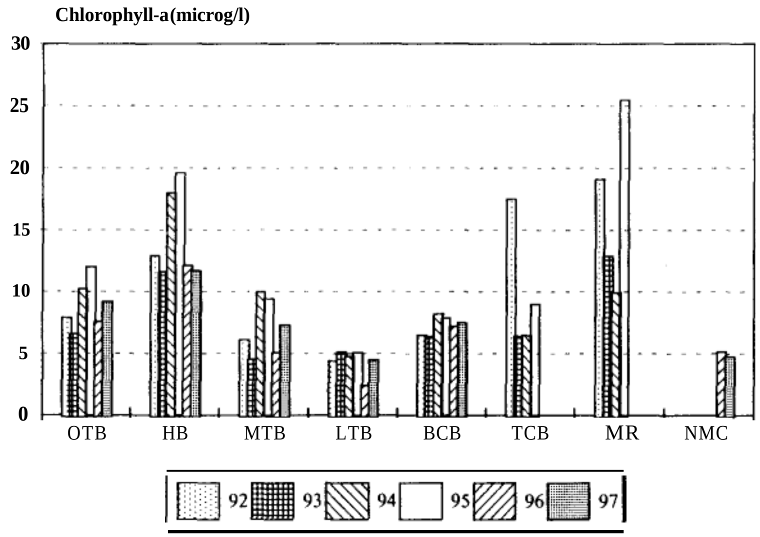

Figure 6- 17. Mean annual chlorophyll-a concentrations in Tampa Bay during 1992-1997.

Water clarity as depicted by mean annual Secchi disk depths was greatest in LTB at about 2.2 to 3 m, followed in order of decreasing water clarity by: MTB, NMC (1996-97 only), OTB, HB, TCB, BCB, and MR (Figure 6-11). In summary, LTB and MTB had the best water clarity, OTB, HB, and NMC had intermediate water clarity, while BCB, TCB, and MR had the poorest water clarity of segments examined in Tampa Bay.

Mean annual turbidity values were relatively low for all bay segments and years reported, ranging from 2 to 6 NTU. The four main bay segments (OTB, HB, MTB, and LTB) exhibited similar year to year patterns with the highest mean value in 1992 (5-6 NTU), and somewhat lower values for other years (about 2.5-4.5 NTU). Year to year mean annual turbidity values for BCB, TCB, and MR segments were more variable and considerably different from each other, and different from the four main Tampa Bay segments. Some of the differences and variability could be attributed to quarterly sampling that occurred in TCB and MR. Overall TCB had the lowest turbidity in any given year.

Rather than comparing mean annual dissolved oxygen concentrations among segments, it was deemed more useful to compare dissolved oxygen concentrations to State water quality standards. All open water areas within the seven bay segments of Tampa Bay have been designated either Class II or Class III waters by the State of Florida. State Class II and Class III surface water quality standards for dissolved oxygen are the same and encompass the following two criteria:

1. average dissolved oxygen concentration over a 24-hour period shall not be less than 5.0 mg/l; and

2. instantaneous measurements of dissolved oxygen concentration shall not be less than 4.0 mg/l.

For each year, as data were available by segment, non-compliance with these State standards was evaluated. To evaluate the 5 mg/l criteria for each year, mean annual dissolved oxygen concentrations were calculated for each site. The percentage of all sites within each segment not meeting the 5 mg/l criteria were recorded and are graphically depicted in Figure 6-13. Alternately, to evaluate the 4 mg/l criteria for each year, a dissolved oxygen measurement was considered in non-compliance in each instance in which a measurement was below 4 mg/l. Likewise, the percentage of all measurements taken each year in a given bay segment (i.e., all measurements at all sites) that were in non-compliance were tabulated and depicted in Figure 6-14.

Considering all seven bay segments, HB had the greatest number of sites that fell below the 5 mg/l State water quality standard for dissolved oxygen (Figure 6-13). Several sites in BCB, OTB, and LTB didn't meet that standard depending upon the year, and sites in the remaining segments rarely if ever fell below this standard.

The percentage of HB samples falling below the 4 mg/l dissolved oxygen State standard was also much greater than other Tampa bay segments. Each year since 1992 about 14%-17% of samples fell below the 4 mg/l standard (Figure 6-14). Except TCB, the other bay segments consistently had a few samples falling below the 4 mg/l standard.

Mean annual total phosphorus concentrations were highest near major tributaries, and tended to decrease as distance from tributaries increased (Figure 6-15). HB had the greatest total phosphorus concentrations (between 0.3 to 0.4 mg/l), while MR, OTB, MTB, and TCB had intermediate values (about 0.2 to 0.3 mg/l most years), and LTB, BCB, and NMC had the lowest concentrations (<=0.22 mg/l for LTB and NMC; <= 0.1 mg/l for BCB). Generally all segments show a decreasing trend in mean annual total phosphorus concentration over the reporting period.

Mean annual total nitrogen values for all seven segments ranged between about 0.3 and 1.1 mg/l (Figure 6-16). The four main bay segments (OTB, HB, MTB, and LTB) had very similar interannual patterns with the greatest mean annual total nitrogen concentration occurring in 1994, and with no discernable trend with time (increasing or decreasing) being apparent. Annual total nitrogen concentrations tended to be greater for segments receiving the most freshwater discharge (e.g., HB, OTB, and MR), compared to segments receiving less discharge (e.g., LTB, and BCB).

Mean annual chlorophyll-a concentrations from 1992 through 1997 (Figure 6-17) ranged from lows of 2.5 to 5 μg/l in LTB to highs of over 25 μg/l in the MR (1995). For the years in which data were reported for both bay segments (1992-1995), the MR had greater values than HB for all years but 1994. Also of note are the extremely high mean annual chlorophyll-a values reported for the MR and TCB in 1992. These high values were not observed in any of the other bay segments, and thus could be related to a common influence due to the close proximity of these two segments. Excluding the MR and TCB, chlorophyll concentrations were greatest in HB, then followed in decreasing order by OTB, MTB, BCB, NMC, and LTB. In the four main segments, except in 1994 and 1995, chlorophyll values in most segments were near or below the established targets.

Due to relatively high chlorophyll-a values in some of the recent years, the MR and TCB represent potential problem areas that should be carefully monitored for signs of elevated phytoplankton biomass in the future. Since these two segments were lumped together and combined with a portion of lower Tampa Bay in 1996 to form the NMC segment, NMC segment results will not show chlorophyll-a patterns representative of the localized areas of TCB and the MR, respectively.

Generally speaking, based on mean annual chlorophyll-a concentrations, water quality in the Tampa Bay estuary has continued to be good through the 1992-1997 reporting period. Chlorophyll-a concentrations measured in OTB, HB, MTB, and LTB were usually at or near target concentrations recently established by the TBEP in 1996. Recent trends in nutrients and water clarity indicate that Tampa Bay is “holding the line” with respect to water quality, and the large gains in water quality realized in the early 1980s have been maintained through the 1990s.

R. Kurz (Surface Water Improvement and Management (SWIM) Program, Southwest Florida Water Management District)

W. Avery (City of Tampa, Bay Study Group)

- CHAPTER HIGHLIGHTS -

- ***Historic submerged aquatic vegetation (SAV) loss has been significant, particularly in the upper portions of Tampa Bay.***

- ***Mapping indicates net increases in seagrass coverage at a rate of about 2% per year between 1988 and 1994.***

- ***Despite increasing trends in seagrass acreage, trends in seagrass bed density appear to be declining between 1988 and 1994.***

INTRODUCTION

Seagrasses are an important natural resource and are present in most shallow coastal waters throughout the world. These aquatic plants support a diverse assemblage of marine organisms including early life history stages of economically important fish and invertebrate species like spotted seatrout and shrimp.

In the U.S., seagrasses have been identified as a valuable habitat, both economically and ecologically, and so monitoring seagrass distribution and health has become an important resource management tool in many coastal ecosystems.

Five species of seagrass are common in the Tampa Bay area including *Thalassia testudinum, Syringodium filiforme, Halodule wrightii, Ruppia maritima,* and *Halophila spp*. The distributions of these species are affected by a number of factors including temperature, salinity, substratum characteristics, nutrients, aerial exposure (i.e., dessication), and available light.

It has been estimated that seagrass beds within the Tampa Bay ecosystem have declined by as much as 80% since the late 1800s. Dredging, pollution, and poor water clarity have been identified as the primary factors leading to seagrass loss in the bay. To assess the temporal and spatial changes in acreage and overall "health," a number of initiatives were necessary to monitor seagrass distributions.

In Tampa Bay, seagrass monitoring has been performed by two groups; the Surface Water Improvement and Management (SWIM) Program of the Southwest Florida Water Management District (SWFWMD) and the City of Tampa's Bay Study Group (BSG). SWFWMD monitors seagrass coverage throughout the Tampa Bay estuary and the Bay Study Group has been monitoring changes to seagrass coverage as part of their water quality program in Hillsborough Bay.

CITY OF TAMPA MONITORING

Since monitoring began in 1986, two species of seagrasses, *Halodule wrightii* and *Ruppia maritima,* have been found within Hillsborough Bay. *H. wrightii,* a pioneering species which creates generally stable meadows, has been the focus of the BSG study. *H. wrightii* baywide areal coverage was about one-half acre in the initial survey and increased to about 137 acres in 1998. Coverage for *R. maritima,* an ephemeral species, has fluctuated widely since 1986. This species has become a minor component of the seagrass coverage in recent years, although areal coverage attained 100 acres in 1996. Generally, *R. maritima* coverage fluctuates between one and five acres annually .

Caulerpa prolifera, an attached green algae that may be a pioneer species for seagrass, was monitored as part of the seagrass program. This algae was an important constituent of the submerged aquatic vegetation of Hillsborough Bay from the mid 1980s to the mid 1990s. Maximum coverage of 543 acres was attained in 1986; however, *C. prolifera* meadows were reduced nearly an order of magnitude following a "25 year" rainfall event in 1988. The algae continued to thrive in northeastern Hillsborough Bay until the mid 1990s when the coverage dwindled and eventually disappeared. No *C. prolifera* has been noted in Hillsborough Bay since 1997.

Prior to 1997, data from seagrass monitoring was generated from specific monitoring sites and aerial photography. Although these data provided seasonal information on the status of the seagrass beds, the method did not address the question of how seagrass coverage may be affected by changes in water quality. To generate this type of data, the City of Tampa established thirteen seagrass monitoring transects, eleven in Hillsborough Bay and two in Middle Tampa Bay. These transects, monitored each October, allow changes in seagrass composition, areal coverage, and density to be monitored over a depth gradient. Transect monitoring will provide data to help understand how changes in water quality may affect the depth of seagrass growth.

In 1998, the City of Tampa participated in the first interagency monitoring effort of seagrass in Tampa Bay. This seagrass monitoring program, developed under the auspices of the Tampa Bay Estuary Program, also uses transects to follow trends in species composition plus the zonation and density of the different species over depth. This program will provide annual data on seagrass trends to those who are charged with resource management in Tampa Bay.

SWFWMD MONITORING

SWFWMD began mapping seagrass distributions in Tampa Ray in 1988 to assess the status and trends of this important bay habitat. Seagrasses were also monitored to assess the effects of improvements in water quality since their growth and productivity can be affected by a number of environmental factors (poor water clarity, excess nutrients) associated with pollution.

The monitoring program consists of both an aerial mapping effort and an extensive field monitoring program. The mapping effort was the first comprehensive mapping of submerged aquatic vegetation (SAV) for the entire Bay area since a Department of Environmental Regulation mapping project in 1982.

Mapping

True color aerial photography, at a scale of 1:24,000, is typically flown biennially (every two years) during late fall/early winter months (October - January) to capitalize on times of maximum water clarity. These photos are analyzed using zoom transfer methodology and are registered to 7% minute USGS quadrangles. Seagrass signatures are identified and classified according to the Florida Department of Transportation (FDOT) Florida Land Use/Cover Classification System. The minimum mapping unit is one acre. Individual polygons are delineated on mylar overlays and digitally transferred to ARC/INFO for analysis.

To ensure accuracy, representative areas are examined in the field to verify both presence and spatial dominance of the seagrass areas. A statistically-based method was derived which requires verifying field conditions at 60 sites compared to the original photo-interpretation. The results indicate that the maps have an accuracy of approximately 99.0%. This level of accuracy has been achieved consistently during the past several years since the maps are only indicating presence, absence, and relative coverage.

Mapping boundaries are based on the seven bay segments previously described in Chapter 3 (Figure 3-3). All subsequent calculations and maps have been based on this bay segmentation scheme to help quantify the areas of change by major bay features (Table 7-1). In addition, only actual changes in seagrass coverage are photo-interpreted, which eliminates "slivers" produced when redelineating seagrass polygons.

Initially, mapping was performed using three categories of seagrass density: sparse, patchy, and continuous. As the mapping progressed, it became evident that using these categories did not always represent the actual seagrass densities found in the field, primarily due to the different morphological characteristics of the five common seagrass species found in Tampa Bay. For example, the broadleafed *Thalassia* gives a continuous signature more often than *Syringodium* and *Halodule*, which both have narrow leaves.

To address this problem, the categories were modified so that only two forms of spatial density categories were mapped: patchy (>25% of unvegetated bottom visible within a bed) and continuous (>25% of unvegetated bottom visible within a bed). This ensured that the maps were more accurate, albeit less descriptive. To address this deficiency a more intensive field monitoring program was initiated on an annual basis to provide more detailed information for the overall mapping effort.

Field Monitoring

Originally, 70 transects were strategically selected to represent the entire bay system. In 1997, the number of transects was reduced to 47 for logistical purposes. These transects range from 300 to over 1000 meters long with information collected at either 50 or 100 meter intervals depending on the length of the transect. Data collected in the field include seagrass species, abundance (percent cover within a 1 m square), blade length, water depth, secchi depth, epiphyte loading, and bottom composition. Irradiance, turbidity, and chlorophyll-a measurements were taken in 1998. Each transect is located by GPS so that the transects can be revisited during future mapping efforts, which are anticipated to be performed every fall.

Results of the most recent monitoring event (August, 1997) are presented in Table 7-3. Lowest mean salinities were found in Old Tampa Bay and Middle Tampa Bay, where four species of seagrass were present. Greatest mean abundances of seagrasses (estimated using the Braun Blanquet method) were found in Boca Ciega Bay and Lower Tampa Bay.

Recent Trends

Trend analysis from the data collected since 1988 indicates the occurrence of both increasing and receding seagrass coverage among the various bay segments. Baywide, seagrass acreage increased by approximately 11%, or 2,585 acres, between 1988 and 1990. Between 1990 and 1992, seagrasses increased by 161 acres, or less than 1%. Between 1992 and 1994, seagrasses increased by 648 acres, or about 3%. Since seagrass mapping began in 1988, seagrass coverage has increased a total of about 14%, or nearly 3,393 acres. However, the net result has been a steady overall increase in seagrass coverage for Tampa Bay at a rate of approximately 2% per year (Table 7-2, Figure 7-1). If this increase were to continue at a constant rate over time, seagrass coverage in the bay could reach the TBEP goal of 38,000 acres in 20-24 years. This scenario is unlikely due to highly variable annual and long-term rainfall patterns which can affect nutrient loading and water clarity.

Using bathymetric data provided by the Florida Marine Research Institute (FMRI), seagrass distributions were analyzed with respect to water depth. Approximately 90% of all seagrass beds occur between depths of 3 and 6 feet, and the percentage of seagrass occurring in this zone has been relatively constant since 1988 (Figure 7-2). However, marked increases have occurred in the percentage of seagrasses occupying depths between 6 and 18 feet, especially between the years 1988 and 1990. This phenomenon is probably a result of increasing water clarity (and greater light availability in deeper waters), which has been increasing steadily in all bay segments since the early 1980s.

Significant water quality improvements have occurred since the City of Tampa implemented advanced wastewater treatment technologies in the late 1970s. These improvements have led to reductions in pollutant loads, notably nitrogen, which can stimulate algal growth in the water column, reduce light penetration, and lower productivity and growth of seagrass beds.

Improvements in controlling nonpoint pollution, including urban stormwater runoff, may have helped reduce nutrient and total suspended solid concentrations in the water column. During the first few years of mapping (1988 - 1993), the Tampa Bay area experienced unusually low rainfall conditions. This and a number of regional stormwater improvement projects may have led to decreased pollutant loading to the bay.

Despite increasing trends in seagrass acreage, trends in seagrass bed density appear to be declining between 1988 and 1994. The majority of thickening (patchy beds coalescing to become continuous beds) and thinning (continuous beds fragmenting to become patchy beds) occurred within the 3 to 6 foot depth zone (Figures 7-3 and 7-4). Most of the thinning has occurred between 1992 and 1994, whereas the majority of thickening occurred between 1988 and 1990. Between 1988 and 1990, thickening of beds occurred in all segments of the bay but was most evident in Middle Tampa Bay in the nearshore areas between Cockroach Bay and Bishops Harbor. Recent (1992-1994) thinning of seagrass beds was most evident in an area extending from the west end of the Howard Frankland Causeway south to Bayboro Harbor in St. Petersburg and also along the southern tip of the Interbay Peninsula in Tampa. The cause of this extensive thinning phenomenon has not yet been determined.

As noted above, seagrass populations in many areas of Tampa Bay appear to be extremely dynamic and fluctuate annually due to a variety of factors. The amount of available light (photosynthetically active radiation, or PAR) to seagrass blades is one of the primary factors which limit productivity and growth. PAR is affected by a variety of factors, including chlorophyll-a concentrations (a measure of algal growth in the water column which can be stimulated by nutrient loading) and color (often a result of tannins in runoff from forested areas).

As water clarity improves, seagrasses should respond positively and expand in their distribution and density. This has been observed by increases in seagrass acreage at deeper depths of the bay. Conversely, losses to seagrass areas may be caused by reductions in water clarity, dessication, suboptimal temperatures during the growing season, or physical disturbances like propeller scarring or wind-driven sediment deposition. Excess nutrients can also cause excessive epiphyte growth on seagrass blades, which can drastically reduce light penetration to the blade and cause plant die-back. Occasional stochastic events such as major storms or hurricanes or anthropogenic impacts from dredging also appear to result in seagrass losses.

Table 7-1. Historic and recent Tampa Bay seagrass coverage (in acres) by bay segment

Segment	Year						
	1950*	1982*	1988	1990	1992	1994	1996
Old Tampa Bay *Bay Segment 1*	10,855	5,943	5,237.8	5,780.8	6,101.7	6,240.7	6,010.1
Hillsborough Bay** (BSG Data) *Bay Segment 2*	2,743	0 (0.04)	15.4 (1.2)	229.9 (4.8)	113.9 (12.8)	156.9 (49.0)	201.4 (100.0)
Middle Tampa Bay *Bay Segment 3*	9,499	4,042	4,998.1	5,580.2	5,285.5	5,612.6	5,329.2
Lower Tampa Bay *Bay Segment 4*	6,106	5,016	4,735.6	5,417.8	5,522.2	5,420.0	5,618.6
Boca Ciega *Bay Segment 5*	10,581	5,770	6,098.1	6,585.6	6,726.7	6,957.6	7,482.7
Terra Ceia *Bay Segment 6*	734	751	880.7	907.2	910.2	906.8	901.7
Manatee River Bay *Segment* 7	126	131	272.7	288.4	288.4	290.8	291.3
Anna Maria Bay *Segment* 8	-	-	1,109.6	1,142.7	1,145.3	1,156.0	1,178.5
Total:	40,644	21,653	23,347.9	25,932.6	26,093.8	26,741.5	27,128.0

*Estimated by Lewis et al., 1985

** Annual seagrass coverages reported by the City of Tampa's Bay Studies Group (BSG) for Hillsborough Bay do not show identical areal extent nor trends compared to the SWFWMD data (these data are shown in parentheses for comparison and are not used in the calculations for total acreage). This discrepancy is likely an artifact of the different mapping techniques employed by each agency. The SWFWMD maps seagrass at a 1:24,000 scale versus a nearly 1:1 scale used by the BSG. In 1990, seagrass coverage in Hillsborough Bay may have been overestimated by SWFWMD due to abundant algal growth north of Port Redwing which was mapped as *Halodule*.

Mapping of seagrasses in Tampa Bay and other coastal waterbodies is serving as a valuable tool for targeting areas in need of additional water quality monitoring or improvement. The 1996 aerial photography will be mapped and analyzed in early 1998, and may provide further evidence of seagrass bed expansion. At this time, the SWFWMD anticipates continuing the mapping program at two year intervals coupled with annual site-specific monitoring.

Other Studies

In 1996, SWFWMD funded a light requirement study for *Thalassia testudinum* in Tampa Bay. SWIM has initiated a similar seagrass study in Charlotte Harbor and will continue with further work in Lemon Bay. These investigations will provide additional information regarding seagrass growth dynamics and pollution reduction stratcgics for Tampa Bay and other SWIM priority waterbodies.

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Lewis, R.R. III, R.G. Gilmore, Jr., D.W. Crewz, and W.E. Odum. 1985. Mangrove habitat and fishery resources of Florida. In: W. Seaman, Jr. (ed.), Florida Aquatic Habitat and Fishery Resources. Florida Chapter of the American Fisheries Society.

Table 7-2. Changes in seagrass acreage between successive mapping years for Tampa Bay. Lower numbers are percentage increase (+) or decrease (-) in acreage.

Segment		Year			
		1982 - 1988	**1988 - 1990**	**1990 - 1992**	**1992 - 1994**
Old Tampa Bay	*Bay Segment 1*	(705.3)	543.1	320.9	139.0
		-11.9%	*10.4%*	*5.5%*	*2.3%*
Hillsborough Bay	*Bay Segment 2*	15.4	214.5	(116.0)	43.0
		>100.0%	*1391.8%*	*-50.5%*	*37.8%*
Middle Tampa Bay	*Bay Segment 3*	956.1	582.1	(294.7)	327.1
		23.7%	*11.7%*	*-5.3%*	*6.2%*
Lower Tampa Bay	*Bay Segment 4*	(280.4)	682.2	104.4	(102.2)
		-5.6%	*14.4%*	*1.9%*	*-1.8%*
Boca Ciega	*Bay Segment 5*	328.1	487.5	141.1	230.9
		5.7%	*8.0%*	*2.1%*	*3.4%*
Terra Ceia	*Bay Segment 6*	129.7	26.5	3.0	(3.3)
		17.3%	*3.0%*	*0.3%*	*-0.4%*
Manatee River	*Bay Segment 7*	141.7	15.8	0.0	2.4
		108.1%	*5.8%*	*0.0%*	*0.8%*
Anna Maria	*Bay Segment 8*	-	33.1	2.7	10.7
			3.0%	*0.2%*	*0.9%*
	Total:	1,694.9	2,584.7	161.2	647.7
	Baywide Percent Change:	*7.8%*	*11.1%*	*0.6%*	*2.5%*

Table 7-3. Results of August 1997 seagrass field monitoring in Tampa Bay.

Bay Segment	Species Present	Mean Blade Length (cm)	Mean Abundance	Mean Epiphyte Load	Mean Salinity (ppt)	Mean Temperature (°C)	Mean Secchi (m)	Sediment Type
Old Tampa Bay	*Thalassia* *Halodule* *Ruppia* *Syringodium*	25 20 15 35	4 4 + 5	m	30.2 (23-36)	28 (26-30)	1.2 (0.9-2.2)	f
Middle Tampa Bay	*Thalassia* *Halodule* *Halophila* *Syringodium*	43 20 2 40	2 3 1 4	m	30.8 (28-34)	32 (28-38)	1.2 (1.0-1.3)	mf
Lower Tampa Bay	*Thalassia* *Halodule* *Syringodium*	45 24 50	4 4 5	m/l	35.9 (34-39)	31 (29-33)	1.6 (0.8-3.0)	mf
Boca Ciega Bay	*Thalassia* *Halodule* *Syringodium*	34 22 40	5 5 5	m/l	36 (34-38)	31 (29-32)	0.7 (0.5-1.0)	f
Manatee River	*Thalassia* *Halodule* *Syringodium*	32 24 34	4 4 4	m/l	32.1 (29-36)	30 (29-32)	1.1 (0.6-1.7)	mf

Abundance scale: r=solitary, +=few or sparse, 1=plentiful<5% cover, 2=numerous 5-25% cover, 3=25-50% cover, 4=50-75% cover, 5=75-100% cover.
Epiphyte load scale: N/A=none, l=light, m=medium, h=heavy.
Sediment type scale: m=medium, mf=medium/fine, f=fine, vf=very fine.

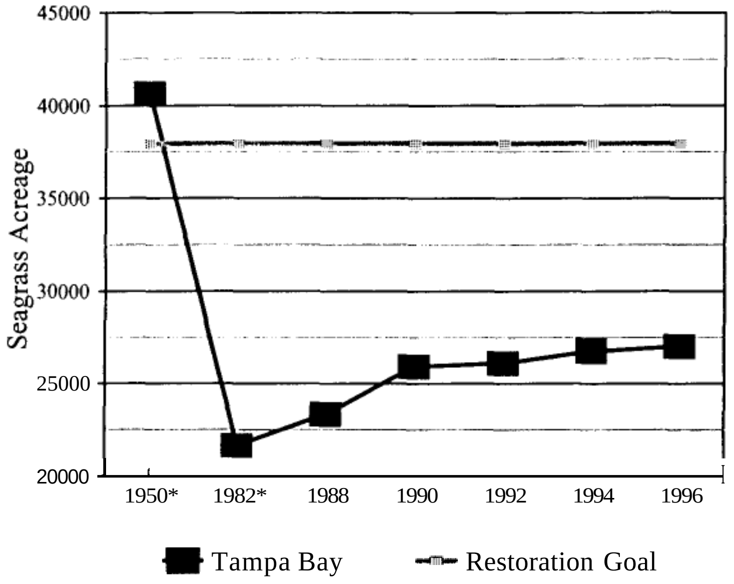

Fig. 7-1. Trends in seagrass coverage for Tampa Bay over time. Grey line is the TBEP seagrass restoration goal. (* = estimated by Lewis et al., 1985).

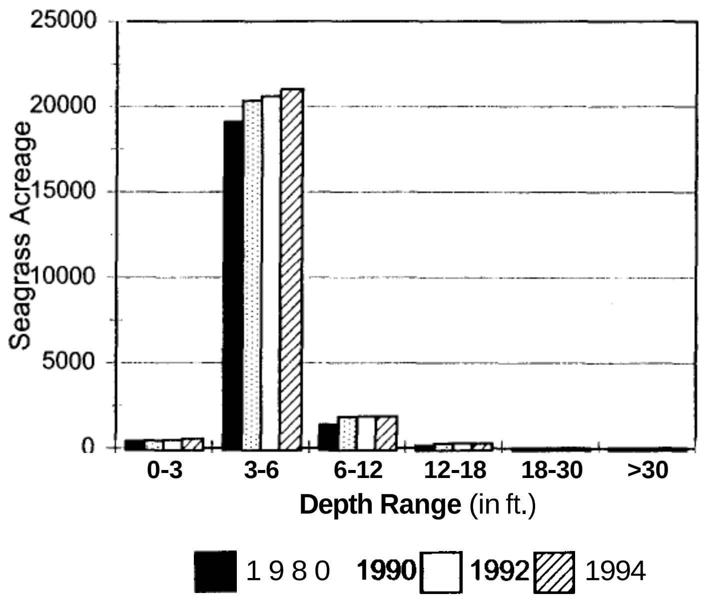

Fig. 7-2. Depth distributions of seagrasses in Tampa Bay.

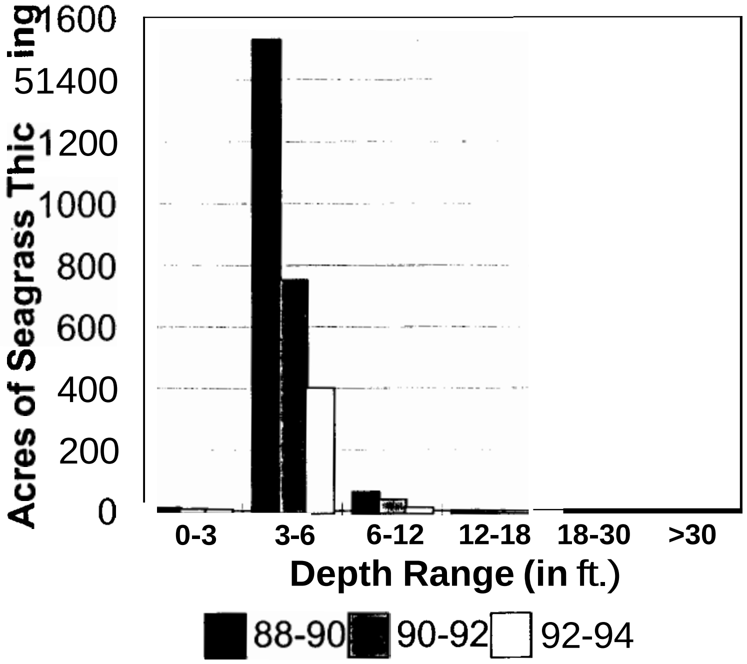

Fig. 7-3. Changes in seagrass density (patchy to continuous) with respect to depth in Tampa Bay.

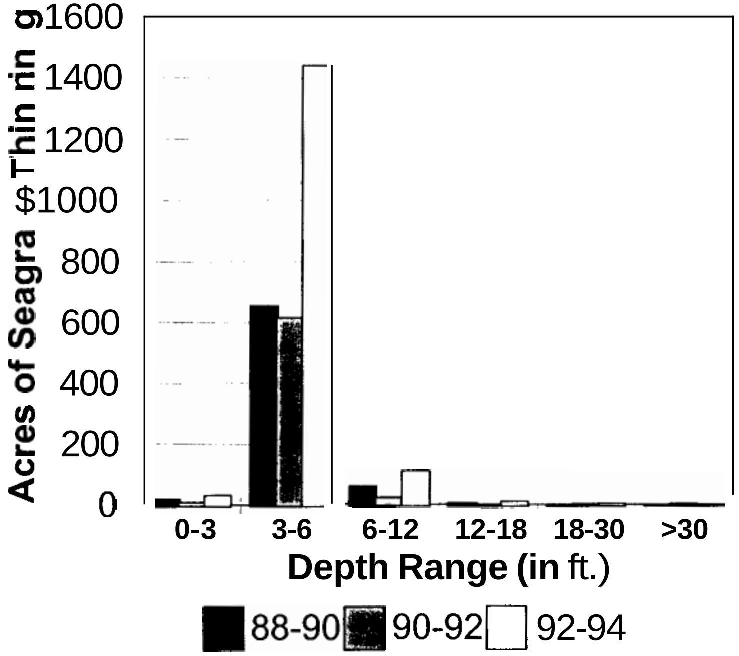

Fig. 7-4. Changes in seagrass density (continuous to patchy) with respect to depth in Tampa Bay.

S. Grabe (EPC of Hillsborough County)

- CHAPTER HIGHLIGHTS -

- ***The baseline conditions for trace metal contamination of Tampa Bay suggest that approximately 6% (24 mi^2 of bay sediments are of "marginal" quality and barely 1 % (4 mi^2) are "subnominal".***
- ***Hillsborough Bay, the most industrialized segment of Tampa Bay, shows the greatest degradation. Approximately 33% (13 mi^2) of Hillsborough Bay sediments are of "marginal" quality and almost 8% are "subnominal".***
- ***The organochlorine pesticide Chlordane was detected at extremely high (>100 ppb) concentrations at single locations in both the Hillsborough River and Old Tampa Bay.***
- ***Subnominal concentrations of polycyclic aromatic hydrocarbons were only found in the Hillsborough River.***
- ***Preliminary data suggest that the Hillsborough, Palm, and Alafia rivers show evidence of greater impairment than other parts of Tampa Bay, including Hillsborough Bay proper.***

INTRODUCTION

Contaminated sediments are of environmental concern because they have been associated with reductions in the numbers of species as well as numbers of animals, or, alternatively, with the proliferation of "pollution tolerant" animals. The Tampa Bay National Estuary Program (TBNEP) addressed both ecological and human health risks associated with contaminated sediments in a recent study (McConnell et al., 1996). This study found that, for Tampa Bay, ecological risks were associated with several metals, high molecular weight polycyclic aromatic hydrocarbons (HMWPAH), and specific organochlorine pesticides, but effects on human health were not indicated. The primary sources of metallic contaminants to Tampa Bay have been identified as urban runoff (chromium, copper, lead, mercury, zinc), atmospheric deposition (cadmium), and point sources (arsenic); agricultural runoff was the primary source of pesticides to the bay (Frithsen et al. 1995).

Charting the Course, the management plan for Tampa Bay (Tampa Bay National Estuary Program, 1996), includes among its objectives: (a) the identification of "hotspots" and sources of contaminants; (b) the improvement of both stormwater treatment and source-controls in order to ameliorate these "hotspots"; and (c) continued monitoring of the bay for changes in response to remediation.

Sediment monitoring for metals, pesticides, and hydrocarbons has been an element of the Tampa Bay National Estuary Program's synoptic monitoring program since 1993. The completion of the 1996 sediment metals analyses now permit a detemiination of "baseline" conditions of metal contamination from which to measure future improvements in Tampa Bay.

RESULTS

Trace Metals. Baseline conditions for trace metal contamination of Tampa Bay suggest that approximately 6% (24 mi2) of Tampa Bay sediments are of "marginal" quality (metal concentrations > Threshold Effects Level [TEL] < Probable Effects Level [PEL] =low probability of being toxic to aquatic life; MacDonald Env. Sci. Ltd., 1994) and barely 1% (4 mi2) are "subnominal" (metal concentrations >PEL= higher probability of being toxic; MacDonald Env. Sci. Ltd., 1994) (Figure 8-1).

Another approach is to compute the mean ratio of sample concentration:PEL for each metal; for Tampa Bay PEL ratios >1.6 indicate highly degraded sediments (MacDonald 1997). Mean PEL ratios by bay segment were <0.6 (Table 8-1); only at one site in Hillsborough Bay was the PEL ratio >1.6.

Concentrations of each of the metals were positively associated with the percentage fine-grained sediments (as percentage of silt+clay); the weakest association was with arsenic and the

Table 8-1. Summary of mean contaminant concentrations by bay segment. Tampr Bay, 1993-1996 (organic contaminant data: 1993 and 1995 only).

Bay Segment	(A)Trace metals (parts per million)								
	AG	AS	CD	CR	CU	NI	PB	ZN	PELRatio
OTB	0.07	1.00	0.12	14.57	3.11	3.64	6.27	8.42	0.05
HB	0.24	1.81	0.74	45.54	14.55	15.64	22.64	57.45	0.17
HR	0.15	1.60	0.87	23.06	40.45	6.40	90.21	118.46	0.28
PR	0.48	1.95	2.74	101.31	38.10	34.81	96.32	257.60	0.57
AR	0.24	1.21	1.85	53.42	14.74	11.54	16.34	64.29	0.22
MTB	0.05	1.37	0.12	9.41	3.13	2.52	3.24	7.57	0.04
LMR	0.04	0.26	0.07	7.25	10.47	1.12	0.92	10.96	0.04
LTB	0.04	2.04	0.11	8.02	5.13	1.77	2.38	3.98	0.04
BCB	0.05	1.26	0.19	15.02	21.25	2.01	3.48	15.48	0.06
TCB	0.04	2.18	0.12	8.34	6.38	0.96	1.10	4.88	0.03
MR	0.06	0.28	0.06	4.28	8.23	0.98	1.68	12.18	0.03

Bay Segment	(B) Organic Contaminants (parts per billion)					
	Chlordane	Tot. DDT	PCBs	LMWPAHs	HMWPAHs	Total PAHs
OTB	4.96	1.45	27.2	38.3	50.2	117.3
HB	3.41	2.42	47.4	101.8	316.1	551.6
HR	77.0	4.92	107.3	709.3	6633.0	11361.3
PR	10.2	10.2	66.0	235.0	1782.5	2954.5
AR	3.14	1.64	<45.0	<63.5	186.3	346.0
MTB	1.36	0.85	23.8	33.6	40.9	100.1
LMR	na	na	na	na	na	na
LTB	1.55	0.77	26.2	35.9	39.7	96.7
BCB	<1.00	<6.00	na	na	na	na
TCB	<1.00	<6.00	na	na	na	na
MR	<1.00	<6.00	na	na	na	na

strongest associations were with silver and lead (Table 8-2).

Hillsborough Bay, the most industrialized segment of Tampa Bay, shows the greatest degradation. Approximately 33% (13 mi^2) of Hillsborough Bay sediments are of "marginal" quality (due to cadmium concentrations >0.68<=4.21 ppm) (Figure 8-1) and almost 8% (3 mi^2) of Hillsborough Bay sediments are "subnominal" (due to chromium concentration >160 ppm and nickel concentrations >42.8 ppm) (Figure 8-1).

Approximately 14% (5 mi^2) of Boca Ciega Bay (1996 data only), 6% (5.7 mi^2) of Lower Tampa Bay, 5% (4 mi^2) of Old Tampa Bay, and 4% (4.8 mi^2) of Middle Tampa Bay have sediments of "marginal" quality. The Manatee River and Terra Ceia Bay sediments appear to be the least contaminated by metals, although almost 8% (1.5 mi^2) of the Manatee River is marginal with respect to silver. These Manatee County data need to be viewed cautiously because estimates are based upon only a single year (1996) of data.

Approximately 5% (1.8 mi^2) of Boca Ciega Bay (1996 only), and only 1% of Old, Middle, and Lower Tampa Bay have "subnominal" sediments.

Anthropogenically enriched sediments (i.e., with metal concentrations higher than backgound levels for Florida estuarine/coastal sediments; Schropp et al., 1990) were found throughout Tampa Bay. Highest incidences were in

Hillsborough Bay (especially cadmium and zinc), the Hillsborough River (cadmium, copper, lead, and zinc), and the Palm River (cadmium, lead, and zinc). Enriched sediments were less frequently observed in the Little Manatee River, Terra Ceia Bay, and the Manatee River, all areas with few samples and limited spatial coverage.

Cadmium enrichment was the most widespread of any metal in Tampa Bay. Given that phosphoritic sediments are typically enriched with cadmium (Nathan, 1984), that central Florida sediments are rich in phosphate, and that the phosphate fertilizer industry is the primary industry using the Port of Tampa (Tampa Bay Regional Planning Council, 1986), this trend is not unexpected.

Organic Contaminants. Although a large fraction of the samples analyzed for pesticides, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs) had concentrations below the method detection limit, some observations on contamination status can be offered. With respect to the organochlorine pesticides, chlordane (TEL=2.26 ppb; PEL=4.79 ppb) was detected in extremely high (>l00 ppb) concentrations at single locations in both the Hillsborough River and Old Tampa Bay. PCBs (TEL=21.6 ppb; PEL= 189 ppb) were only rarely detected, although the method detection limit was generally greater than the TEL. PCB concentrations greater than the PEL were found at single locations in both the Hillsborough River and Hillsborough Bay. PAHs were more widespread in their distribution than organochlorine pesticides and PCBs. Concentrations of LMWPAH and HMWPAHs greater than the, PEL were only found in the Hillsborough River, although concentrations greater than the TEL were found in Hillsborough Bay and the Palm River.

Table 8-2. Association of trace metal concentrations (log,, n+1 ppm) with the percentage of silt+clay (arcsine $\%SC^{.5}$) in Tampa Bay, 1993-1996.

Metal	Correlation coefficient
Arsenic	0.44
Cadmium	0.56
Chromium	0.66
Copper	0.64
Lead	0.71
Nickel	0.68
Silver	0.76
Zinc	0.68

CONCLUSIONS

The data collected during 1993-1996 to establish "baseline" conditions for Tampa Bay show a somewhat lower incidence of trace metal contamination than reported in other studies of Tampa Bay (Long et al., 1991; Coastal Environmental, Inc., l996; Long et al., 1996). This is likely due, at least in part, to differences in study designs and objectives, as well as criteria for contamination.

The study design adopted for this monitoring program provides unbiased estimates of variable means for each of the segments of Tampa Bay, as well as the bay as a whole. The NOAA studies (Long et al., 1991; Daskalaskis and O'Connor, 1994; Long et al., 1994; Long et al., 1995a; Carr et al., 1996) targeted depositional areas known to be contaminated and therefore would be expected to depict a "worst-case" scenario. Additionally, there are differences in the criteria for contamination. The current program has adopted the guidelines developed for the State of Florida (MacDonald Environmental Sciences Ltd., 1994) whereas the NOAA studies employed Long and Morgan's (1990) criteria.

The ecological impact of sediments defined as "enriched", "marginal", and "subnominal" using the chosen sediment quality assessment guidelines may actually be less than is implied by these data. Contaminants, such as trace metals, need to be "available" in order to impact resident biota. Bioavailability is not necessarily correlated with the environmental concentrations of a particular contaminant (Arjonilla et al., 1994). Abiotic factors which may determine bioavailability include acid-volatile sulfides, iron-oxides, redox potential/pH, and salinity (Bryan and Langston, 1992). Of these ancillary variables, salinity is the only one measured in this study.

The behavior and physiology of the benthic fauna will also determine the degree to which a species is impacted by contaminated sediments (Rainbow, 1990). Sessile deposit feeders, such as the polychaetes which predominate in Tampa Bay (e.g., *Mediomastus* spp., various Spionidae; Grabe et al., 1996) are more likely to be affected by contaminated sediments than vagile fauna (e.g., crabs, shrimps), which may be able to emigrate from or avoid contaminated areas (Hebel et al., 1997). Additionally, some species are capable of physiologically regulating tissue concentrations of a particular metal(s) to the extent that body burdens do not correlate with environmental concentrations (Samant et al., 1990). Likewise, fish species which prey upon deposit feeders or which swallow quantities of sediments while feeding are also more likely to accumulate contaminants (Mac and Schmitt, 1992).

The efforts to date have helped to identify "hot spots" of sediment contamination as set forth in the management plan. Of concern is the observation, albeit based upon a very small subset of the data, that the Hillsborough, Palm, and Alafia rivers show evidence of greater impairment than Hillsborough Bay proper (Figure 8-1; Table 8-2). To better resolve the issue of sediment contamination in these tributaries, the sampling design has been modified to specifically include 5-6 sampling sites in each river during 1997-2000.

PEL Quotient
(Metals)

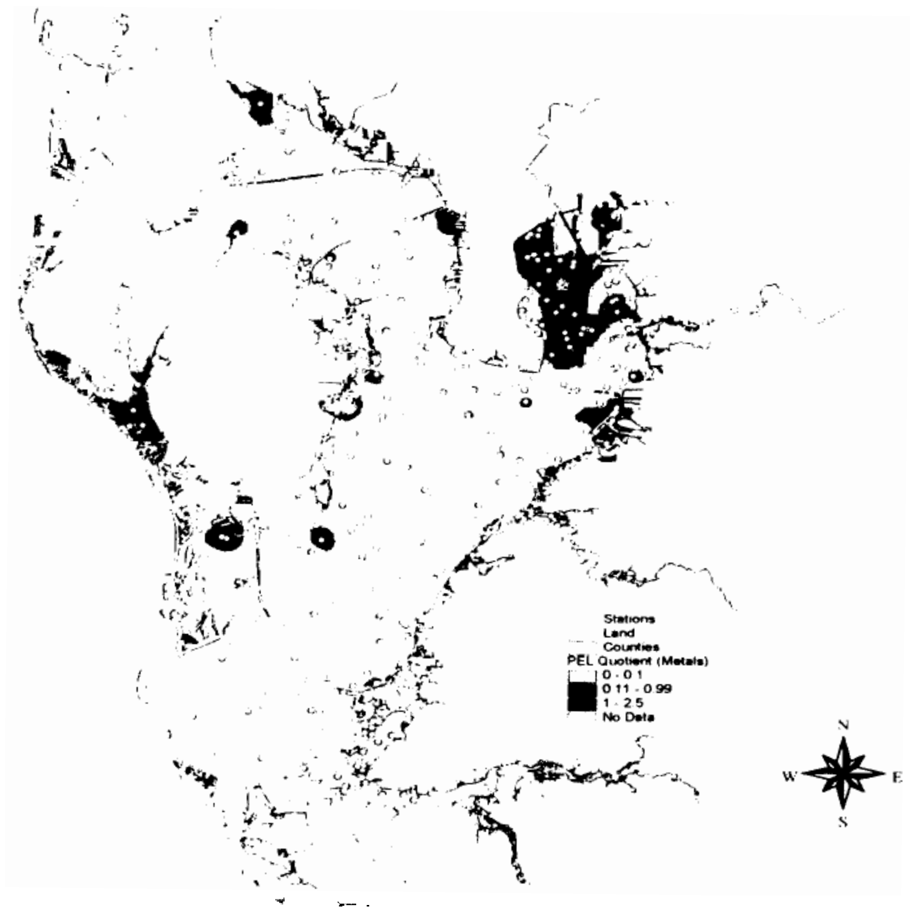

Figure 8-1. Mean PEL Quotient for trace metals in Tampa Bay 1993-1996.

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- CHAPTER HIGHLIGHTS -

☞ *Overall, Hillsborough Bay showed a relatively low species richness, diversity, and benthic index.*

☞ *In contrast, Terra Ceia Bay and Boca Ciega Bay had relatively high diversity and benthic index values.*

☞ *Abiotic factors such as salinity, depth, dissolved oxygen, and percent silt + clay all affect the benthic community structure. Of these, salinity appears to be the most important factor.*

☞ *Salinity was lowered by increased rainfall over the monitoring period, most notably in 1995. As a result, drops in species richness and diversity were observed. The effects of salinity were most noticeable in Hillsborough Bay.*

☞ *The capitellid polychaete* Mediomastus ambiseta *was one of the dominant species during the first two years of the program. However, its abundance had dropped since 1994.*

☞ *Other dominant taxa included tubificid oligochaetes, the cirratulid polychaete* Monticellina dorsobranchialis, *the spionid polychaete* Paraprionospio pinnata, *and the amphipod* Ampelisca holmesi.

☞ *Species dominance varied from year to year and from segment to segment. Factors influencing what taxa were dominant included habitat type and salinity.*

INTRODUCTION

The benthic community is made up of the organisms living on and within the bottom sediments. Thus, the benthic community is an important indicator of changes in the quality of the surrounding waters and sediments. In 1993, a synoptic bay-wide benthic monitoring program was initiated for Tampa Bay. This monitoring program is incorporated into the Tampa Bay National Estuary Program's (TBNEP) Comprehensive Conservation and Management Plan (CCMP) for Tampa Bay (TBNEP, 1996).

The study design embraced concepts developed by the USEPA for their Environmental Monitoring and Assessment Program (EMAP). Sample locations, stratified by bay segment, were selected randomly, with a known probability. Such an approach permits the estimation of "degraded" and "healthy" areas of each of the bay segments and determination of confidence intervals for those estimates (Versar, 1992; Courtney et al., 1993; Coastal Environmental Inc., 1994). Sample locations for 1993-1996 are shown in Figure 9-1. Samples were collected during the late summer/early fall period to reduce the effects of seasonality. This time of year was also chosen because it is believed to be the time of greatest stress on the benthic community (referred to as the Index Period). Alden et al. (1997) showed that differences between reference and degraded benthic communities is greatest during the summer. During this period, the bay experiences the highest water temperatures, lowest salinity, and lowest dissolved oxygen levels of the year.

Several abiotic and biotic parameters are examined to aid in describing the condition of the benthic community (Table 9-1). Abiotic parameters presented include station depth, temperature, salinity, dissolved oxygen, and percent silt + clay of the sediment. Biotic parameters examined include the number of species (richness), abundance, diversity (H'), evenness (J'), and the dominant taxa present. These parameters are defined in Karlen (1996).

A Benthic Index has also been developed to assess the health of Tampa Bay (Coastal Environmental, 1995). The Benthic Index is a modification of the index developed by EMAP for the Louisianian Province. Components of this index include Shannon-Wiener Diversity, abundance of tubificid oligochaetes, capitellid polychaetes, gastropods, and amphipods.

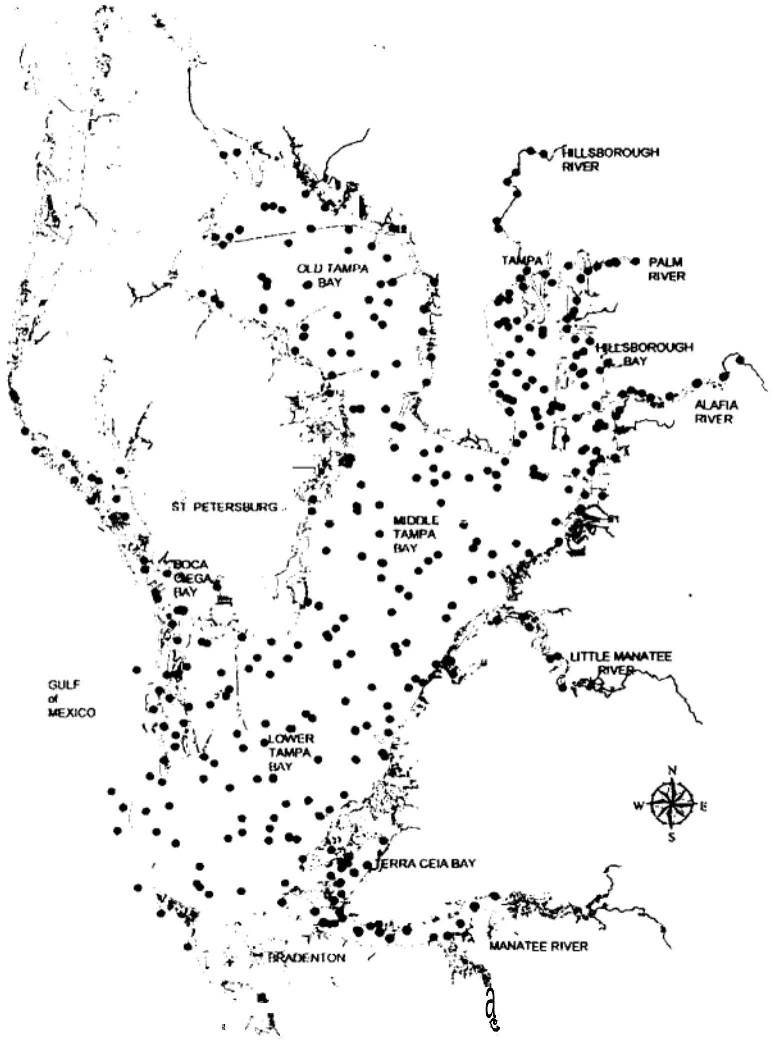

Figure 9-1. Sampling locations for the Tampa Bay Benthic Monitoring Program 1993-1996.

In this chapter, results from the first four years (1993-1996) of the Tampa Bay benthic quality monitoring program are described for the Hillsborough Bay (HB), Terra Ceia Bay (TCB), and Manatee River (MR) segments. For the Boca Ciega Bay (BCB) segment, data analysis of samples is described for 1995 and 1996. Sample processing is still ongoing for the remaining bay segments.

Biotic parameters were calculated using the Community Analyses System 5.0© (Bloom, 1994) and statistical analysis was carried out using the SYSTAT® 7.0 (SPSS Inc., 1997) software package. Significant differences among years were tested using a one-way analysis of variance (ANOVA) on $\log_{10}(n+1)$ transformed data. In cases where there were a large number of outlying data points, a non-parametric Kruskal-Wallis analysis of variance was used. Since the Kruskal-Wallis test does not assume a normal distribution, data were not transformed. For BCB, a Mann-Whitney U Test was performed instead of Kruskal-Wallis, since there were only two years of data. The Bonferroni pair-wise comparison test was used to detect differences between years when a significant difference among years was detected. Probabilities (p) of <0.05 were judged to be statistically significant. Multiple regression analysis was used to detect the influence of abiotic parameters on a given biotic parameter. Probabilities of <0.15 were judged to be significant for the multiple regressions.

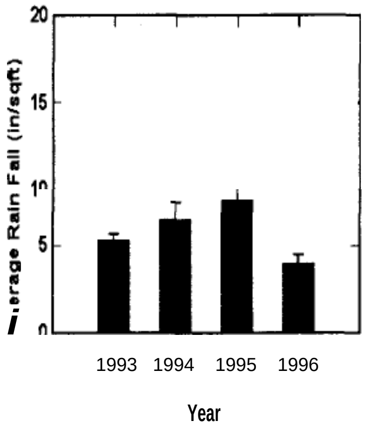

Figure 9-2. Average rainfall for August-October (source: SWFWMD, unpublished data).

HILLSBOROUGH BAY

Table 9-1 summarizes the mean values for the abiotic and biotic variables during 1993-1996. The same nineteen stations were sampled in 1993 and 1994. The increase in sampling size in 1995 and 1996 was due to the re-randomization of the station locations. The mean sample depth shows an apparent decrease from 1993-1995, and an increase in 1996; however, there is no significant difference seen among the four years. The apparent decrease in 1995 is most likely due to the larger sample size, which included more near-shore stations than the previous years. Mean bottom temperature fluctuated by approximately 1°C between years, being higher in 1993 and 1995. The differences between years were significant: 1994 and 1996 were lower than 1993 and 1996. Mean bottom salinity showed a definite decrease from 1993-1995, increasing again in 1996, with 1995 being significantly lower than the other three years and 1994 being lower than 1993 and 1996. This trend appears to be due to an increase in precipitation in 1995 (Figure 9-2). The influence of several river systems also affects the salinity regime in HB. Annual mean values for bottom dissolved oxygen and percent silt + clay were not significantly different.

Species richness, abundance, diversity, evenness, and the benthic index all showed a decreasing trend from 1993-1995 with an increase in 1996 (Table 9-1). This trend was shown to be significant for species richness, abundance, and diversity, but not for evenness or the benthic index. Species richness was lower in 1994 and 1995 than in 1993, and 1995 was lower than 1996. Total abundance was lower in 1995 than in 1993 and 1996. Diversity was lower in 1995 than in 1993 and 1996; 1994 was significantly lower than 1993. Species richness, abundance, diversity, evenness, and benthic index showed a significant positive association with both salinity and dissolved oxygen (Table 9-2; Figure 9-3).

All biotic parameters had a negative relationship with depth and percent silt + clay (Figure 9-3). The exception to this was evenness; which showed a positive association with percent silt + clay (Table 9-2). Salinity apparently had the strongest effect on all the biotic parameters. As mentioned above, salinity was significantly lower in 1995, when most of the biotic parameters were also at their lowest.

For the 1993 and 1994 sampling periods, the capitellid polychaete *Mediomastus ambiseta* and the bivalve mollusk *Mysella planulata* dominated the benthic community in HB (Table 9-3). Interestingly, *M. ambiseta* was absent from the HB samples in 1995 and 1996. *Mediomastus ambiseta* also was absent in a previous survey conducted in 1963 by the Bureau of Commercial Fisheries (BCF) (Taylor, 1971; Karlen et al., 1997). Santos and Simon (1980) recorded the dominance of the congeneric species, *Mediomastus californiensis*, in 1977 following a summer defaunation event. *Mediomastus californiensis* dominated the community for five months then disappeared from the system. *Mysella planulata* was present at only a single station in the 1963 study, but was one of the most abundant mollusks present in 1969, when the BCF stations were resampled (Hall, 1972). Santos and Simon (1980) also found that *M. planulata* was dominant initially during their study, and could rapidly regain dominance after defaunation events due to hypoxia. In 1995, a new assemblage of species dominated HB. The two dominant taxa were the paper mussel *Amygdalum papyrium* and the amphipod *Ampelisca holmesi*.

This change may have been due to the lower salinity observed in that year or to the station depth. For the 1996 sampling period, the dominant taxa were again *M. planulata* and *A. holmesi*, with *M. planulata* strongly dominating the benthic community. *Mediomastus anibiseta*, *M. planulata* and *A. holmesi* each had a positive association with salinity and negative associations with depth (Figure 9-4) and percent silt + clay (Table 9-2). *Mysella planulata* also showed a negative association with temperature (Table 9-2). *Amygdalum pupyrium* showed a negative association with depth (Figure 9-4), and percent silt + clay, but did not appear to be influenced by the other abiotic factors (Table 9-2).

HB has several rivers flowing into it and also is the site of a major port and industrial area. This bay segment is considered to be more degraded relative to other segments in Tampa Bay (Hall, 1972; Grabe, 1997a and 1997b). HB has higher

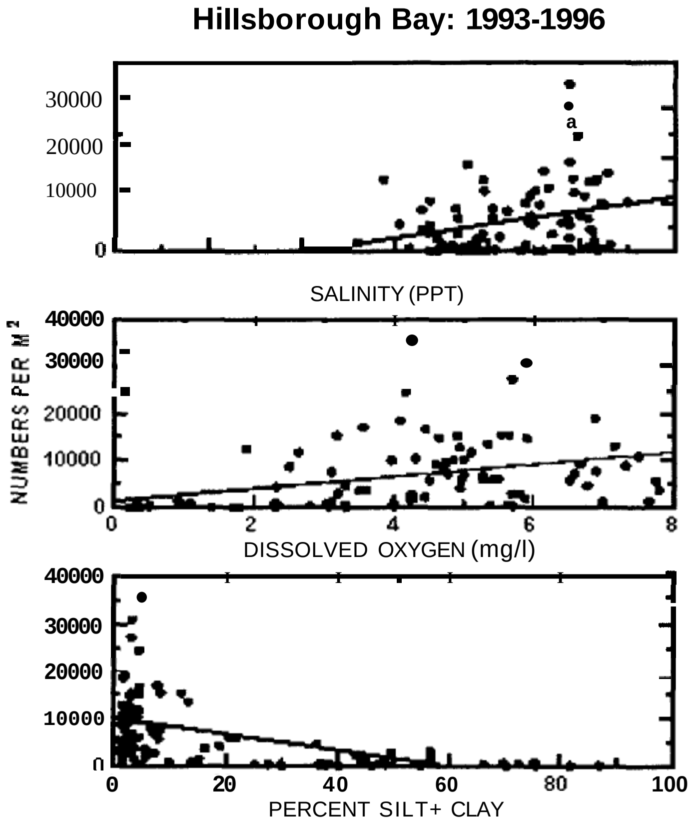

Figure 9-3. Linear regression of total benthic abundance and salinity, dissolved oxygen, and percent silt + clay for Hillsborough Bay, 1993-1996.

sediment percent silt + clay content than the other bay segments (Grabe, 1997b). Salinity appears to be one of the controlling factors that drives changes in the benthic community from year to year. During the initial year of the study, the Tampa Bay region experienced below average rainfall, which resulted in higher salinity in HB. The summer of 1995 saw a higher amount of rainfall (Figure 9-2), which contributed to lower salinity in HB. The decrease in species richness, abundance, diversity, and the change in dominant taxa are likely associated with the lowered salinity.

TERRA CEIA BAY

The same seven stations were sampled in Terra Ceia Bay (TCB) for benthic community analysis in October 1993, 1994, and 1995. Eight stations were sampled in 1996. These included the original seven stations from the previous years. Since the same stations were resampled each year in TCB, no significant difference was seen between years for mean sample depth. Table 9-1 summarizes the trends for abiotic parameters in TCB. Significant differences were observed in the mean bottom temperature between years, (1994 > the other,three years). Bottom salinity was also significantly different between years, (1995 < other years; 1994< 1996). No significant difference in bottom dissolved oxygen or percent silt + clay was seen between years in TCB .

Species richness, abundance, diversity, evenness and the benthic index each showed a decreasing trend from 1993 to 1995 followed by an increase

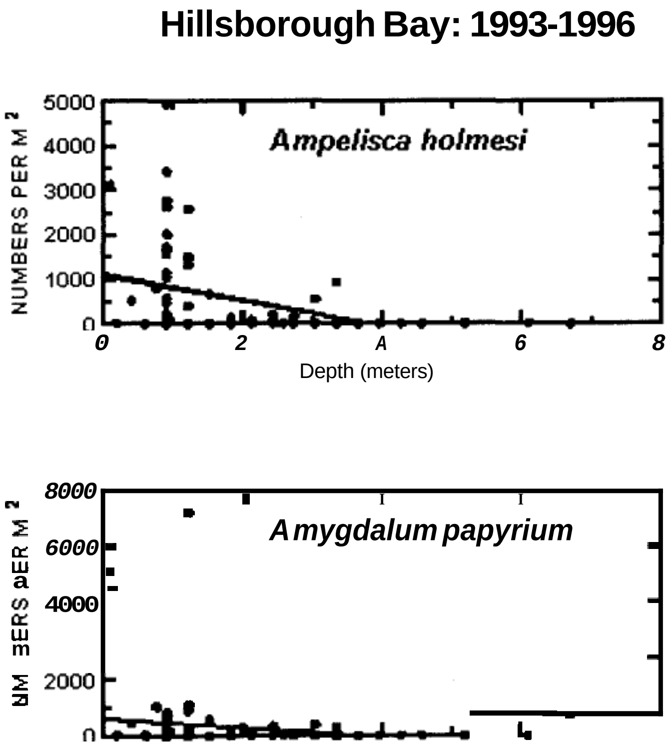

Figure 9-4. Linear regression **of** *Ampelisca holmesi* and *Amygdalum papyrium* vs. station depth in Hillsborough Bay, 1993-1996.

in 1996 (Table 9-1). Species richness was significantly higher in 1993 than the other three years. The high species richness observed in I993 may be an artifact of sample processing. During 1993, two replicates per station were analyzed and the replicates were pooled. Abundance was not significantly different among the years. Diversity was lower in 1994 and 1995 than 1993 and the benthic index was lower in 1994 compared to 1993. Species richness, abundance, diversity, and the benthic index were negatively associated with depth (Table 9-4). Diversity, evenness, and the benthic index appeared to be positively associated with salinity (Table 9-4). Unlike HB, salinity did not appear to be a major influence the benthic community. This may be due to a more stable salinity regime in TCB, perhaps due to a lack of freshwater inflow and close proximity to the mouth of Tampa Bay. Abundance showed a positive association with percent silt + clay, while evenness was negatively influenced by the percent silt + clay (Table 9-4).

The dominant species in TCB in 1993 were the amphipod *Ampelisca holmesi*, the capitellid polychaete *Mediomastus ambiseta*, and tubificid oligochaetes (Table 9-5). The dominant taxa in 1994 were the cirratulid polychaete *Monticellina dorsobranchialis;* tubificid oligochaetes; and the spionid polychaete *Paraprionospio pinnata* (Table 9-5). In 1995, tubificid oligochaetes strongly dominated the benthic community. *Monticellina dorsobranchialis* and *P. pinnata* were also among the dominant taxa present (Table 9-5). The dominant taxa in 1996 were again tubificid oligochaetes; *M. dorsobranchialis;* and the amphipod *A. holmesi* (Table 9-5). *Mediomastus ambiseta* showed a negative association with salinity (Table 9-4). *Monticellina dorsobranchialis* was negatively associated with percent silt + clay and *P. pinnata* was positively associated with depth (Table 9-4). It should be cautioned that the tubificid oligochaetes are being "lumped" at the family level due to uncertainties in identification. In the future, this group will be split into several species, which may affect their dominance rating.

MANATEE RIVER

The same eleven stations were sampled in the Manatee River (MR) in October 1993, 1994, and 1995. A total of thirteen stations were sampled in 1996 (including the original eleven stations from the 1993-1995 sampling years). Since the same locations were sampled from year to year, there was no significant difference in station depth between sampling year. Table 9- 1 shows the four year trends in the abiotic parameters for MR. The mean bottom water temperature was significantly higher in 1995 and 1996 than in 1993 and 1994. There was a trend of decreasing salinity from 1993-1995, with the salinity being significantly lower in 1995 than 1996. Neither bottom dissolved oxygen nor percent silt + clay showed significant differences between years.

Table 9-1 shows the four-year trends for. the biotic parameters in the MR. Mean species richness was significantly higher in 1993 than the other three years. Again, this may be an artifact due to varying sampling intensity. No significant differences between years was found for the other biotic parameters. Species richness, diversity, and the benthic index showed a significant, positive association with salinity (Table 9-6). Species richness, diversity, and evenness were positively associated with depth and negatively associated with percent silt + clay, as was the benthic index (Table 9-6). The benthic abundance was negatively associated with depth and positively with percent silt + clay (Table 9-6).

In 1993, the amphipod *Ampelisca abdita* and the bivalve *Mulinia lateralis* dominated the benthic community (Table 9-7). The dominant taxa for 1994 included *M. dorsobranchialis, M. ambiseta* and *P. pinnata* (Table 9-7). The dominant taxa in 1995 included the amphipod *Grandidierella bonnieroides*, the cumacean *Cyclaspis* cf. *varians,* and *M. dorsobranchialis* (Table 9-7). In 1996, the dominant species included *A. abdita* and *G. bonnieroides* (Table 9-7). *Monticellina dorsobranchialis* and *P. pinnata* were positively associated with depth, while *M. lateralis, A. abdita, G. bonnieroides,* and *C. cf. varians* were negatively associated with depth (Table 9-6). *Mediomastus ambiseta* and *G. bonnieroides* were positively associated with temperature, while *M. dorsobranchialis* and C. cf. *varians* were negatively associated with temperature (Table 9-6). None of the dominant taxa showed a significant association with salinity (Table 9-6). *Monticellina dorsobranchialis* was negatively associated with dissolved oxygen while G. *bonnieroides* showed a positive association with dissolved oxygen (Table 9-6). *Mulinia lateralis, A. abdita,* and *G. bonnieroides* and *C.* cf. *varians* were positively associated with percent silt + clay (Table 9-6).

BOCA CIEGA BAY

In 1995, Boca Ciega Bay was added to the monitoring program. Twenty-one stations were sampled in 1995 and 1996. These stations were randomized for each year. Table 9-1 shows the two year trend for the abiotic parameters in BCB. No significant differences were observed in the mean station depth, mean bottom temperatures, bottom dissolved oxygen, or percent silt + clay between the two years. Salinity, however, was significantly lower in 1995 than 1996.

None of the biotic parameters examined were found to be significantly different between 1995 and 1996 (Table 9-1). All of the biotic parameters showed a negative association with percent silt + clay; and species richness and abundance were negatively associated with depth (Table ,9-8). Evenness and the benthic index were positively associated with salinity (Table 9-8).

The dominant taxa in 1995 included spirorbid polychaetes (possibly 2 to 3 species), tubificid oligochaetes, and *M. dorsobranchialis* (Table 9-9). The dominance by spirorbids, however, was due to high abundance at only four stations (Grabe and

Karlen, 1996). Spirorbids build calcareous tubes on seagrass blades and several stations were located in beds of the seagrass *Thalassia testudinum* (turtle grass) in 1995. The dominant taxa in 1996 included tubificid oligochaetes and the tanaid crustacean *Leptochelia* (Table 9-9). Spirorbids were found to have a positive association with dissolved oxygen (Table 9-8), which may be a consequence of their association with seagrasses. Spirorbids also showed a negative association with depth and a positive association with percent silt + clay (Table 9-8). *Monticellina dorsobranchialis* was associated with temperature. Tubificid oligochaetes and *Leptochelia* were negatively associated with depth (Table 9-8). Based on the benthic index scores, BCB appeared to be one of the "healthier" portions of Tampa Bay. This may be due to the higher salinity and the abundance of seagrass habitat. BCB also appeared to be a very heterogeneous system, with most (>67%) of the species being found at only one or two stations (Grabe and Karlen, 1996).

CONCLUSIONS

Salinity appears to play a major role in determining the benthic community structure throughout the Tampa Bay system. This is most apparent in HB, where the species richness, abundance, and diversity decreased with salinity. This shift in the benthic community was most notable in 1995, when sampling followed a period of high precipitation. HB may be more affected by salinity than some of the other segments due to the influence of several river systems which flow into HB. The change in dominant taxa that was observed in 1995 was also most likely due to salinity. Generally, there is an increase in species richness and diversity towards the mouth of the bay, where salinity is higher.

Other abiotic factors also influence the benthic community structure. Of the parameters looked at, the bottom dissolved oxygen and the percent silt + clay content of the sediments also have strong associations with the benthic community measures. Generally, the benthic community is "healthier" in areas of higher dissolved oxygen and lower percent silt + clay.

Terra Ceia Bay and the Manatee River appear to be quite different systems despite their close proximity (Karlen and Grabe, 1996). TCB typically showed a higher diversity, evenness, and benthic index than MR, especially in 1993 and 1996. MR showed higher overall abundance, however. These differences were less apparent in 1994 and 1995 when rainfall was higher, though TCB consistently had a higher salinity than MR. Dominant taxa also differed between TCB and MR. Unlike the other bay segments in the program, the sampling locations have remained fixed since the initiation of the monitoring program. This has limited the spatial coverage of these two bay segments.

The high species richness, diversity, evenness, and benthic index seen in Boca Ciega Bay were most likely due to higher salinity (due to its proximity to the Gulf of Mexico) and the presence of seagrass beds. There is also considerable heterogeneity within the benthic community with most taxa occurring at few locations. Despite a high rate of development and growth along it's shores, BCB seems to be "healthier" relative to other segments of Tampa Bay.

Table 9-1. Sumn ry Table of Abiotic and Biotic Parameters

	Hillsborough Bay				Terra Ceia Bay				Manatee River				Boca Ciega Bay			
	1993	1994	1995	1996	1993	1994	1995	1996	1993	1994	1995	1996	1993	1994	1995	1996
Sample Size (Stations)	19	19	30	26	7	7	7	8	11	11	11	13	N/A	N/A	21	21
Mean Sample Depth (meters)	2.6	2.2	1.9	3.7	1.9	2.2	1.7	1.9	2.7	2.8	2.6	2.1	N/A	N/A	1.6	1.8
Bottom Temperature (°C)	29.8	28.6	29.9	28.9	28.0	26.3	27.8	27.7	27.0	25.9	29.2	28.8	N/A	N/A	27.3	27.9
Bottom Salinity (‰)	24.4	21.4	18.0	24.5	17.4	16.3	11.9	18.5	14.4	11.8	9.3	15.8	N/A	N/A	30.2	32.7
Bottom Dissolved Oxygen (mg/l)	3.88	3.84	4.66	4.15	5.74	5.63	4.73	6.28	4.57	3.79	4.11	5.00	**N/A**	**N/A**	6.39	5.96
% Silt + clay	17.7	27.8	17.0	21.7	5.4	5.3	3.2	3.4	6.6	6.8	5.4	7.8	**N/A**	**N/A**	7.5	10.4
Species Richness	37	20	16	25	63	34	29	34	55	28	32	33	**N/A**	**N/A**	45	42
Abundance	8933	5228	3999	9132	5266	6293	4429	4075	13008	6216	10350	18639	**N/A**	**N/A**	10125	6644
Diversity	3.31	2.26	2.12	2.72	4.83	3.42	3.30	4.03	3.54	3.14	3.42	3.01	**N/A**	**N/A**	3.71	4.11
Evenness	0.68	0.68	0.54	0.65	0.81	0.70	0.70	0.83	0.62	0.67	0.70	0.60	**N/A**	**N/A**	0.70	0.78
Benthic Index	16.92	11.67	12.71	15.71	26.93	16.91	16.23	23.76	21.60	17.76	18.39	18.11	**N/A**	**N/A**	20.63	23.20

	R^2	Depth	Temp.	Salinity	D.O.	%Silt+Clay
Species Richness	0.73	-0.43 *	NS	+3.40 ****	+0.76 ****	-0.85 ****
Abundance	0.72	-0.86 *	NS	+6.10 ****	+2.14 ****	-1.71 ****
Diversity	0.53	-1.65 **	**NS**	+8.36 ****	+1.52 ****	-1.57 **
Evenness	0.20	-0.50 ***	NS	+1.20 ****	+0.45 ***	+0.29 ****
Benthic Index	0.43	-0.50 ***	NS	+1.53 ****	+0.66 ****	NS
Mediomastus ambiseta	0.25	-2.06 **	NS	+8.82 ****	NS	-1.41 ***
Mysella planulata	0.51	-2.38 ***	-14.3 **	+8.29 ****	NS	-2.42 ****
Amygdalum papyrium	0.37	-2.94 ****	NS	NS	NS	-0.67 *
Ampelisca holmesi	0.44	-3.84 ****	NS	+4.42 **	NS	-1.05 **

Data $Log_{10}(n+1)$ transformed; % Silt + Clay Arcsin transformed; Table values represent regression coefficients .
NS = Not Significant * = p<0.15 ** = p<0.05 *** = p<0.01 **** = p<0.001

	1993			1994			1995			1996		
	Rank	%Abund.	%Freq.	Rank	%Abund.	%Freq.	Rank	%Abund.	%Freq.	Rank	% Abund.	%Freq.
Mediomastus ambiseta (P)	1	17	58	**2**	11	**53**	X	X	X	X	X	X
Mysella planulata (B)	2	11	**68**	**1**	12	53	**6**	5	40	1	26	58
Amygdalum papyrium (B)	X	X	X	**X**	X	X	1	**13**	**40**	X	X	X
Ampelisca holmesi (A)	X	X	X	X	X	X	**2**	**13**	**40**	2	4	**58**

Table 9-4. Terra Ceia Bay Multiple Regression Analysis

	R^2	Depth	Temp.	Salinity	D.O.	%Silt+Clay
Species Richness	0.22	-0.90 ***	NS	NS	NS	NS
Abundance	0.21	-0.82 *	NS	NS	NS	+2.69 ***
Diversity	0.35	-3.59 ***	NS	+5.07 **	NS	NS
Evenness	0.29	NS	NS	+0.78 ***	NS	-0.90 **
Benthic Index	0.32	-0.50 **	NS	+1.07 **	NS	NS
Mediomastus ambiseta	0.11	NS	NS	-5.06 **	NS	NS
Paraprionospio pinnata	0.29	+4.19 **	NS	NS	-4.00 *	NS
Monticellina dorsobranchialis	0.17	NS	NS	NS	NS	+10.8 ***
Ampelisca holmesi	0.14	NS	+29.5	+5.53 *	NS	NS

Data $Log_{10}(n+1)$ transformed; % Silt + Clay Arcsin transformed; Table values represent regression coefficients .

NS = Not Significant * = p<0.15 ** = p<0.05 *** = p<0.01 **** = p<0.001

Table 9-5: Terra Ceia Bay Dominant Taxa (P = Polychaete O = Oligochaete A = Amphipod Crustacean X = not ranked in top five).

	1993			1994			1995			1996		
	Rank	%Abund	%Freq	Rank	%Abund	%Freq	Rank	%Abund	%Freq	Rank	% Abund.	%Freq.
Mediomastus ambiseta (P)	2	6	71	X	X	X	X	X	X	X	X	X
Monticellina dorsobranchialis (P)	4	3	86	1	28	71	2	8	71	2	8	88
Paraprionospio pinnata (P)	5	3	71	3	8	71	3	7	71	X	X	X
Tubificid Oligochaetes(O)	3	4	71	2	12	86	1	28	100	1	16	88
Ampelisca holmesi(A)	1	10	86	X	X	X	X	X	X	3	7	88

Table 9-6. Manatee River Multiple Regression Analysis. NS = Not Significant;* = $p<0.15$;** = $p<0.05$;*** = $p<0.01$;**** = $p<0.001$

	R^2	Depth	Temp.	Salinity	D.O.	%Silt+Clay
Species Richness	0.36	+0.23 *	NS	+0.50 ***	NS	-0.42 *
Abundance	0.09	-0.47 *	NS	NS	NS	+0.88 *
Diversity	0.41	+1.29 **	NS	+2.06 ***	NS	-4.62 ***
Evenness	0.24	+0.26 ***	+1.01 *	NS	NS	-0.75 ***
Benthic Index	0.38	+0.13 *	NS	+0.24 **	+0.21 **	-0.40 *
Mediomastus ambiseta	0.11	NS	+11.5 *	NS	NS	NS
Paraprionospio pinnata	0.37	+3.46 ***	NS	NS	NS	NS
Monticellina dorsobranchialis	0.33	+3.04 *	-9.61 *	NS	-3.13 *	NS
Mulinia lateralis	0.56	-6.33 **	NS	NS	NS	+11.4 *
Ampelisca abdita	0.41	-3.12 ***	NS	NS	NS	+8.91 ****
Grandidierella bonnieroides	0.51	-2.66 ***	+16.8 ***	NS	+1.56 *	+4.98 ***
Cyclaspis cf. *varians*	0.49	-4.51 *	-22.2 *	NS	NS	+12.2 **

Data $Log_{10}(n+1)$ transformed; % Silt + Clay Arcsin transformed; Table values represent regression coefficients .

Table 9-7. Manatee River Dominant Taxa (P = polychaete, B = bivalve mollusk, C = cumacean crustacean, A = amphipod crustacean, X = not in top five)

	1993			1994			1995			1996		
	Rank	% Abund.	% Freq.	Rank	% Abund.	% Freq.	Rank	% Abund.	% Freq.	Rank	% Abund.	% Freq.
Mediomastus ambiseta (P)	X	X	X	2	6	82	X	X	X	X	X	X
Monticellina dorsobranchialis (P)	X	X	X	1	19	73	3	**9**	64	3	8	62
Paraprionospio pinnata (P)	X	X	X	3	7	73	X	X	X	X	X	X
Mulinia lateralis (B)	***2***	11	73	X	X	X	X	X	X	X	X	X
Cyclaspis cf ***varians*** (C)	X	X	X	X	X	X	2	8	91	X	X	X
Ampelisca abdita (A)	1	21	64	X	X	X	X	X	X	1	43	77
Grandidierella bonnieroides (A)	X	X	**X**	X	X	X	1	18	55	2	5	92

Table 9-8. Boca Ciega Bay Multiple Regression Analysis						
	R^2	Depth	Temp.	Salinity	D.O.	%Silt+Clay
Species Richness	0.31	-0.79 **	NS	NS	NS	-1.36 ***
Abundance	0.36	-2.26 ***	NS	NS	NS	-2.85 ***
Diversity	0.14	NS	NS	NS	NS	-3.61 ***
Evenness	0.16	NS	NS	+2.60 **	NS	-0.74 ***
Benthic Index	0.28	NS	NS	+2.34 *	NS	-1.19 ****
Monticellina dorsobranchialis	0.00	NS	+8.51 *	NS	NS	NS
Spirorbid Polychaetes	0.54	-3.78 *	NS	NS	+13.4 ***	+5.38 *
Tubificid Oligochaetes	0.35	-4.93 ****	NS	NS	NS	NS
Leptochelia sp.	0.20	-4.19 **	NS	NS	NS	NS
Data $Log_{10}(n+1)$ transformed; % Silt + Clay Arcsin transformed; Table values represent regression coefficients .						
NS = Not Significant * = p<0.15 ** = p<0.05 *** = p<0.01 **** = p<0.001						

Table 9-9: Boca Ciega Bay Dominant Taxa							
		1995			1996		
		Rank	%Abund.	%Freq.	Rank	%Abund.	%Freq.
Monticellina dorsobranchialis	(P)	3	3	62	X	X	X
Spirorbid Polychaetes	(P)	1	32	24	X	X	X
Tubificid Oligochaetes	(O)	2	7	71	1	7	57
Leptochelia sp.	(T)	X	X	X	2	8	33

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- CHAPTER HIGHLIGHTS -

- *The Fisheries-Independent Monitoring Program has used seines, trawls, and trammel nets to sample finfish and select macroinvertebrate populations in Tampa Bay since 1989.*

- *Juvenile red drum recruitment peaked in 1991 and 1995 and was relatively lower in 1997.*

- *Recruitment ofjuvenile sheepshead appears to have occurred in three-year cycles, with a year of relatively strong recruitment (1991, 1994, and 1997) followed by two years of moderate to low recruitment.*

- *Male andfemale sheepshead grow at similar rates through agefour, after whichfemales tend to be larger than males.*

- *Young-of-the-year spotted seatrout recruitment was highest in 1989 and 1991 and lowest in 1990, with fairly constant recruitment since 1991.*

- *Blue crab recruitment was highest in 1989, lowest in 1990, and relatively consistent between 1991 and 1996.*

INTRODUCTION

Since 1983, the Florida Department of Environmental Protection (FDEP) has been developing a systematic and continuing program whose purposes have been to monitor commercial and recreational marine fisheries and to collect and integrate essential information used in the management and enhancement of Florida's marine resources. Four basic components compose Florida's Marine Fisheries Monitoring Program: the Fisheries-Independent Monitoring (FIM) program, the Florida Marine Fisheries Information System ("trip ticket"), the Trip Interview Program (TIP), and the National Marine Fisheries Service's (NMFS). Marine Recreational Fishery Statistics Survey (MRFSS). Each component monitors the status of a different aspect of Florida's marine fisheries. The Fisheries-Independent Monitoring program assesses fish stocks within individual estuarine systems, whereas the other programs estimate fishing pressure and landings, commercial and recreational, on a larger geographic scale.

The Florida Marine Research Institute's (FMRI) Fisheries-Independent Monitoring program was initially developed to assess the recruitment of resource species that use estuarine and near-coastal waters as nursery areas, and as such, was designed to sample animals during pre-fishery life stages. Such an approach allows researchers to avoid many of the problems inherent in fisheries-dependent monitoring and provides stock estimates that are of much greater predictive utility than are estimates determined from fisheries-dependent monitoring. Long-term fisheries-independent monitoring of pre-fishery life stages of finfish stocks should allow managers to formulate fisheries-management policies proactively rather than reactively, which has often been the traditional approach.

The FIM program employs a holistic approach to sampling, so that in addition to collecting data on commercially and recreationally important finfish stocks, information on selected macroinvertebrates and finfish stocks that are not of direct fisheries importance is also collected. The program also records extensive site-specific information on environmental and biological variables that allows researchers to evaluate species interactions, habitat dependencies, and the effects of environmental influences on fishery recruitment processes.

Stratified-random-sampling and directed-sampling surveys[1] are currently employed by the FIM program to assess the status of fishery stocks in Tampa Bay. Information on the length-frequency, age structure, reproductive condition, and estimates of relative abundance are provided by the stratified-random-sampling survey. Stratified-random sampling is conducted monthly, year-round, with 21.3-m seines, 6.1-m otter trawls, and 183-m haul and purse seines.

[1] The fixed-station-sampling survey, which was discussed in the 1992-1993 Tampa Bay Environmental Monitoring Report, was terminated in 1995 and will not be discussed in this report

Before each sampling event, the sites to be sampled are randomly selected.

The directed-sampling survey also provides information on length-frequency, age structure, and reproductive condition, but this survey targets two species (red drum and striped mullet) that are inherently under-sampled by the gears used in the stratified-random-sampling survey. The area of the bay to be sampled is either assigned (striped mullet) or randomly selected (red drum) before each sampling event. Target species are collected in trammel nets set upon visually detected schools of fish.

The FIM program was originally developed with funding provided by a Department of Interior, U.S. Fish and Wildlife Service's Federal Aid to Sportfish Restoration grant. Although funding under the federal grant continues, the program is now primarily supported by state funds generated from the sale of saltwater fishing licenses. The program is intended to be sustained on a continuing basis and eventually to be expanded to include the monitoring of all major estuarine and coastal nursery areas in the state. Routine monitoring programs have been established in Tampa Bay (l989), the northern half of Charlotte Harbor (1989), the northern and southern portions of the Indian River Lagoon (1990 and 1997, respectively), Florida Bay (1995), Cedar Key (1996), and Apalachicola Bay (1997).

RESULTS

Nearly five million animals (fishes and select macroinvertebrates), representing 199 taxa, have been collected and released in 8,878 stratified-random and 463 directed-survey samples (Table 10-1) collected in Tampa Bay since 1989. In the 1997 stratified-random-sampling survey alone, more than 1,700 samples were taken (Figure 10-1); in these samples, more than 800,000 animals were collected and all of Tampa Bay's major areas and habitat types were sampled. The 21.3-m seines (offshore, beach, and boat sets) have collected 88% of the animals since 1989, with the beach-seine sets collecting the largest number of animals (1,761,458; Table 10-1). Otter trawls, which have collected just 10% of the total number of animals, sampled the most diverse assemblage of species (150 taxa; Table10-1). The 183-m haul and purse seines and the two trammel nets (459-m and 366-m), which are designed to collect subadult- and adult-sized finfish, collected animals with larger mean sizes than did any of the other gear types.

Survey results concerning three fish species (red drum, sheepshead, and spotted seatrout) and one macroinvertebrate (blue crab) are discussed in this report.

Table 10-1. The FIM program's stratified-random- and directed-sampling surveys, 1989-1997: the number of samples, animals, and taxa and the mean sizes of animals collected, by year(s) and gear type.

Gear	Years Sampled	No. Samples	No. Animals	No. Taxa	Mean Size (mm)
Stratified-random-sampling survey					
21.3-m seine (offshore set)	1989-1997	2,183	1,167,599	132	33
21.3-m seine (beach set)	1989-1997	1,505	1,761,458	124	35
21.3-m seine (boat set)	1989-1997	1.216	1,256,322	112	32
6.1-m otter trawl	1989-1997	3,254	455,271	150	55
183-m haul siene	1996-1997	420	49,887	88	139
183-m purse seine	1997	300	32,657	75	166
Subtotal		8,878	4,723,194	196	
DIrected-sampling survey					
459-m trammel net	1993-1997	129	4.117	22	487
336-m trammel net	1993-1997	334	32,339	60	343
Subtotal		463	36,456	82	
Total		9.341	4.759.650	199	

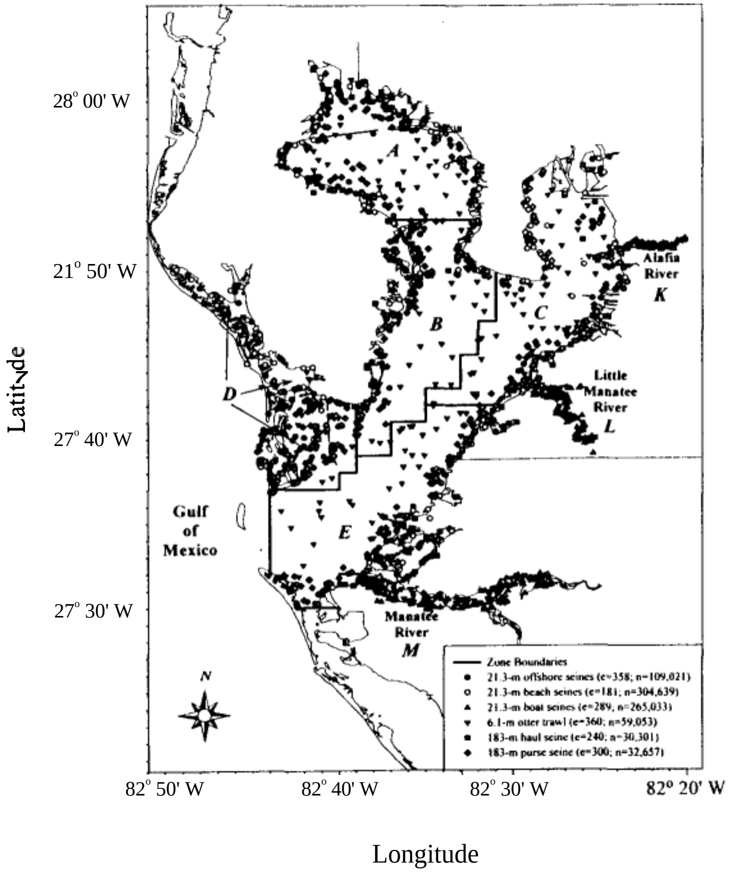

Figure 10-1. Zones (designated by capital letters A-E and K-M) and sites sampled by the Fisheries-Independent Monitoring program during stratified-random sampling in Tampa Bay, 1997. In the key, e denotes the number of samples taken and n indicates the number of animals collected.

Red drum

The red drum is a popular recreational species throughout Florida. Overfishing by recreational and commercial fisheries depleted adult populations of red drum throughout the Gulf of Mexico during the late 1980s. Strict federal and state regulations effectively eliminated the inshore and offshore fisheries, both commercial and recreational, in 1987. In 1990, a limited recreational fishery in state waters was reestablished.

Adult red drum spawn in offshore waters during the early fall, and small juveniles (<= 35mm standard length) recruit into lower-salinity backwater areas of Tampa Bay from September to December. Relative abundance (median number of fish per set) of juvenile red drum in Tampa Bay was highest in 1991 and 1995 (1.2 and 1.5 fish per set) and lowest in 1997 (0.4 fish/set; Figure 10-2). Juvenile recruitment success probably varies with natural fluctuations in adult spawning success or in juvenile mortality.

Length-frequency distributions for subadult and adult red drum in Tampa Bay have remained fairly consistent during the five years that the FIM program has been conducting directed sampling with trammel nets (Figure 10-3). Red drum median size has ranged from a low of 545 mm standard length in 1995 to a high of 595 mm standard length in 1993. The consistency in sizes of red drum collected during these five years is an indication of the stability of the red drum fishery in Tampa Bay.

Sheepshead

Sheepshead have traditionally been a recreational fishery on the Gulf Coast of Florida; on average, 83% of the sheepshead landed between 1986 and 1996 were taken by the recreational fishery (Figure 10-4). Since 1986, recreational landings have fluctuated from a low of 916,510 pounds in 1987 to a high of 3,245,561 pounds in 1992, with no obvious trend. Commercial landings on the Gulf Coast of Florida stabilized at approximately 600,000 pounds in 1992 after increasing steadily from a low of 281,802 pounds in 1986. Commercial landings declined in 1996 (138,594 pounds) to their lowest levels since 1986, most certainly because of the net-ban amendment (enacted in July 1995). This amendment, which required that the commercial fishery stop using entangling gears (gillnets and trammel nets), caused a shift in gears to castnets, in which much fewer sheepshead could be caught.

The sheepshead is a species commonly associated with submerged structures such as bridge pilings, oyster beds, and offshore reefs. Juvenile sheepshead, however, tend to recruit to shallow inshore waters with drift algae or seagrass bottoms. Newly recruited individuals enter Tampa Bay during the early spring and remain in these shallow-water habitats until approximately July. During the late summer months, the juvenile sheepshead move to their adult habitats of submerged structure.

Juvenile sheepshead (<=40 mm standard length) recruitment into Tampa Bay appears to have followed a three-year, cyclical pattern since 1989; two years of low to moderate relative abundance have typically been followed by a year of higher relative abundance (Figure 10-5). The lowest relative abundances for juvenile sheepshead in Tampa Bay occurred during 1989 and 1996 (0.042 and 0.000 fish per set, respectively). Relative abundance was highest in 1991 (0.234 fish per set), with lesser peaks in 1994 and 1997 (0.190 and 0.120 fish per set, respectively).

The incorporation of gear types most likely to capture subadult- and adult-sized fishes has allowed the FIM program to collect fish for life-history (age, growth and reproduction) analyses, which are necessary to accurately assess a stock's status. To determine a fish's age, rings that are deposited annually in a fish's ear stone are counted under a microscope. Sheepshead in Tampa Bay reach a maximum age of at least 14 years (Figure 10-6). Male and female sheepshead grow at about the same rate through age four, after which females tend to be larger than males.

Spotted Seatrout

The spotted seatrout is found from Delaware south along the Atlantic Coast, and throughout the Gulf of Mexico. Throughout its range, it is an important recreational and commercial species. In July 1995, the state of Florida implemented a ban on the use of entangling gears (gillnets and trammel nets) within state waters, which reduced commercial landings of spotted seatrout by more than 90%. At about the same time, recreational size and bag limits were changed to reduce the recreational harvest of this species. Monitoring of spotted seatrout abundances by the FIM program should provide an early indication of the effectiveness of these management tools.

In Florida, spotted seatrout have a very protracted reproductive season: young-of-the-year (<100 mm standard length) fish recruit into the Tampa Bay estuary from April to October. Newly recruited spotted seatrout tend to settle out in shallow estuarine areas, where they are most efficiently sampled by the 21.3-m seines. During their recruitment period, relative abundances of young-of-the-year spotted seatrout are highest (>0.80 fish per set) in zones with median salinities of between 13 and 25 ppt (Zones A, B, C, K, and M; Figure 10-7) and lowest in zones with median salinities of less than 10 (Zone L) or greater than 30 ppt (Zones D and E). Annual recruitment of young-of-the-year spotted seatrout into Tampa Bay was highest in 1989 and 1991 (1.6 and 1.2 fish per set, respectively; Figure 10-8) and lowest in 1990 (0.4 fish per set). Since 1991, annual recruitment has been relatively steady, fluctuating between 0.6 and 1.0 fish per set.

Blue Crabs

The blue crab represents an important commercial and recreational fishery in Florida's inshore waters. The potential for increased fishing pressure on blue crab populations has caused recent concern, however, as commercial fishermen who caught fish with entangling gears before the gears were outlawed by the net-ban amendment shift their effort to the blue crab fishery. A juvenile recruitment index for blue crabs provides one method of assessing the status of the blue crab stocks.

Although the FIM program was established to collect information on finfish stocks, it also records data on selected macroinvertebrate species (penaeid shrimp, blue crabs, and stone crabs) during its routine sampling. Juvenile blue crabs (<=65 mm carapace width) are collected in 21.3m seine samples throughout the year, but are most abundant between September and June. Recruitment success, which was highest in 1989 (0.87 fish/set) and lowest in 1990 (0.23 fish/set), was relatively consistent between 1991 and 1996 (Figure 10-7).

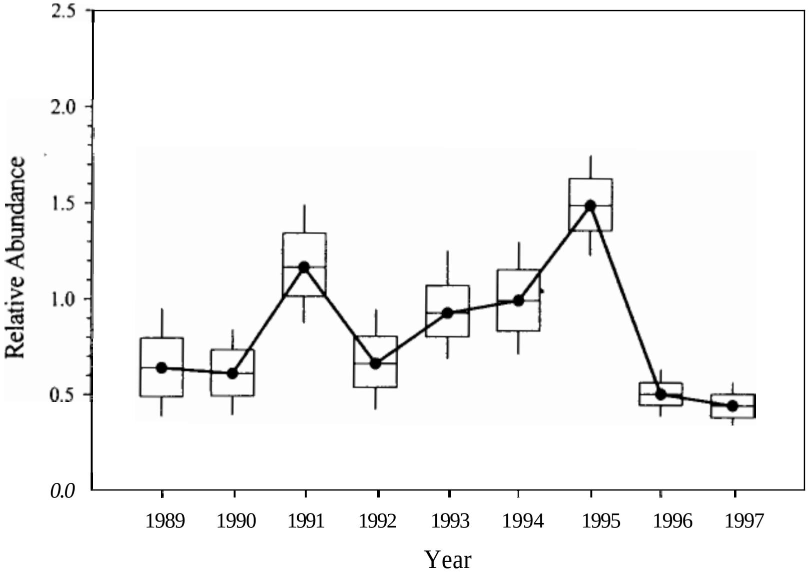

Figure 10-2. Annual indices of the relative abundance (fish per set) ofjuvenile red drum (<=35mm standard length) in Tampa Bay. Data are from the fall (Sep. - Dec.) stratified-random-sampling surveys, 21.3-m seine component, 1989-1997. The box represents the 25th-75th percentiles, the vertical line extends from the 10th-90th percentiles, and the horizontal line and filled circle indicate the median value.

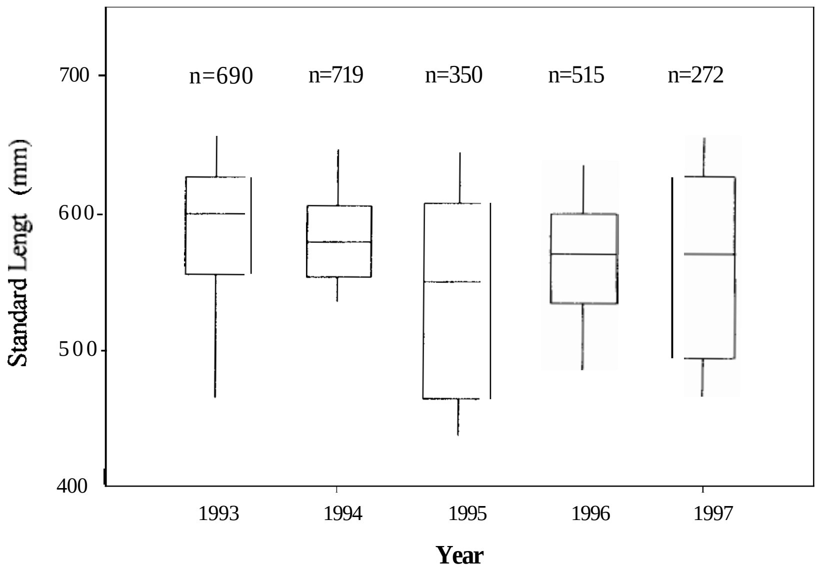

Figure 10-3. Annual size distribution of red drum collected in Tampa Bay during the directed-sampling surveys, 1993-1997. The number above each year (n=) indicates the number of red drum collected each year. The box represents the 25th-75th percentiles, the vertical line extends from the 10th-90th percentiles, and the horizontal line indicates the median value.

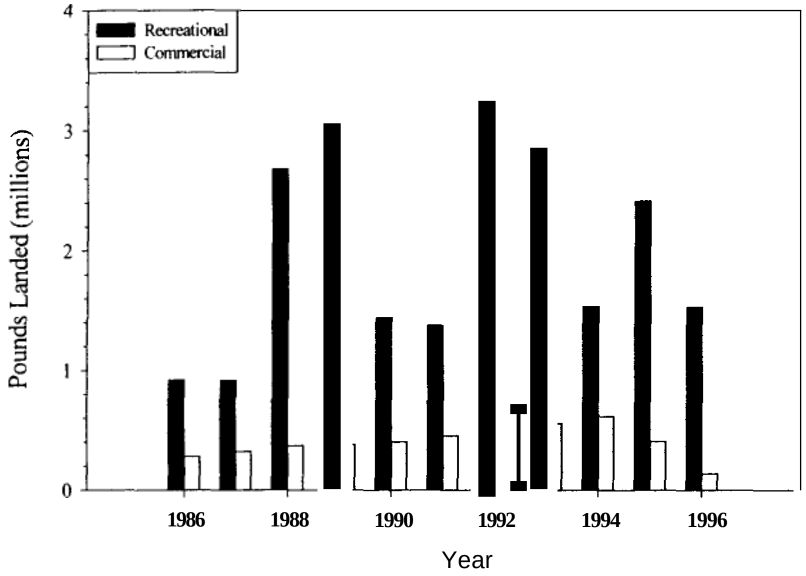

Figure 10-4. Commercial ("trip ticket" data) and recreational (MRFSS data) landings of sheepshead from the Gulf coast of Florida, 1986-1996.

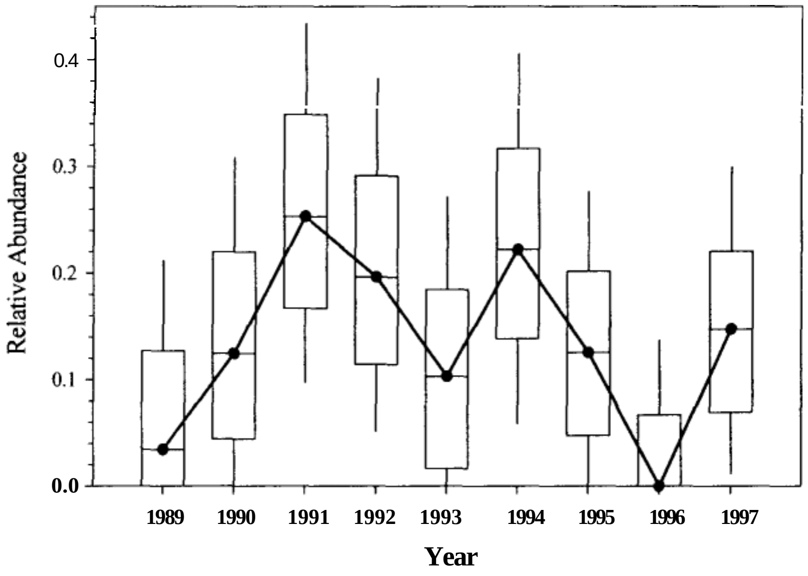

Figure 10-5. Annual indices of the relative abundance (fish per set) of juvenile sheepshead (<=40mm standard length) in Tampa Bay. Data are from the spring (Mar. - Jun.) stratified-random-sampling surveys, 21.3-m seine component, 1989-1997. The box represents the 25^{th}-75^{th} percentiles, the vertical line extends from the 10^{th}-90^{th} percentiles, and the horizontal line and filled circle indicate the median value.

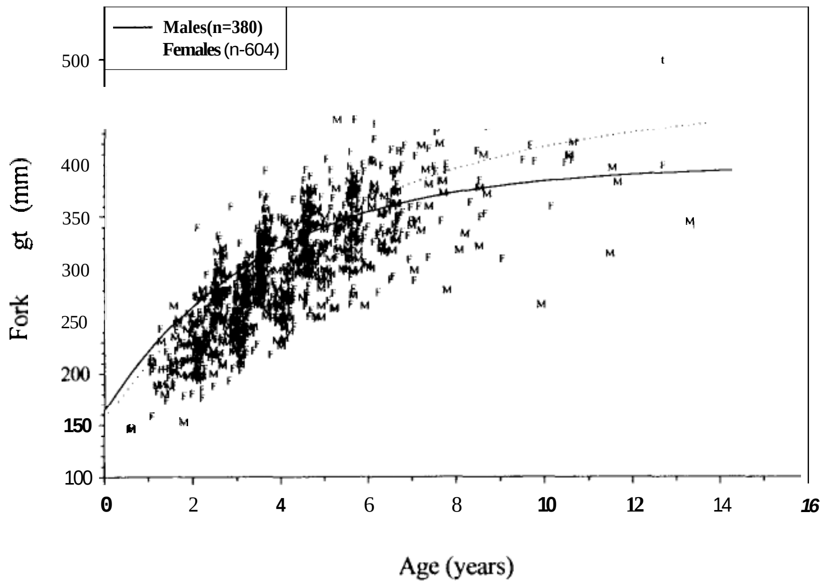

Figure 10-6. Growth curves for male and female sheepshead in Tampa Bay. Males are depicted by the solid line and the symbol M; females are depicted by the dotted line and the symbol F. n indicates the number of fish analysed.

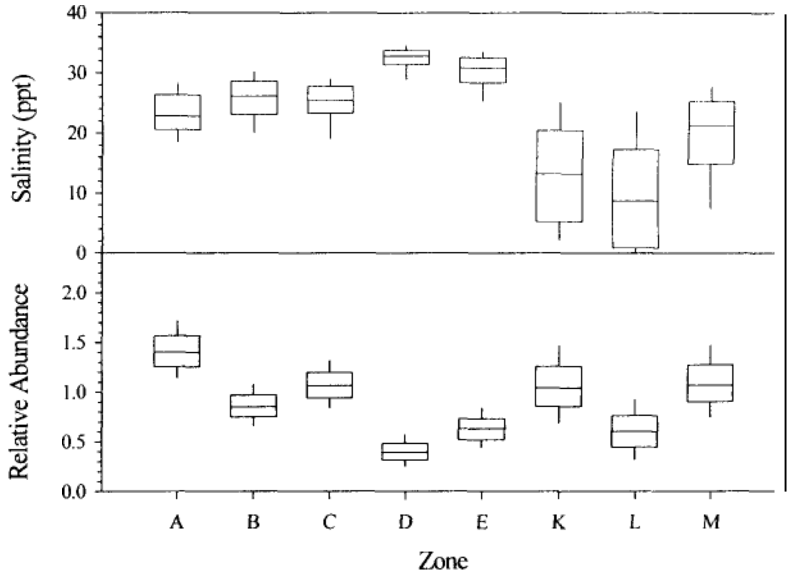

Figure 10-7. Relative abundance (fish per set) of young-of-the-year spotted seatrout (<=100mm standard length) and surface salinities by zone for Tampa Bay. Data are from the stratified-random-sampling surveys (Apr. - Oct.), 21.3-m seine component, 1989-1997. The box represents the 25th-75th percentiles, the vertical line extends from the 10th-90th percentiles, and the horizontal line and filled circle indicate the median value.

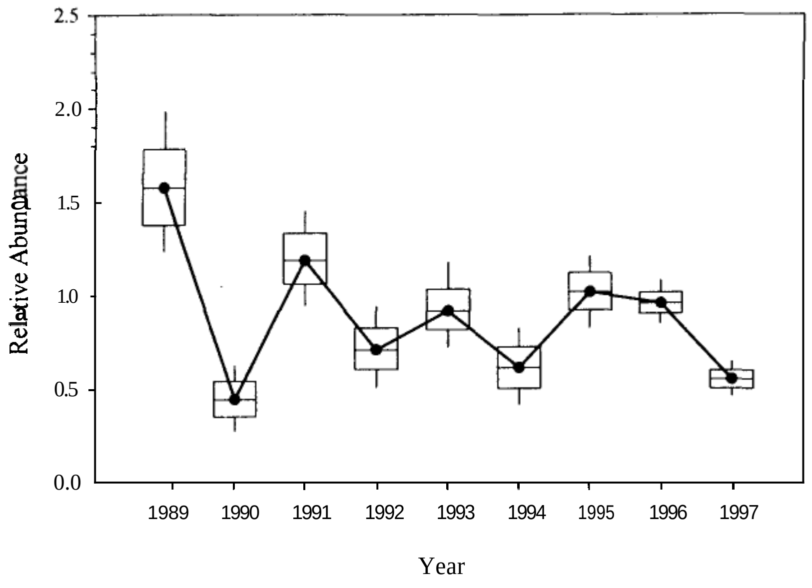

Figure 10-8. Annual indices of the relative abundance (fish per set) of young-of-the-year spotted seatrout (< l00mm standard length) in Tampa Bay. Data are from the stratified-random-sampling surveys (Apr. - Oct.), 2 1.3-m seine component, 1989-1997. The box represents the 25th-75th percentiles, the vertical line extends from the 10th-90th percentiles, and the horizontal line and filled circle indicate the median value.

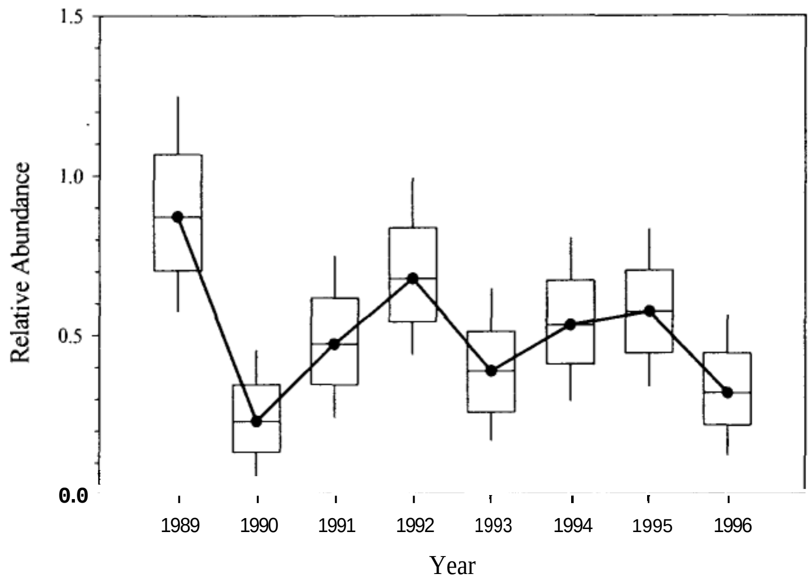

Figure 10-9. Annual indices of the relative abundance (crabs per set) ofjuvenile blue crab (<=65mm carapace width) in Tampa Bay. Data are from the stratified-random-sampling surveys (Sep. - Jun.), 2 1.3-m seine component, 1989-1997. The box represents the 25th-75th percentiles, the vertical line extends from the 10th-90th percentiles, and the horizontal line and tilled circle indicate the median value.

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- CHAPTER HIGHLIGHTS -

- ***Annual manatee deaths have increased 3-fold from the period 1976-1984 to 1985-1997.***
- ***Wintering and summering manatee populations have increased since 1983 (from 60 in 1983 to 190 in 1994 in winter and from 70 to 100 animals in summer).***
- ***Manatees wintering in Tampa Bay can range north as far as the Suwanee River and south to the Everglades.***
- ***Bottlenose dolphin densities are homogenous around the bay's periphery, and slightly higher around the bay's mouth.***
- ***Dolphin population size appeared to be stable over the period 1988-1998.***

INTRODUCTION

The endangered Florida manatee, *Trichechus manatus latirostris,* and the bottlenose dolphin, *Tursiops truncatus,* can be found in Tampa Bay during every month of the year. Other species of dolphins and an occasional whale are sometimes observed in nearby Gulf of Mexico waters and infrequently strand on Gulf beaches, but are not commonly found within the bay. Because of their lack of tolerance to water less than 20°C (68oF), manatees aggregate at the warm-water discharges of power plants and springs during cold fronts. Dolphins have a more protective layer of blubber and can tolerate bay water temperatures during any month.

Studies of manatees and dolphins in Tampa Bay were not extensive before the mid-1980s. Limited aerial surveys conducted in the 1970s and early 1980s identified the bay's power plants as winter refugia for manatees; the maximum count for bay refuges was approximately 60 animals. Photographic-identification ("photo-ID") studies of bottlenose dolphins in Sarasota Bay, Boca Ciega Bay, and lower Tampa Bay identified resident dolphin groups that occasionally interact, but data on use of the entire bay were not available. Therefore, a number of studies were initiated or expanded in the late 1980s to fill gaps in data concerning marine mammals in Tampa Bay.

MANATEE MONITORING PROGRAMS

Aerial Surveys

A statewide synoptic survey of all manatee wintering habitats in Florida and southeast Georgia was coordinated by the Florida Department of Environmental Protection (FDEP, formerly the Department of Natural Resources). It was conducted ten times from 1991 to 1998 (Ackerman, 1995) by numerous biologists from 10 state, federal, county, and private cooperating agencies. The record statewide count was 2,639 manatees made during February 1996, with 1,457 manatees counted on the west coast of Florida, and 138 manatees in Tampa Bay (5.2% of the state total, 9.5% of west coast). The highest synoptic count in Tampa Bay was 164 manatees in January 1997 with 2,229 counted statewide and 1,329 on the west coast (7.4% of state total, 12.3% of west coast; B. Ackerman, FDEP, unpublished data).

Year-round aerial surveys of manatees and dolphins in Tampa Bay's nearshore waters were also conducted to determine their distribution and relative abundance by marine mammal biologists from FDEP and Eckerd College, between November 1987 and June 1997 (Reynolds et al., 1991; Weigle et al., 1991; FDEP, 1998; I.E. Wright et al., in preparation). A total of 121 surveys were conducted from small, high-winged airplanes flying at a height of 150 m and a speed of 130 km/hr. Each survey required two airplanes flying simultaneously, one covering each side of the bay. The flights were designed to maximize manatee counts by concentrating on shallow nearshore waters where manatees and their primary food source, seagrasses, are usually located. Flight paths were parallel to the shoreline, and the airplane circled when manatees or dolphins were spotted until a reliable estimate of the number of animals was obtained. Deeper waters in the middle of the bay were not surveyed. Data collected for each sighting included location, species, number of adults and calves, and behavior. All data were recorded on copies of navigation charts and entered into the FDEP's Marine Resources Geographic Information System (MRGIS) for spatial analysis. All of the aerial survey data and flight paths are available on the FDEP Atlas of Marine Resources CD-ROM (FDEP, 1998) in ArcView and Arc/Info (Environmental Systems Research Institute, Redlands, CA) GIS software format. A technical report summarizing the manatee aerial survey research is in preparation (Ackerman et al., in prep).

Winter distribution of manatees in the bay was centered around the Tampa Electric Company's (TECO) power plant discharge at Apollo Beach and the Florida Power Corporation's (FPC) power plant discharge in St. Petersburg. During periods between the passage of cold fronts, manatees leave the power plants to feed on nearby seagrass meadows. From 1987 to 1997, the number of manatees counted in Tampa Bay during the winter months, December through February, showed a statistically significant increasing trend (Figure 11-1). The mean number of manatees counted during the winter surveys rose from 54 in 1987-88 to 135 in 1996-97. The maximum count of 190 manatees occurred on January 24, 1994. The location showing the largest increase in counts was the discharge area at the TECO plant in Apollo Beach. A winter no-entry zone for watercraft was implemented at the discharge area in 1986. In 1989, the zone was upgraded to a year-round no-entry zone because of the increasing use of the canal by manatees.

In the warm months, March through November, manatees counts also increased, with the mean number of manatees counted rising from 43 in 1987 to 85 in 1997 (Figure 11-2). The highest count from April to October was 120 manatees on October 23, 1996. Apparently, many of the animals that use the bay as a winter refuge migrate to other habitats north and south of Tampa Bay in summer. Manatees that continue to use the bay during warm months disperse to favored habitats throughout the bay. Spatial analysis of the aerial survey data revealed that areas showing medium to high use by manatees included McKay Bay, Apollo Beach near the TECO power plant, Simmons Park in Ruskin, the mouth of the Little Manatee River, Terra Ceia Bay and the adjoining lower Manatee River, Braden River, Anna Maria Sound, Weedon Island, Safety Harbor, Rocky Point, and Culbreath Bayou (Figure 11-3).

West Coast Telemetry

Staff of the FDEP have used satellite and VHF radio-transmitters on manatees in Tampa Bay since February 1991 to determine habitat utilization patterns, to delineate migratory routes and short-term movements, and to accumulate observational and life-history data on individual manatees. The telemetry project ended in February 1997. The tagging process involved capturing manatees (usually at a power plant in winter), fastening a belt around the narrow part of the tail stock, and attaching a floating transmitter housing to the belt with a 1.2-meter semi-rigid nylon tether. The capture and tagging were conducted under authority granted by U.S. Fish and Wildlife Service (USFWS) Permit Number PRT-773494. When each animal was tagged, body measurements were taken and scar-patterns were recorded for future recognition. The signal from the satellite transmitter was received by NOAA's TIROS weather satellites, and processed by the Service Argos (Largo. MD) receiver, giving a set of location coordinates and the date and time of the location, water temperature, and animal activity. Data were delivered daily via Internet or downloaded by FDEP staff in St. Petersburg immediately after a satellite pass. Research teams in the field used the most recent satellite locations to determine general areas where manatees were located; they then used the VHF radio signals from the tag to locate tagged manatees. The research crew observed the manatee and recorded its behavior and movements or performed necessary maintenance by switching out the tag housing.

By following the movements of individual manatees in freshwater, brackish water, and saltwater habitats, valuable information was obtained about manatee behavior and habitat

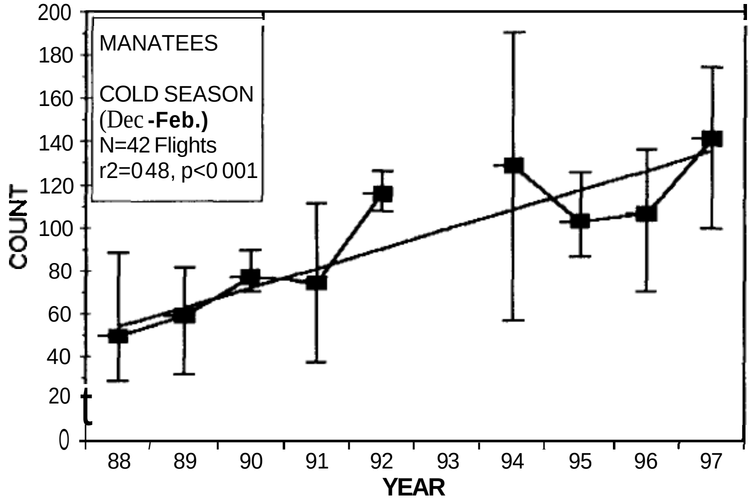

Figure 11-1. Manatee counts from 42 aerial surveys conducted in the cold season (December to February). The study was conducted year-round from November 1987 to June 1997. Data shown include the yearly high, low, and mean (■) counts by year and a linear regression analysis that denotes a trend of increasing counts in cold seasons.

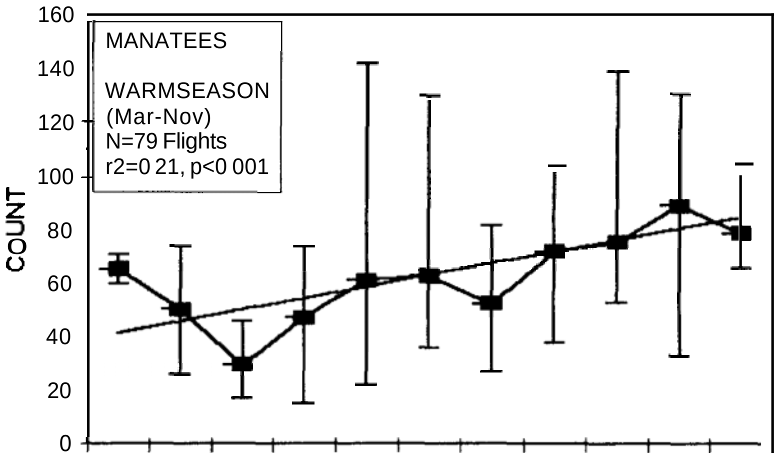

Figure 11-2. Manatee counts from 79 aerial surveys conducted in the warm season (March to November). The study was conducted year-round from November 1987 to June 1997. Data shown include the high, low, and mean (■) counts by year and a linear regression analysis that denotes a trend of increasing counts in warm seasons.

preference. Fifty-nine manatees were tagged during the project, including 35 females and 24 males. Forty-four animals were free-ranging and 15 were tagged upon release from rehabilitation facilities. Forty-seven of the manatees were tagged and released in Tampa Bay, seven in southwest Florida, four in the Everglades, and one in Citrus County. Manatees tagged in Tampa Bay ranged as far south as the Ten Thousand Islands in Everglades National Park, or north past the Suwannee River before returning to Tampa Bay in the winter.

Areas of high manatee use, individual activity patterns, and habitat preferences within Tampa Bay and other locations along the West Coast were documented. The Arc/lnfo GIS was used to analyze movement patterns of individual animals. Immature manatees and adult females with calves generally confined their activities to well-defined ranges in particular areas. In contrast, adult males, and females without calves, traveled extensively within and outside of the Tampa Bay area. Males tend to travel circuits, probably to locate females in estrus. More complex analyses are being conducted to determine travel corridors and estimate time spent in specific habitats. A technical report on the manatee telemetry research will be completed in 1999 (Weigle et al., in prep).

Figure 11-3. Spatial distribution of manatee counts from 79 aerial surveys conducted in the warm season (March to November). The study was conducted year-round from November 1987 to June 1997. Deep-water areas in the middle of the bay were not surveyed.

Beginning in 1993, each animal captured during the telemetry project was implanted with a pair of subcutaneous, passive integrated transponders (or PIT tags; Wright et al., 1998) that provide long-term marking of individuals for identification purposes. The tags proved to be very beneficial in identifying dead manatees that were badly decomposed when recovered. The tags will continue to be implanted in rehabilitated and free-ranging manatees.

Other projects have also benefited from the field activities of the telemetry study. When manatees are captured for tagging, FDEP staff collect blood and tissue samples from healthy, wild individuals. Ultrasound measurements of blubber thickness are collected during captures for comparison with measurements from dead and injured animals, to establish a technique to evaluate animal condition.

During tracking and at aggregations, scarred manatees from Tampa Bay to the Everglades were photographed for inclusion in the statewide Manatee Individual Photoidentification System (MIPS) coordinated by the U.S. Geological Survey's (USGS) Sirenia Project and FDEP. The computerized system is a catalog of photos of distinctively scarred manatees, which allows researchers to track the movements and life events of individuals over time, as well as examine survival and calving rates. Photographs of all manatee carcasses brought to the FDEP Marine Mammal Pathobiology Laboratory are compared to those in the catalog.

Table 11-1. Causes and numbers of manatee deaths reported in the Tampa Bay area from 1985 to 1997. Data from the Florida Department of Environmental Protection, Endangered and Threatened Species Program.

CAUSE OF DEATH	YEAR DEATH REPORTED													TOTAL
	85	86	87	88	89	90	91	92	93	94	95	96	97	
Watercraft	3	2	0	1	3	1	3	4	0	5	5	4	4	35
Gate/Lock	0	2	0	0	0	0	0	0	0	0	0	0	0	2
Other Human	0	0	0	1	1	0	0	0	0	0	0	0	0	2
Perinatal	2	2	4	4	3	5	8	3	1	2	4	6	5	49
Other Natural	1	0	1	1	2	3	1	1	5	5	3	6	3	32
Undetermined	2	3	0	0	0	5	2	1	2	4	6	5	7	37
TOTAL	8	9	5	7	9	14	14	9	8	16	18	21	19	157

Mortality

In 1974, scientists at the USGS Sirenia Project (at that time under the USFWS) in Gainesville and Dr. Daniel Odell at the University of Miami established a carcass recovery and necropsy program to determine causes of manatee deaths reported in the southeast U.S (Ackerman et al., 1995; Wright et al., 1995). The FDEP assumed responsibility for the program within Florida in 1985, initially using FDEP staff, manatee scientists (under contract with the FDEP) at the University of Miami, and veterinarians at Sea World of Florida to conduct necropsies. Field staff were gradually hired by the FDEP to replace the contracted services, and a pathobiologist was hired by the FDEP in 1989 to oversee the necropsy and rescue program. The

FDEP Marine Mammal Pathobiology Laboratory (MMPL) was built in 1993 at Eckerd College in St. Petersburg with funds from a USFWS Endangered Species Grant. There are four other FDEP field stations, in Jacksonville, Melbourne, and Tequesta on the east coast, and Port Charlotte on the west coast. FDEP field staff use refrigerated trailers to transport manatee carcasses to the MMPL. Staff of FDEP also coordinate manatee rescues statewide.

From 1985 through 1997, 157 manatee deaths were verified in Hillsborough, Manatee, and Pinellas counties (Table 11-1), a mean of 12.1 animals per year (SD=5.2, n=13 years). Deaths are classified into seven categories (Ackerman et al., 1995; Wright et al., 1995). Collisions with watercraft caused 35 deaths, 22% of the total. During the previous nine-year period between 1976 and 1984,33 deaths were confirmed in the Tampa Bay area, an average of 3.7 manatees per year (SD=1.5, n=9); five deaths (15%) were caused by watercraft. Significantly more manatee carcasses were recovered between 1985 and 1997 than between 1976 and 1984 (t-test, $p<0.001$). Watercraft-related deaths increased from a mean of 0.6 to 2.7 per year.

"Perinatal" deaths were natural causes of death to newborn manatees, less than 1.5 m long and still dependent on their mothers. These constituted the largest class of manatee deaths (31% of the total) in Tampa Bay. Nearly half of the perinatal mortalities were determined to be from specific natural causes (predominantly bacterial infections); the remaining animals were too decomposed to determine a specific cause of death. Stress factors, such as boat strikes or near misses, early separation from or abandonment by mothers due to human disturbances, and mortality of mothers with calves may contribute to some of the perinatal deaths.

The category of "Other Natural" causes of death (20% of all deaths) includes animals that died as a result of natural phenomena such as disease, infections, cold-related stress, and red-tide toxicity. The "Undetermined" category (24%) includes juveniles and adults that are generally too decomposed for a specific cause of death to be determined. Data about each carcass, the cause of death, and where it was found are available on CD-ROM in ArcView GIS format (FDEP, 1998).

Rescue and Rehabilitation

Staff at the FDEP MMPL are responsible for coordinating the rescue of injured manatees statewide, in cooperation with the USFWS Manatee Coordinator in Jacksonville. A manatee-rescue boat was designed by MMPL staff to deploy a net 120 m long and 9 m deep, so that injured animals can be captured in most situations encountered. Injured manatees rescued in Tampa Bay are usually transported to either of two manatee rehabilitation facilities: Sea World of Florida in Orlando or the Lowry Park Zoo in Tampa. Sea World has participated in manatee rehabilitation since the 1970s. The Lowry Park manatee hospital was completed and began taking injured animals in mid-1991.

The goal of the rescue and rehabilitation process is to treat manatees and then release them back into the wild population. Since 1991, FDEP has tagged and monitored 21 rehabilitated manatees on the west coast of Florida, including 11 rescue-release, six orphans, and four captive-born manatees. Two manatees were released in Pinellas and Hillsborough counties. Other west coast releases were in Citrus, Sarasota, Charlotte, Lee, Collier, and Monroe counties. A captive-born manatee, "Valentine," was recently deemed to have successfully adapted to the wild after being monitored in the Everglades area for 2.5 years, and his tagging assembly was removed in March 1998.

BOTTLENOSE DOLPHIN MONITORING PROGRAMS

Aerial Surveys

From November 1987 to June 1997, bottlenose dolphin abundance and distribution in Tampa Bay were monitored by Eckerd College and FDEP staff (Weigle et al., 1991; unpublished data). They conducted 121 aerial surveys of the bay using the same methodology for manatee aerial surveys, and observed dolphins in virtually every part of the bay. Counts were highly variable, ranging from a low of 11 to a maximum of 232 per survey. The mean number of dolphins per survey also varied between years, ranging from 58 to 102 dolphins, and there was no significant linear trend in the counts over the study period. There was also no significant difference in dolphin counts between winter

(December-February) and non-winter time periods.

The spatial distribution of dolphin density was generally homogenous along the survey route which covered nearshore waters. The areas of highest dolphin densities were found around the mouth of the bay near Mullet Key, Egmont Key, and northern Anna Maria Island.

Photo-Identification

Dolphin Biology Research Institute (DBRI)/Chicago Zoological Society

Dr. Randall Wells and his colleagues conducted low-level monitoring of bottlenose dolphins in Tampa Bay between 1988 and 1993 (Wells et al., 1996; Urian et al., 1997). Funded by the National Marine Fisheries Service, the project was designed to detect large-scale interannual changes in the abundance and production of dolphin stocks in Tampa Bay and to establish a historical database for determining trends in dolphin populations in the Tampa Bay area.

During a six-week period from early September through October of each year, research staff conducted dolphin photo-ID surveys from small boats to estimate a variety of population-rate parameters. Staff used photo-IDs of distinct characteristics of the dolphin's dorsal fin, along with body scars and coloration patterns, to catalog distribution and behavioral patterns of individual animals. When surveys are conducted over an extended study period, resightings of recognizable individuals provide data to estimate population size based on mark-recapture analyses and to monitor birth rates, mortality, immigration, emigration, and transience.

A catalog of 858 different dolphins was developed for Tampa Bay during the project, building on a catalog of 150 individuals first identified in the area during 1975-1987. Identifiable dolphins constituted a high proportion (62% to 82% annually) of all dolphins sighted. The yearly proportion of first-time identifications declined steadily from 74% in 1988 to 14% in 1993, suggesting a relatively closed population of dolphins in Tampa Bay.

Staff used three methods to estimate unmarked animals and the total population: 1) estimation based on the marked (recognizable) proportion of the total group size for each sighting, 2) estimation based on the resightings of marked animals during surveys, and 3) estimation based on the resighting rate of marked animals. All three methods produced similar mean population estimates for the study: 524 using mark-proportions, 569 using mark-resight, and 516 using resighting-rate methods.

Linear regression analyses of the abundance estimates indicated that there were no significant changes in dolphin abundance during the surveys because the slopes of the regression lines for estimated population vs. year were not significantly different from zero. The birth rate also showed little variation, ranging from 2.8% to 4.0%. Mortality was difficult to measure because of the changes in coverage by stranding network participants, as discussed below.

By combining annual mean maximum rates for immigration (5.5%), emigration (2.3%), and transience (4.5%), the annual proportion of the dolphin population that experienced a change in range (or habitat use) was estimated at 12.3%. These data also suggest that a relatively closed population of dolphins use Tampa Bay.

The estimates of the dolphin population in the bay are considerably higher than the mean and maximum counts made during aerial surveys conducted during the same time period (Weigle et al., 1991). Previous studies have concluded that due to water turbidity and the similar coloration between the water and dolphins, aerial surveys tend to substantially underestimate the numbers of dolphins. Also, aerial surveys were not conducted in the deeper portions of Tampa Bay because the route was planned to cover only shallow-water habitats, which are favored by manatees. Observers in boats also have other methods for locating dolphins that the aerial surveyors could not use, such as noting behavior of birds over dolphin groups and being able to spend more time searching an area.

Several recommendations were made in the final report. Monitoring on at least an annual basis should be continued; more frequent surveys could allow researchers to detect patterns in seasonal fluctuations and better determine population parameter changes.

Dolphin community structure is being examined by Chicago Zoological Society staff (K. Urian, Urian et al., 1997) to define meaningful geographic units for managing the dolphin populations. Photo-ID efforts have been expanded up to eight km offshore from Mullet Key southward to Stump Pass; more than 600 dolphin sightings collected during July 1997-August 1998 are currently undergoing analysis (K. Brockway). Comparisons with other photo-ID projects north (as far as Cedar Key, Ester Quintana, University of Florida) and south along the central west coast of Florida have resulted in no evidence of large-scale exchange with Tampa Bay. GIS is being used to integrate habitat data with dolphin sightings. Collection of genetics data along with telemetry data on an individual's movements would assist in determining dolphin community structure. A manual of dolphin photo-ID research techniques has been developed and adopted by researchers at a variety of study sites in order to standardize methodology (Urian and Wells, 1996).

Eckerd College

Dr. John Reynolds and undergraduate students at Eckerd College began an intensive study to understand biology and habitat use of bottlenose dolphins in Boca Ciega Bay and adjacent areas of Tampa Bay and the Gulf of Mexico in 1993. The work involves identification of individual dolphins using photo-ID techniques and is conducted under a letter of General Authorization issued by the National Marine Fisheries Service to Reynolds. Working in cooperation with Dr. Beth A. Forys (Biology and Environmental Studies Departments, Eckerd College -- Geographic Information Systems), Dr. J. Dean Stewman and Dr. Kelly Debure (both Computer Science Department, Eckerd College -- Computer Vision), and Dr. Edmund L. Gallizzi (Computer Science Department, Eckerd College -- Videography), a number of databases or analytical tools have been developed, including the following: 1) a catalog containing 548 distinctively marked individual dolphins; 2) a CIS-compatible (Arc/Info and ArcView) database which includes locations of dolphin sightings, environmental factors (tides, bathymetry, seagrasses, weather, and water conditions); dolphin behaviors and other parameters, to permit determination of high-use habitats for local dolphins; 3) presence or absence of calves or young of the year; 4) software (called DARWIN) designed to facilitate and automate the process of matching dolphin dorsal fins; and 5) field use of laptop computers, GIS, and Global Positioning Systems to automate data collection and to make recorded data more accurate and easier to analyze and map. Many of the innovations or refinements are described by Forys et al. (1998).

The Eckerd College Dolphin Project interacts with Dr. Randy Wells and his colleagues at the Dolphin Biology Research Institute/Mote Marine Laboratory, and with scientists at the Clearwater Marine Aquarium. In the Eckerd College study area, 350 of the dolphins in the catalog were recorded by Eckerd College personnel; the other 198 were recorded by Wells and his colleagues during their periodic surveys of Tampa Bay waters or by Brad Weigle (1990) at the University of South Florida in the early 1980s. Some of the animals originally sighted by Weigle are still observed by Eckerd College personnel.

The Eckerd College Dolphin Project has resulted in several senior theses and professional presentations; topics have included 1) GIS studies of dolphin habitat use; 2) changes in dolphin habitat use and in production of calves following the commercial net ban enacted in July 1995; 3) home-ranging patterns; 4) association patterns among individual dolphins; and 5) development and application of the DARWIN computer matching program. All of these efforts continue. In addition, Reynolds and his students and colleagues received grants from the National Marine Fisheries Service to compare results of concurrent aerial and boat surveys of dolphins to determine the probability of sighting a group of dolphins along a survey track ("g(O)"), and from the Disney Conservation Fund to examine ambient noise levels in Boca Ciega Bay and possible effects of anthropogenic noise on dolphin behaviors and habitat use.

A second marine mammal research program at Eckerd College collaborates with the FDEP's Marine Mammal Pathobiology Laboratory. Dr. Reynolds and Dr. Sentiel Rommel (FDEP) and Eckerd College graduate Meghan Bolen (FDEP) are studying manatee anatomy and life history. Rommel and Reynolds published an extensive description of the manatee gastrointestinal tract and have submitted a paper on the manatee diaphragm and buoyancy control. Bolen's senior thesis from Eckerd College serves as the basis for another manuscript on ages of manatees that died in the 1996 manatee red tide epizootic. In 1998-2000, Rommel, Reynolds, Bolen, and Dr. James Powell (FDEP) plan to investigate manatee reproductive biology and life history, as well as the lymphatic organs and tissues in manatees; such research will permit better understanding of changes in manatee life history attributes and health status.

A third program involving marine mammals at Eckerd College is headed by Dr. W. Guy Bradley (Biology Department, Eckerd College). Working in collaboration with Reynolds and Dr. William B. Roess (Emeritus, Biology Department, Eckerd College), Bradley and several undergraduate students have worked to isolate, clone, sequence, and express interleukin-2 and other cytokines of a number of species of marine mammals, including Florida manatees, bottlenose dolphins, killer whales *(Orcinus orca)*, and polar bears *(Ursus maritimus)*. The work is reviewed by Bradley and Reynolds (in press). Plans in the future include work with other interleukins or with interleukin-2 in other species, as well as a new project (in collaboration with Drs. Carl Luer and Cathy Walsh of Mote Marine Laboratory) to better understand manatee immunology. This research will involve the development of an assay for interleukin-2 in the manatee; this will be extremely useful in assessments of manatee immunocompetence and overall health status in the bay and elsewhere.

Mortality

Reports of cetacean strandings in Florida are managed by Dr. Daniel K. Odell and Dr. Nelio B. Barros, co-scientific coordinators for the southeastern U.S. Marine Mammal Stranding Network. The primary participants in the Tampa Bay portion of the Network are volunteers from four marine research organizations who are issued Network permits by the National Marine Fisheries Service to retrieve dolphin and whale carcasses and perform necropsies to determine cause of death and obtain tissue samples for other research projects. The Clearwater Marine Aquarium, Mote Marine Laboratory, the FDEP Marine Mammal Pathobiology Laboratory, and the Tampa Bay Marine Animal Stranding Team respond to most of the reported strandings. Other permitted individuals assist in the Tampa Bay area on an "as-needed" basis.

From 1985 through 1997, 433 dead bottlenose dolphins were recovered along the shorelines of Pinellas, Hillsborough, and Manatee counties (Table 11-2). These data represent the minimum number of strandings in these counties, since all carcasses are probably not reported to the authorities. Although the coverage of Tampa Bay strandings by volunteers has varied considerably over the years, a major increase in reported strandings occurred in 1986. This increase in the number of strandings most likely reflects the increase in coverage and not an actual increase in stranding frequency.

Rescue and Rehabilitation

Mote Marine Laboratory

Mote Marine Laboratory's (MML) Marine Mammal Stranding Program has successfully rehabilitated and released four bottlenose dolphins and two roughtoothed dolphins since 1992. One adult male bottlenose dolphin, "Freeway," was known from the DBRI photo-ID catalog as a long-term Tampa Bay resident. He was treated for 107 days and released back into his home range, where he was tracked and/or resighted for at least six months following release. In 1994, MML expanded its program,

Table 11-2. Bottlenose dolphin deaths reported in the Tampa Bay area, 1985-1997. Data provided by Daniel K. Odell, Nelio B. Barros, and Steven Clark, southeastern U.S. Marine Mammal Stranding Network.

COUNTY OF STRANDING	YEAR DEATH REPORTED													TOTAL
	85	86	87	88	89	90	91	92	93	94	95	96	97	
Hillsborough	1	1	3	3	2	10	6	10	8	3	1	6	2	56
Manatee	2	8	4	9	6	7	15	10	9	6	4	12	2	94
Pinellas	6	15	8	17	17	15	33	35	24	33	19	36	25	283
TOTAL	9	24	15	29	25	32	54	55	41	42	24	54	29	433

opening a state-of-the-art whale and dolphin hospital in Sarasota, and has accepted animal patients from as far away as North Carolina.

Clearwater Marine Aquarium

The Clearwater Marine Aquarium (CMA) has been a member of the Southeast United States (SEUS) Stranding Network since 1979. It is authorized by the National Marine Fisheries Service (NMFS) to respond to marine mammal stranding events. CMA's Marine Animal Stranding Response Team is on call around the clock. The team consists of biologists, animal handlers, veterinarians, and trained volunteers. The team has responded to more than 300 marine mammal stranding events since 1979 (150 since 1993), which include many species of cetaceans: bottlenose dolphin, short-snouted spinner dolphin *(Stenella clymene)*, striped dolphin *(Stenella coeruleoalba)*, rough-tooth dolphin *(Steno bredanensis)*, dwarf sperm whale *(Kogia simus)*, pygmy sperm whale *(Kogia breviceps)*, beaked whale *(Mesoplodon europaeus)*, Risso's dolphin *(Grampus griseus)*, Fraser's dolphin *(Lagenodelphis hosei)*, and Bryde's whale *(Balaenoptera edeni)*. Most of the animals CMA responded to were dead when discovered or reported. Information and specimens were then collected and provided to other scientists for ongoing research.

When cetaceans do strand alive, the chances of rehabilitation are slim. Since 1993, CMA has successfully rehabilitated and released four bottlenose dolphins, two of which were monitored after release using satellite-linked transmitters. To effectively monitor rehabilitated cetaceans, CMA makes every effort to fit the animals with a tracking device (such as a satellite transmitter) so their post-release movements can be recorded. CMA studies the effectiveness of rehabilitation techniques and the animal's life history, ecology, and home range, by monitoring where they travel after release and using information about the animals' health while under care.

Most live bottlenose dolphins that become stranded are in advanced stages of disease, and very few survive. Of the six live-stranded bottlenose dolphins handled by CMA from 1987 to 1993, only one was released back into the wild. From 1993 through 1998, CMA encountered 11 live-stranded bottlenose dolphins, and six were released back into the wild. In 1996, three bottlenose dolphins stranded alive. Two were trapped by low tide in Tampa Bay in St. Petersburg. Blood samples were analyzed for both animals to confirm their health and they were returned to deep water where they resumed normal swimming behavior. The third dolphin, "Rudy", stranded in December 1996 in Panacea, Florida. He was successfully rehabilitated and released in March 1997 with a satellite transmitter, 40 km off Clearwater. Post-release movements were monitored, but few transmissions were received. The last reported location was off Cape Hatteras, North Carolina, 42 days after release. In 1997, three bottlenose dolphins stranded alive. Two, a mother/calf pair, stranded in Belleair Beach in October 1997, and were successfully rehabilitated and released. The mother dolphin was fitted with a satellite transmitter. They were released together 2 km off of Clearwater, Florida in April 1998. Tracking data were received for a total of 152 days. In early 1998, CMA monitored a bottlenose dolphin which was trapped in a brackish lagoon in Pinellas County. Two attempts failed to persuade the dolphin to leave the lagoon and go out to Boca Ciega Bay via the Cross Bayou Canal. The dolphin was previously cataloged by CMA, Eckerd College, and Mote Marine Laboratory.

The success of CMA's rehabilitation program is due to the many volunteers, staff, veterinarians (Bill Goldston and Robin Moore), scientists, and supporters who provided their time, hard work, expertise, and funding. Special thanks go to scientists from Mote Marine Laboratory, Sea World of Florida, the FDEP, and the National Marine Fisheries Services for providing expertise, support, and guidance.

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A. Schnapf (National Audubon Society)

- CHAPTER HIGHLIGHTS -

- ***The Tampa Bay region is home to some 28 species of colonial waterbirds totaling nearly 200,000 individuals, arguably the largest population in the state.***
- ***The breeding population totals 35,000-45,000 pairs annually at 20 or more sites. Up to half the total occurs in Hillsborough Bay alone.***
- ***Most rare or coastal species have stable or increasing populations, while many of those that forage commonly or primarily in freshwater wetlands are decreasing.***
- ***Raccoons greatly affect the size and stability of nesting colonies.***

Introduction

The Tampa Bay system is home to some 28 species of colonial waterbirds and allies, totaling about 44,000 breeding pairs and their young, or nearly 200,000 birds (Table 12-1). This population is arguably the largest and most diverse in Florida, given the decline of wading bird numbers in the Everglades in recent decades. Maintaining present diversity and overall numbers in a growing metropolitan area of over 2.2 million people is a major challenge that will require the best efforts of both the public and private sectors.

Pelicans and other species that nest in groups (called "colonies") are among the most visible, beautiful, and popular wildlife species in Florida. Because of their large size and colonial habits, they are also fairly easily censused. Their populations are therefore widely regarded as useful indicators of the health of coastal and wetland ecosystems. The National Audubon Society (NAS) annually attempts to find and census all known coastal colonies in Tampa Bay. Results from 1994-1998 are reported here.

During the five-year period, total numbers ranged from 34,000 to 46,000 breeding pairs (Table 12-1). Two species, White Ibis and Laughing Gull, accounted for half to two-thirds of all individuals. Year-to-year fluctuation was probably due in most cases to rainfall patterns and wetland productivity. Longer-term changes, however, were likely a response to urbanization and loss of breeding or foraging habitats, especially wetlands. A few uncommon species (Reddish Egret, Roseate Spoonbill, American Oystercatcher, Caspian, Royal and Sandwich Terns) have experienced sustained population increase.

Twenty-four active or recently active sites were censused (Figure 12-1, Table 12-2). Nineteen were islands, while five were on causeways along shorelines or on undeveloped lots. Seven colonies including all five causeway sites were abandoned during our study (Table 12-3). Two sites were lost to residential development, one to chronic human disturbance, and three to raccoon predation. The seventh site, Howard Frankland Causeway, was abandoned due to habitat manipulations intended to decrease risk to drivers and birds alike.

Isolation from mammalian predators, particularly raccoons, is a major determinant of colony site selection. In Tampa Bay, most colonies (and all large, persistent ones) are located on islands. But no island is completely inaccessible. During this study, raccoons reached at least eight colonies. Population numbers at each of these sites declined while predators remained. Raccoons were live-trapped and removed wherever possible, but at the end of 1998 they were still present at least at three sites (Table 12-3).

Breeding populations of several species of wading birds, particularly White Ibis, experienced dramatic increase in 1998 due to extremely unusually advantageous foraging conditions provided by the El Nino/Southern Oscillation (ENSO) event of 1997-98. Unseasonal winter rains were followed by extreme drought conditions from late March through June, causing rapid wetland drydown and concentration of prey organisms.

Species Population Status

Brown Pelican - 1,600-2,000 breeding pairs annually since 1994, with one major colony (Tarpon Key) affected by raccoons. About 20% of the state breeding population occurs in Tampa

Table 12-1. Breeding birds of the Tampa Bay System, 1994-1998: Annual population estimates (breeding pairs).

Species	Listed Species	1994	1995	1996	1997	1998
Brown Pelican	SSC	1,648	2,065	1,650	1,121	1,664
Double-crested Cormorant		648	645	543	457	459
Anhinga		210	272	333	223	276
Great Blue Heron		278	312	333	284	314
Great Egret		532	687	786	506	875
Snowy Egret	SSC	807	1,060	883	709	844
Little Blue Heron	SSC	305	302	253	308	273
Tricolored Heron	SSC	681	596	697	420	744
Reddish Egret	SSC	71	76	67	62	57
Cattle Egret		5,800	4,841	4,337	6,647	2,382
Green Heron*		+	+	+	+	+
Black-crowned Night-Heron		79	199	266	113	265
Yellow-crowned Night-Heron		190	174	183	102	91
White Ibis	SSC	7,300	10,795	9,301	6,241	17,232
Glossy Ibis		405	507	740	328	546
Reseate Spoonbill	SSC	109	148	111	139	186
Wood Stork	E	64*	36	103	74	53
Snowy Plover**	T	0	1	0	1	1
Wilson's Plover**		+	+	0	4	**30**
American Oystercatcher**	SSC	67	76	77	94	88
Willet**		11	11	31	3	16
Laughing Gull		15,020	19,300	10,500	11,500	13,000
Gull-billed Tern		2	2	0	0	1
Caspian Tern		80	91	93	67	**75**
Royal Tern		2,170	2,694	2,255	3,250	2,977
Sandwich Tern		270	444	445	528	539
Least Tern	T	170	45	85	107	150
Black Skimmer	SSC	600	580	685	756	767
Totals		37,518	45,960	34,757	34,044	43,905

* = 64 nests active at Dot-Dash on April 1, abandoned on May 12.

** = Species not colonial. Pairs nesting elsewhere are not included in estimates.

\+ = Present but not censused.

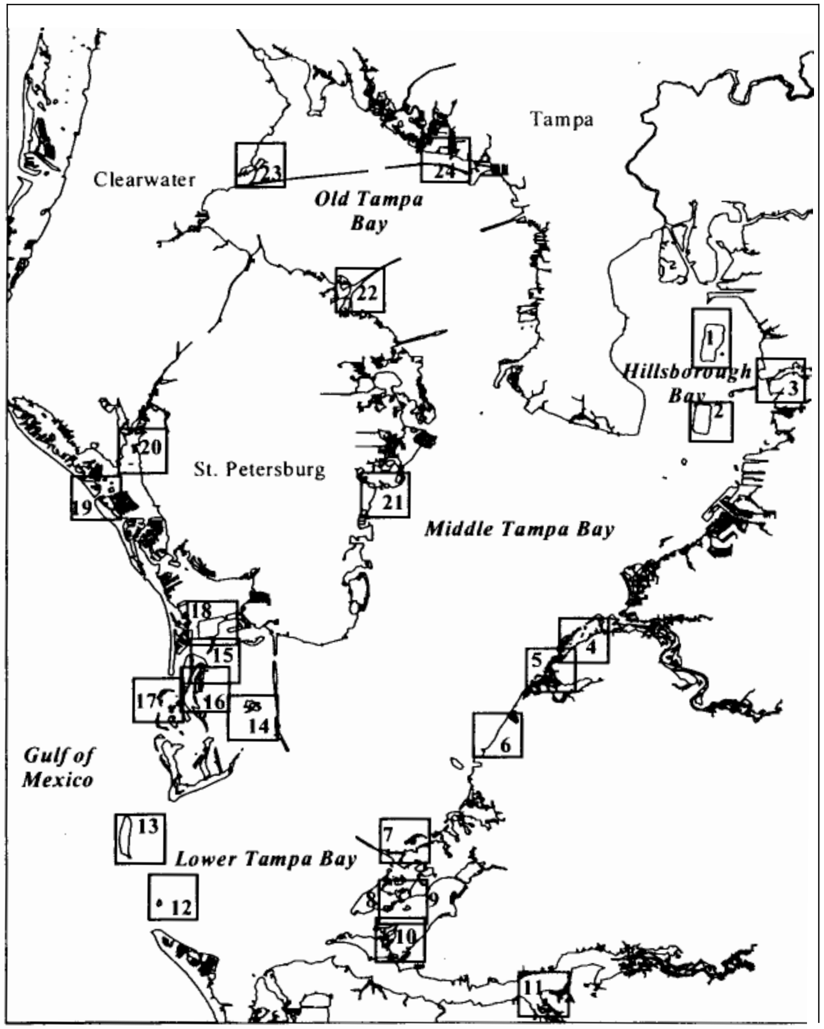

Figure 12-1. Bird colonies of Tampa Bay. Colonies identified by numbers designated in Table 12-2.

Bay, with numbers increasing slowly after a sharp decline in 1990-1994.

Double-crested Cormorant - Data suggest possible decline from 650 to 450 pairs during the period, but this species has a very long nesting season and early pairs may be under-represented.

Anhinga - About 200-300 pairs breed at three colonies in Tampa Bay, with the largest numbers at Alligator Lake. Numbers have declined recently at Washburn Sanctuary and Tarpon Key, perhaps due to raccoon predation. Primarily a freshwater nester, with only small numbers on the coast.

Great Blue Heron - Population appears stable with annual estimates ca. 300 pairs. Actual population is somewhat higher, since peak nesting effort precedes censuses at most colonies.

Great Egret - Stable in recent years with about 500-800 pairs annually. Increased to 875 pairs in 1998 (and increase sharply in Clearwater and Sarasota colonies as well), undoubtedly due to ENSO. Numbers subsided again in 1999.

Snowy Egret - About 800-1,000 pairs annually. Population appears stable for now, but this species has declined significantly since the early 1980s in Tampa Bay, and probably statewide.

Little Blue Heron - The Tampa Bay nesting population appears stable at about 300 pairs. This species nests and forages primarily in

Table 12-2. Coastal bird colonies of the Tampa Bay System, 1994-1998: Species diversity and population size.

Colonies	Number of Species					Breeding Pairs				
	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998
1. Spoil Island 2D	3	2	3	1	1	6,180	526	544	35	35
2. Spoil Island 3D	5	7	7	6	7	124	5,301	4,144	5,018	7,160
3. Alafia Bank	21	21	17	17	17	10,499	13,801	11,075	7,596	18,122
4. Cockroach Bay ELAPP	7	9	nd	8	8	120	144	nd	150	102
5. Hole in the Wall	nd	1	nd	1	nd	nd	15	nd	9	nd
6. Piney Point	12	12	12	11	12	3,865	3,274	3,320	3,715	2,990
7. Skyway Sandbar	nd	0	nd	3	0	nd	0	nd	17	0
8. Miguel Bay	nd	1	nd	2	1	nd	11	nd	3	10
9. Washburn Sanctuary	16	16	16	16	16	3,434	1,993	2,155	892	2,061
10. Washburn Jr	0	0	0	8	0	0	0	0	40	0
11. Dot-Dash	4	9	8	12	8	97	1,158	831	2,890	349
12. Passage Key NWR	8	8	8	10	9	8,682	8,698	6,447	9,003	8,325
13. Egmont Key SP/NWR	nd	2	0	3	2	nd	162	0	142	49
14. Tarpon Key	15	16	15	16	16	2,234	1,720	1,643	1,129	886
15. Little Bird Key	1	nd	4	6	7	3	nd	11	17	78
16. Tierra Verde	-	-	1	0	0	-	-	75	0	0
17. Shell Key	6	7	5	7	7	1,192	7,775	3,194	2,293	2,401
18. Isla	1	0	0	0	0	100	0	0	0	0
19. John's Pass	2	7	2	2	3	46	258	10	19	58
20. Dogleg Key	6	7	12	10	9	75	126	327	395	424
21. Coffeepot Bayou	10	10	10	10	11	64	184	142	239	315
22. Howard Frankland	1	0	0	0	0	90	0	0	0	0
23. Alligator Lake	9	11	9	11	9	458	498	781	447	553
24. Courtney Campbell	6	8	4	0	1	172	319	53	0	5

nd = No data/no survey.
– = Site not previously active.

freshwater habitats, and is vulnerable to continuing alteration of wetlands.

Tricolored Heron - About 500-700 pairs annually. Currently stable, but like the Snowy Egret and Little Blue Heron, this species has declined significantly in the last 20 years.

Reddish Egret - Hunted for their nuptial plumes and extirpated from Tampa Bay by 1900, this species was found nesting here again in 1974. Since then numbers have increased to 60-75 pairs locally, about 15-20% of the state population.

Cattle Egret - The most abundant heron in Florida, with about 5,000 pairs nesting in Tampa Bay colonies. The low number (2,400 pairs) in 1998 was thought due to impact of drought on insect prey (ENSO). This species nests later than other species, and may be underestimated.

Green Heron - Not a colonial nester, so not censused during annual surveys. A few nests found annually. No trend available.

Black-crowned Night-Heron - About 200-250 pairs estimated in Tampa Bay, but this species is very difficult to census and trends are difficult to document. Black-crowns are believed to be declining in Florida and in the Tampa Bay area over the past 20 years.

Yellow-crowned Night-Heron - Another species that defies census efforts, Yellow-crowns often nest in small mainland colonies that are not detected. The estimates presented here (90-190 pairs) do no reflect true numbers, and the true population trend is not known.

White Ibis - About 6,000-11,000 pairs locally, with a remarkable increase to 17,000 in 1998 (ENSO). Annual numbers strongly reflect local wetland conditions, and numbers were sharply lower again in 1999. This species is believed to have declined locally be about two-thirds since the 1940s, due to loss of wetlands and wet pastures. Despite these losses, the Alafia Bank population remains one of the largest in the state.

Glossy Ibis - First recorded nesting at Alafia Bank in 1969, so perhaps a recent recruit to Tampa Bay breeding fauna. Primarily an inhabitant of freshwater habitats, with about 400-600 pairs at two Tampa Bay colonies. Numbers appear to have increased slowly over the last 20 years but continuing urbanization may reverse this trend. About 10% of the state population occurs here.

Roseate Spoonbill - Probably extirpated from Tampa Bay by 1900, but rediscovered nesting in 1975. Strong increase during 1990s. During this study 110-150 pairs were found at four sites, with over 180 in 1998 as a result of ENSO conditions (and probably relocation of some pairs from Florida Bay). About 15% of the state population.

Wood Stork - This endangered species nests at a single site in Tampa Bay, the Dot-Dash colony at the mouth of the Braden River. Numbers varied from about 40 to 100 pairs annually. In 1994 the colony was abandoned following disturbance by jet skiers, and numbers were reduced in 1995.

Snowy Plover - An obligate inhabitant of barrier beaches, particularly near passes and intertidal sand flats. With a maximum of three pairs of birds found annually on the beaches of Tampa Bay (especially Ft. DeSoto and Shell Key), and no more than 10 or so estimated for the entire region, this species is on the brink of local extinction.

Wilson's Plover - More common than the Snowy and more flexible in its habitat requirements, but rarely surveyed. Inhabits barrier island sand dunes, spoil islands and salt barrens. We estimate the Tampa Bay population at about 100 pairs, but this is little more than a wild guess useful only for order of magnitude.

American Oystercatcher - Stable of increasing with up to 94 pairs censused at area colonies. Including known pairs at other localities, Tampa Bay population is a minimum of 125 pairs, roughly 40% of the state population.

Willet - Breeds in high marsh habitats along islands and beaches, where difficult to census. Local population size unknown; we typically find about 15-20 pairs on islands in Hillsborough Bay. Vague guesstimate of Tampa Bay population is 100 pairs.

Laughing Gull - This species has declined sharply from the early 1980s, when 50,000 pairs were estimated in careful censuses. Currently only 10-15,000 pairs occur locally. Key factors may be reduced food supply due to improved garbage disposal practices, and raccoon predation at Shell Key.

Gull-billed Tern - Very rare and difficult to find in Tampa Bay. Sporadic nester with 0-10 nesting pairs found annually over last two decades. Usually nests among Black Skimmers, Least Terns, or Black-necked Stilts.

Caspian Tern - Now three colonies in the state, with about 90 pairs in Hillsborough Bay. Numbers have increased since early 1970s, when just 10-15 pairs were known. State population ca. 175 pairs.

Royal Tern - Two colonies in Tampa Bay totaling ca. 3,000 pairs, about 85% of state population. Numbers have increased over the past decade due to careful protection at Passage Key and Island 3D.

Sandwich Tern - Nests with Royal Terns. Local population now exceeds 500 pairs at two colonies (95% of the state population). Known population in early 1980 was less than 20 pairs!

Least Tern - Typically 100-150 pairs censused annually, but colonies move frequently. Most pairs now nest on gravel rooftops where they may be difficult to locate or survey. Colonies at the Skyway Sandbar, Isla and Tierra Verde have been lost to development or chronic human disturbance, while Shell Key failed in 1988-199 due to raccoon predation.

Black Skimmer - About 600-700 pairs in six colonies locally. Including another 300 pairs at colonies near Clearwater, 50-67% of the state population nests in the region.

Management Needs

It is remarkable that virtually every active colony in the Tampa Bay system receives some measure of protection as of 1998 (Table 12-1). These efforts are uneven, however, and must be expanded and improved. Certain sites (and species) are especially vulnerable to disturbance by humans, pets and raccoons. Discarded fishing line continues to entangle and kill colonial waterbirds, especially at colonies near passes and along the Intracoastal Waterway, and is regarded as the single most significant cause of mortality of adult Brown Pelicans.

Watershed issues remain extremely important to the long-term welfare of many colonial waterbird species. They are highly mobile, and may move throughout the watershed during the nesting season seeking food. Following nesting, they may move to other parts of the state or even other states, and therefore are affected by wetland conditions and other factors well beyond the reach of the Tampa Bay Estuary Program. In the next few years, however, census efforts should be expanded to colonies in the watershed. Wetlands acquisition, protection and other habitat protection measures should be accelerated. Food supply and foraging habitat will remain critical issues in an urbanizing region where wildlife competes with bulldozers for open space.

Table 12-3. Coastal bird colonies of the Tampa Bay System, 1994-1998: Protected status and presence of mamalian predators.

Colony Name	Raccoons 1994-1998	Raccoons 1999	Abandoned	Protected Status/Agency
1. Spoil Island 2D	✓			TPA/NAS
2. Spoil Island 3D				TPA/NAS
3. Alafia Bank	✓			NAS
4. Cockroach Bay ELAPP				HCRM
5. Hole in the Wall				AP/HCRM
6. Piney Point				TECO
7. Skyway Sandbar	✓		✓	AP
8. Miguel Bay				
9. Washbum Sanctuary	✓	✓		NAS
10. Washburn Jr				NAS
11. Dot-Dash				ANS
12. Passage Key NWR				FWS
13. Egmont Key SP/NWR				FPS/FWS
14. Tarpon Key	✓	✓		FWS
15. Little Bird Key				FWS
16. Tierra Verde			✓	
17. Shell Key	✓	✓	✓	AP/SPAS
18. Isla				
19. John's Pass	✓	?	✓	
20. Dogleg Key				TWB/NAS
21. Coffeepot Bayou				PF
22. Howard Frankland	?		✓	
23. Alligator Lake				SH
24. Courtney Campbell	✓	?	✓	FDOT/TAS

TPA	= Tampa Port Authority
NAS	= National Audubon Society
HCRM	= Hillsborough County Resource Management Team
TECO	= Tampa Electric Company
AP	= Aquatic Preserve, Florida Department of Environmental Protection
FPS	= United States Fish and Wildlife Service
SPAS	= St. Petersburg Audubon Society
TBW	= Tampa BayWatch
PF	= Pelican Fund
SH	= Town of Safety Harbor
FDOT	= Florida Department of Transportation
TAS	= Tampa Audubon Society

CHAPTER 13 - OCCURRENCE AND DISTRIBUTION OF SEA TURTLES IN TAMPA BAY. FLORIDA

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- CHAPTER HIGHLIGHTS -

☞ *Loggerhead. green, and Kemp's ridley turtles have been observed nesting on beaches in the Tampa Bay area. Hawksbill turtles have also been observed (rarely) in the area.*

☞ *An average of 35 loggerhead nests has been documented on Egmont Key annually from 1989-1997.*

☞ *Strandings data indicate that Tampa Bay is used by adult loggerheads, while primarily juvenile and immature Kemp's ridley, green and hawksbill turtles appear to frequent the bay waters.*

☞ *Logger head and ridley (and perhaps green) turtles appear to be year-round residents in Tampa Bay, with sighting occuring in all segments of the bay. Raccoons greatly affect the size and stability of nesting colonies.*

INTRODUCTION

Four species of sea turtles (loggerhead--Caretfa caretta, green turtle--*Chelonia mydas,* Kemp's ridley--*Lepidochelys kempii,* and hawksbill--*Eretmochelys imbricata)* occur in the area encompassed by the Tampa Bay Estuary Program (TBEP). The loggerhead is listed as Threatened and the other three are listed as Endangered under the Endangered Species Act.

Very little information is available in the scientific literature that is specifically about the sea turtles that occur in Tampa Bay. However, two programs, the Statewide Nesting Beach Survey program and the Sea Turtle Standing and Salvage Network (STSSN), exist that include long-term monitoring of turtles in the TBEP area. The nesting surveys are conducted annually by various governmental and private entities on beaches near the mouth of Tampa Bay (e.g., Anna Maria Island, Egmont Key, Fort DeSoto). These data collection efforts are coordinated by the Florida Marine Research Institute (FMRI), under whose auspices data summaries are produced and distributed to the public and to various government agencies. The FMRI also coordinates the recovery and documentation of injured or dead sea turtles found stranded in the Tampa Bay area (and throughout the state) through the STSSN. Eighteen states participate in the network, which is coordinated at the federal level by the National Marine Fisheries Service.

Neither the Statewide Nesting Beach Survey program nor the STSSN specifically addresses the occurrence of live turtles in the bay. In 1994, the FMRl began a pilot study of this topic which was continued and expanded under the auspices of TBEP funding. Federal recovery plans for the various species (U.S. Fish and Wildlife Service and National Marine Fisheries Service, 1992; National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1991a, 1991b, 1992) emphasize the need for in-water studies to document distribution patterns, seasonality, and habitat use of sea turtles.

Historical background

Several publications from the early and mid-1800s suggest that loggerhead and green turtles were once numerous in Tampa Bay. A report by Williams (1837) stated that "Fish and turtle are abundant; in the SW part in particular,... The Spanish fishermen keep a schooner here, to carry fish and turtle to Havana. From 15-20 men are constantly employed in curing them and in conveying them away to market." Pizzo (1968) reported that in 1824-1886, "Tampa Bay teemed with fish and turtle," and Sunshine (1880) stated that in Tampa Bay, "(g)reen and loggerhead turtles are taken, and form a lucrative traffic." According to the diary of Captain Wyche Hunter written in 1840, turtle steaks were frequently issued to the soldiers stationed on the peninsula where Macdill AirForce Base is now located (Wik, 1960).

Collins and Smith (1893) reported that 10,000 lbs of marine turtles were landed in 1889 in Hillsborough County (which at that time also included Pinellas County); in 1890, 10,244 Ibs were landed. It is not known where these turtles were captured, and thus it remains unknown whether any were taken from within Tampa Bay. Turtle eggs were also reported in the fisheries statistics, so it is possible that some of the catch included turtles slaughtered on the nesting beach. Curiously, catch statistics given by these authors for adjacent Manatee County show approximately six times as many pounds of turtles landed than for Pinellas County, yet fewer turtle eggs. Turtles were not identified to species.

Brice (1897) noted that the turtle fishery along Florida's west coast had been considered comparatively important in an investigation made in 1890 by the United States Fish Commission. However, by the time of his study, it was reported that "in the Tampa region the green turtles are nearly all killed off and that it does not now pay to follow the business." One vessel from Tampa and two from Punta Rassa fished for turtles part of the year using a total of four nets and caught 9,375 Ibs. Most references to the natural resources of the Tampa Bay area and the turtle industry of the Gulf of Mexico after 1900 no longer mention the marine turtles of Tampa Bay (McKay, 1924; Ingle and Smith, 1949; Carr, 1969; Lewis and Courser, 1972; Rebel, 1974). The Gulfport Historical Council (1985) reported that fishermen in the Gulfport area (southern Pinellas County) during the early part of the century were sometimes treated to sea turtles. Parsons (1962) reported that green turtles were trucked from Tampa for the turtle soup industry, but the origin of these turtles is not identified. Limoges (1975) stated that sea turtles are sighted in the bay on rare occasions.

Reynolds and Patton (1985) provided the most detailed account of marine turtles in the Tampa Bay area, including comments on nesting activity, research initiatives, and recommendations for future conservation and management action. Most other reports and publications about the bay that mention marine turtles are brief and refer to this source (Department of Environmental Regulation, 1986; Lewis, 1987; Lewis and Estevez, 1988).

A report on statewide nesting activity of marine turtles by Meylan et al. (1995) includes data for specific beaches within the TBEP area for 1979-1992 (see below).

Studies are currently underway by the Army Corps of Engineers to examine the abundance and seasonality of sea turtles in the navigation channel that serves ships using the Port of Tampa. The study involves quarterly sampling with shrimp trawls in the navigation channel, as well as satellite tracking of selected individuals to monitor turtle movements. Results of these studies will undoubtedly add important new information to what is known about marine turtles in the bay and in the adjacent offshore waters.

NESTING ACTIVITY

Nesting surveys in the Tampa Bay area are conducted by numerous entities, including county parks, state parks, conservation organizations, and private citizens. All parties carrying out the surveys are permitted by the Florida Department of Environmental Protection. Annual summaries submitted to FMRI include the following data: number of kilometers of beach surveyed, survey frequency, dates of survey, dates of the first and last nest, number of false crawls (unsuccessful nesting attempts), and total number of nests.

Data on nesting activity of marine turtles in the TBEP area during the period of 1982-1997 are presented in Table 13-1. The TBEP area is defined in this chapter as the inshore waters between 27°22'07"N and 28°07'05"W, but nest survey areas extended slightly beyond this at both the north and south boundaries. All but two nests recorded in this area have been attributed to loggerhead turtles; a single nest at Ft. DeSoto in 1994 was that of a green turtle, and a nest on Madeira Beach in 1989 was made by a Kemp's ridley (Meylan et al., 1994).

Although the Statewide Nesting Beach Survey database was created in 1979, TBEP area beaches were not monitored until 1982 (Table 13-1). From 1982 - 1987, surveys were conducted on an irregular basis in several areas; in Pinellas County, results for all beaches were pooled under the single category "County Beaches." This category includes beaches within Pinellas County that are north of the TBEP area. The extent of beach within each survey zone and the frequency of the surveys have varied from year to year, with increasingly thorough coverage over time.

Nearly all ocean-facing (Gulf) sandy beaches in the TBEP area are used as nesting habitat by marine turtles. One loggerhead nest was documented well inside Tampa Bay (at Northshore Park in St. Petersburg) on 16 June 1993 (confirmed by DEP staff), but nesting inside the bay appears to be rare. Reconnaissance by FMRI of 48 sandy beach areas inside the bay during eight days in June and July of 1995 revealed only one previously undocumented nesting site, Passage Key, in the mouth of the bay.

Evidence of four emergences (one certain nest) were noted on this key on July 7 and July 24, and attributed to loggerhead turtles on the basis of track characteristics. In August 1995, we were informed by U.S. Fish and Wildlife personnel that the refuge manager for Passage Key (a National Wildlife Refuge) had observed a loggerhead nesting on June 8, 1995. This was apparently the first documented nest on the island, which is only infrequently visited by humans for the purpose of assessing seabird populations.

Nesting also occurs inside Tampa Bay at Shell Key (also called Cabbage Key), south of Pass-a-Grille. This and other sandy keys in the vicinity are known to support low-level nesting by loggerhead turtles. Nesting activity was noted during aerial surveys conducted by DEP during 1989-91 (A. Foley, personal communication).

The most pristine nesting beach in the TBEP area is Egmont Key, which lies in the mouth of Tampa Bay. An average of 35 loggerhead nests has been documented on the key annually from 1989-1997. The lack of artificial lights, beachfront development, and beach armoring make the key a particularly valuable control site for studies of human-related impacts. The key is a state park, and thorough coverage of the nesting beach is provided by park personnel.

Because of variability in survey effort and data collection methods, the number of nests presented in Table 13-1 cannot be used to evaluate long-term trends in the nesting activity of loggerheads in the TBEP area. Large natural fluctuations in the number of turtles arriving annually at nesting beaches is a common, well-documented phenomenon that further complicates trend evaluation. The relative contribution of loggerhead nests in the TBEP area to the state total is small: in 1997, nesting in the TBEP area comprised 0.05% of the state total of 65,305 loggerhead nests. Despite this small quantitative contribution, nesting in the TBEP area is important from the standpoint of maintaining a wide geographic nesting distribution of the Florida loggerhead population.

An extensive range provides the population with resilience in the event of catastrophic events such as hurricanes, and it also helps to preserve genetic diversity within the population. Marine turtle nesting habitat is seriously threatened in Florida and elsewhere by coastal construction (and its attendant artificial lighting), coastal armoring, and an increasing human presence on the beach (Meylan et a1.,1995).

Strandings of Marine Turtles

Strandings of dead or injured marine turtles along Florida's coastline are monitored by FMRI as part of the STSSN. All records of inshore strandings in the Tampa Bay area (defined herein to be between latitudes 27°22'07"N and 28°07'05"W) for 1980 through 1997 were reviewed. Information recorded on each stranded turtle included: species identification, stranding location, stranding date, size of the turtle, presence/absence of tags, condition of the carcass, and visible carcass anomalies (evidence of entanglement, propeller wounds, fish hooks, etc.).

A total of 216 records of dead or injured turtles exists for the inshore waters of the Tampa Bay area for 1980-1997 (Table 13-2). Loggerhead turtles are by far the species most frequently documented, followed by Kemp's ridleys, green turtles, and hawksbills. Reporting efficiency has increased significantly since the network was initiated, partly as a result of increased public awareness, and hence the increase in the number of recorded strandings over the reporting period is partly attributable to this. It is important to note that these data reflect only inshore strandings; offshore strandings, which occur on Gulf beaches, are far more numerous. Also, stranding records represent a minimum estimate of mortality because not all dead turtles wash ashore, and some of those that do are either not found or not reported.

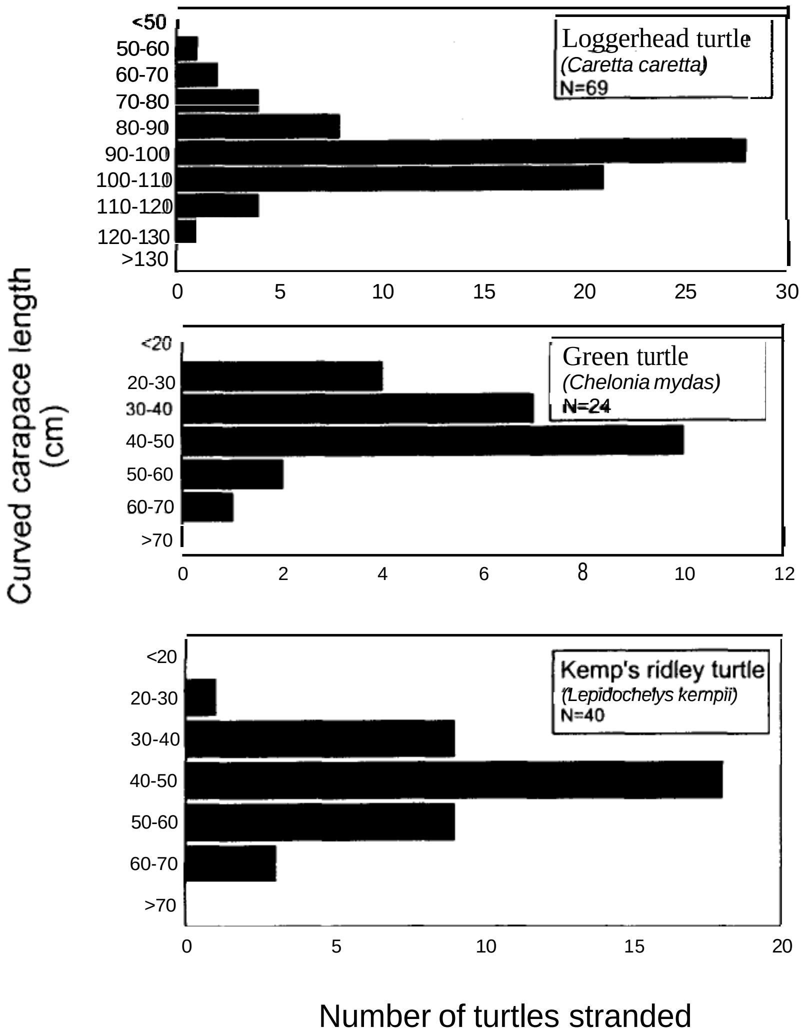


Figure 13-1. Size-class distributions of marine turtles that stranded in inshore waters of the Tampa Bay area, 1980-1997 (data source: Florida Sea Turtle Stranding and Salvage Network Database).

The size class distributions of stranded turtles documented from Tampa Bay are shown in Figure 13-1. The distributions are markedly different for loggerheads as compared with green turtles and Kemp's ridleys. The distribution is skewed towards large size classes of loggerheads ($\bar{x}$ = 95.4 ± 11.9 cm curved carapace length, N = 68, range 58.4-121.9) with the majority being adults (sexually mature). The size distributions of green turtles (Figure 13-1) ($\bar{x}$= 39.4 ± 8.72 cm, N = 24, range 27.0 - 66.8) and Kemp's ridleys ($\bar{x}$ = 45.2 ± 8.54 cm, N = 40, range 29.8 - 67.0) are similar to each other, and document the presence of mostly juvenile and subadult (immature) turtles. In fact, with the exception of the three ridleys in the 60-70 cm size category, all can be considered immature. The largest number of both green turtles and ridleys fall in the 40-50 cm size interval. All six hawksbill strandings have involved immature animals ($\bar{x}$ = 38.8 ± 11.2 cm, N = 5, range 27.3 - 53.3).

Figure 13-2 shows the seasonality of documented strandings of loggerheads, green turtles, and ridleys during 1980-1997. Strandings of loggerheads were most numerous from March through June, with a smaller peak in October and November. Green turtle strandings were documented primarily outside the summer months, with a peak in February and March. Strandings of Kemp's ridleys have occurred in all months except August, with no obvious seasonal pattern.

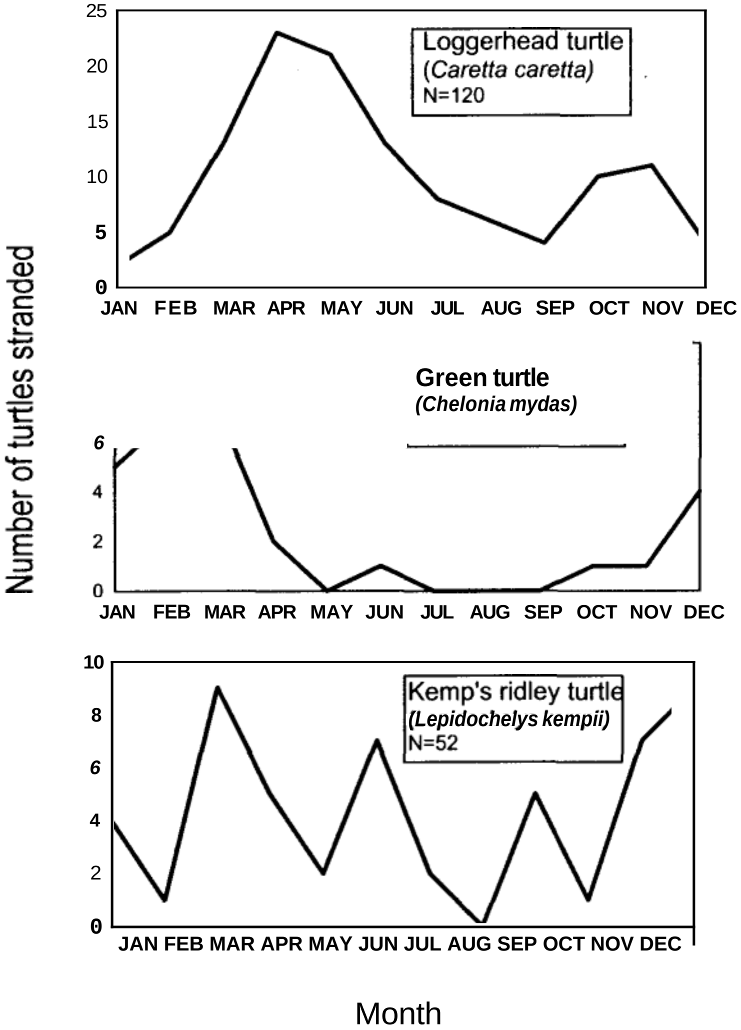


Figure 13-2. Seasonality of strandings of marine turtles in inshore waters of the Tampa Bay area, 1980-1997 (data source: Florida Sea Turtle Stranding and Salvage Network Database).

Figures 13-3 through 13-5 depict locations at which stranded turtles have been found in the bay area. Dead or injured loggerheads and Kemp's ridleys have been recovered in all sectors of the bay; green turtle strandings have been far more restricted in distribution, with most occurring near the mouth of the bay. All hawksbill strandings (not shown) have been in the outer bay area.

Although stranding distributions provide some useful information about distributions of live turtles, particularly in inshore waters, it is important to note that dead turtles can be transported considerable distances by tides or currents. Also, turtles that strand in areas frequently visited by people are more likely to be reported. Bearing these caveats in mind, the data still seem to suggest that loggerheads and ridleys have a wider distribution within the bay than green turtles and hawksbills.

External carcass anomalies (not necessarily causes of death) reported in the stranding records are given in Table 13-3. These numbers are considered absolute minimum occurrences because the lack of remarks on a stranding form does not necessarily indicate the lack of carcass anomalies. It is important to note that the factors causing carcass anomalies may occur either ante- or post-mortem, and it is not always possible to distinguish between the two.

Figure 13-3. Stranding Locations of Loggerhead Turtles *(Caretta caretta)* in Inshore Waters of the Tampa Bay Area (1980-1997)
(Source: Florida Sea Turtle Stranding and Salvage Network)

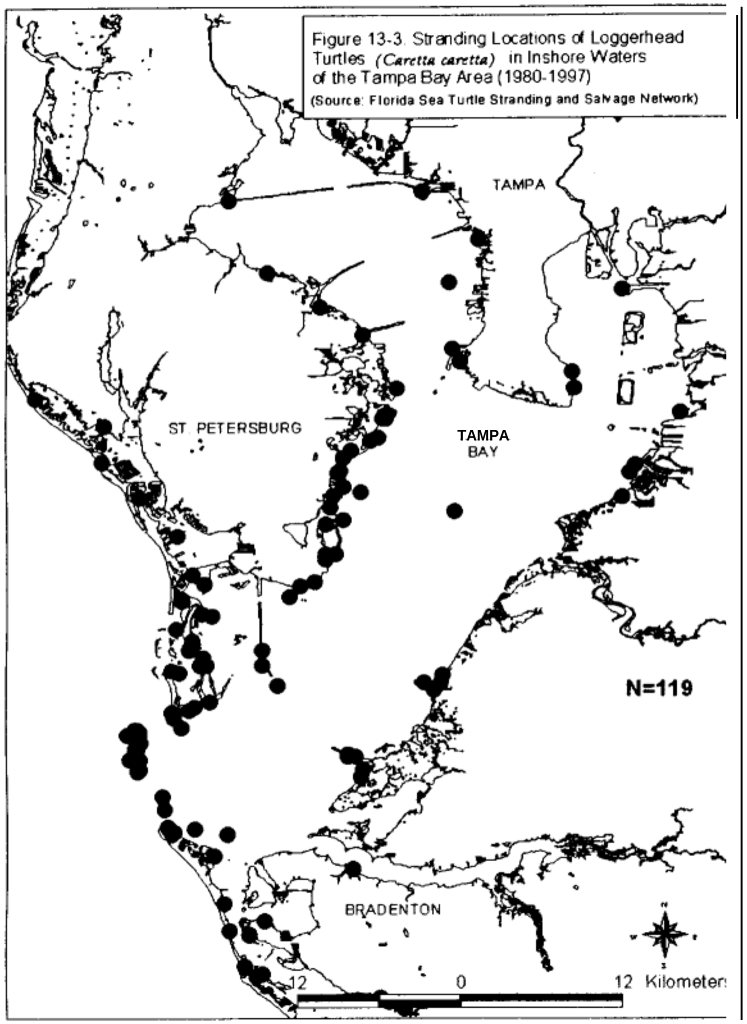
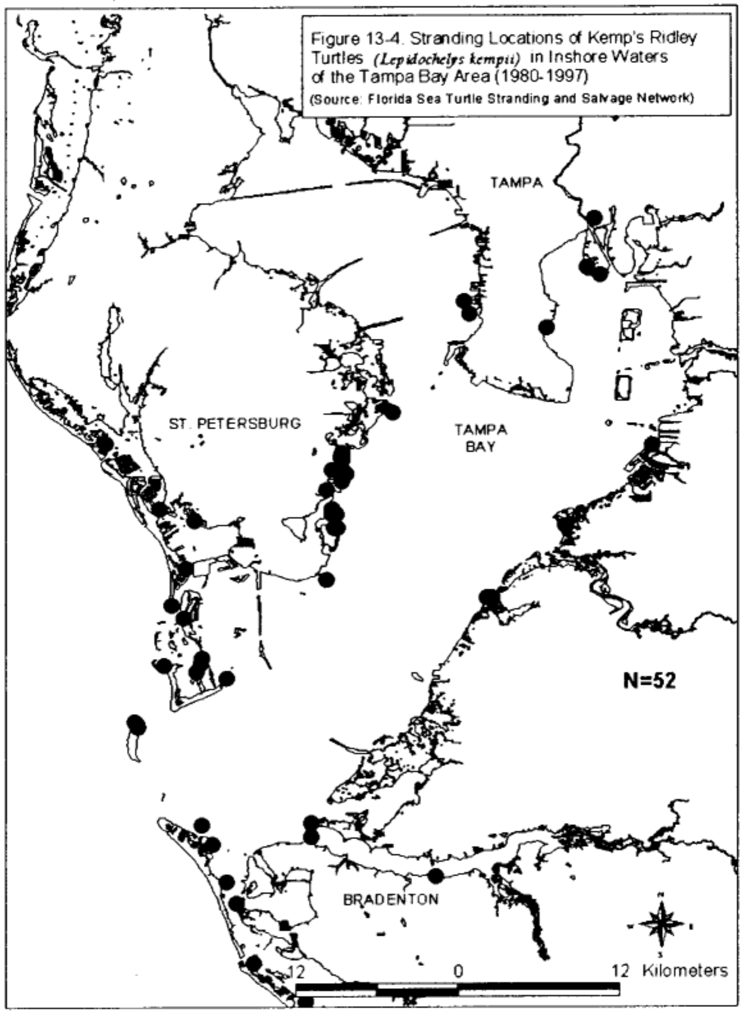


Figure 13-4. Stranding Locations of Kemp's Ridley Turtles *(Lepidochelys kempii)* in Inshore Waters of the Tampa Bay Area (1980-1997)
(Source: Florida Sea Turtle Stranding and Salvage Network)



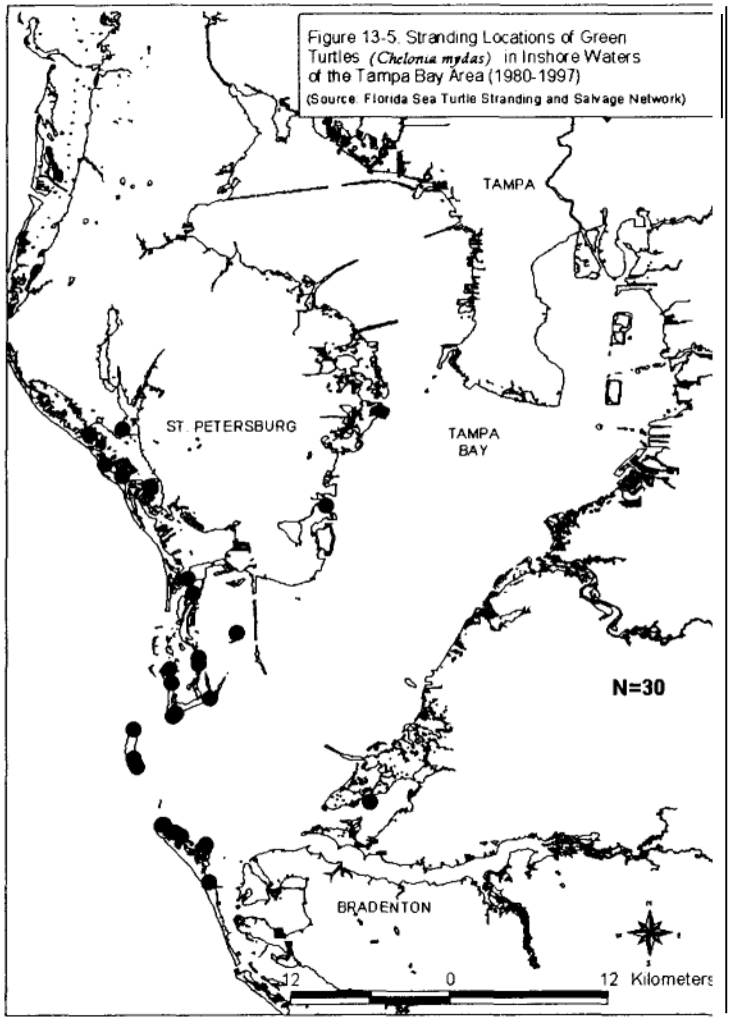


Figure 13-5. Stranding Locations of Green Turtles (*Chelonia mydas*) in Inshore Waters of the Tampa Bay Area (1980-1997)
(Source: Florida Sea Turtle Stranding and Salvage Network)

Boat-related injuries (including propeller wounds and possible boat collision injuries) were the most frequently observed carcass anomaly for loggerheads; five ridleys and one hawksbill also showed evidence of boat injuries. Seven cases of entanglement were reported, affecting all species. Fibropapillomas, which are large tumors occurring on the soft parts of the turtle, were the most common carcass anomaly on stranded green turtles. The disease fibropapillomatosis is known to occur in other species of sea turtles, but is by far most commonly seen in green turtles. Tumors were not observed on individuals of any other species that stranded in Tampa Bay.

The size class distribution of green turtles found with papilloma-type tumors is shown in Figure 13-6. The distribution is similar to the overall size class distribution of green turtles in the bay with the exception that the smallest size class (20-30 cm curved carapace length) is not represented. That may be a reflection of the small sample size, but it may also be related to the timing of onset of the disease (or at least the manifestation of tumors).

Distribution in Tampa Bay

To investigate the distribution and seasonality of live marine turtles in Tampa Bay, we compiled records of sightings from various sources. We reviewed all manatee aerial survey data collected during 121 flights made between November 1987 and June 1997 by FMRI's Endangered and Threatened Species section and Dr. John Reynolds of Eckerd College. These consisted of

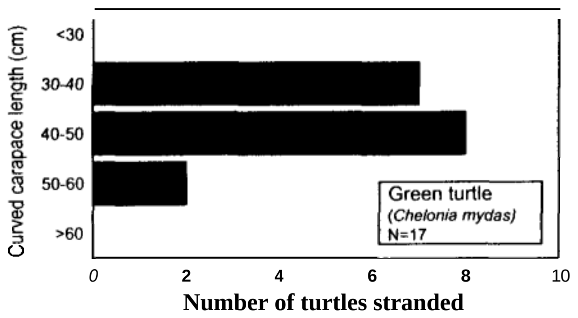


Figure 13-6. Size-class distribution of green turtles *(Chelonia mydas)* with papilloma-type tumors that stranded in inshore waters of the Tampa Bay area; 1980-1997.

flights made at monthly or bi-monthly intervals. Turtles were noted opportunisticallyduring these flights and their locations were marked on detailed nautical charts. The surveys were conducted in nearshore waters (from the shoreline to about 1.0 km offshore), at an altitude of 600' and an airspeed of 80-85 knots. Further details of survey methodology are given by Reynolds et al. (1991).

Another source of live turtle distribution data was aerial surveys flown from July 1995 through October 1996 as part of a study of recreational anglers being conducted by FMRI Fisheries Dependent Monitoring group. These surveys were conducted at approximately 500' altitude at 90-110 knots, following a route along the shorelines, boat channels, and bridges of Tampa Bay (and other areas). Each of the zones in the study were flown two or four times during each two-month period. Turtle locations were recorded with a Global Positioning System (GPS) unit.

We also compiled sightings of turtles made by personnel of the National Marine Fisheries Service during aerial surveys for marine mammals along the west Coast of Florida in September and October of 1994, and for red drum in November of 1995. Positions of turtles were recorded with a GPS unit. Our database of live marine turtles in Tampa Bay also included captures made incidental to research on sharks conducted by Mote Marine Laboratory's Center for Shark Research. Turtles were captured in monofilament gill nets.

In addition to compiling existing records of marine turtles in the bay, FMRI marine turtle staff directly sampled for marine turtles in the bay. Thirty-one scouting trips designed to spot turtles surfacing to breathe and six netting trips were made from 1995-1998. Large-mesh nets connected end-to-end were set in a linear array extending approximately 300 m. The nets were tended continuously in order to remove captured turtles and bycatch. We had two separate opportunities to sample for marine turtles in Tampa Bay with shrimp trawls. On May 15-16 and June 12-13 of 1995, we chartered a 55' shrimp boat (the Seaweed IV) that was equipped with two 25' trawls. The nets were not outfitted with Turtle Excluder Devices (TED'S). We conducted 30 30-minute paired tows on these four days. Endpoints of the tows were recorded with GPS.

Three records from the STSSN involved healthy, live turtles and were therefore included in the live sighting database. We also included miscellaneous sightings made by FMRI personnel conducting field work in the bay.

Figure 13-7 depicts the spatial distribution of live turtles as recorded by the various sources above. Miscellaneous reports include observations made by individuals other than FMRI staff. It should be noted that two surveys (the FMRI Recreational Fisheries Aerial Survey and the NMFS aerial surveys) included waters adjacent to the TBEP area, and these sightings are also included in Figure 13-7. The majority of sightings were attributable to the FMRI manatee aerial surveys (n=54 turtles) and to the FMRI Recreational Fisheries Aerial surveys (n=85).

Live turtles were sighted in all sectors of the bay, with more observed in the southern part of the bay than in the northern part. The greatest number of sightings was made in the area around Terra Ceia, just south of the southern end of the Skyway Bridge. A variety of data sources (aerial surveys, net captures, and sightings from boats) confirmed the importance of this area.

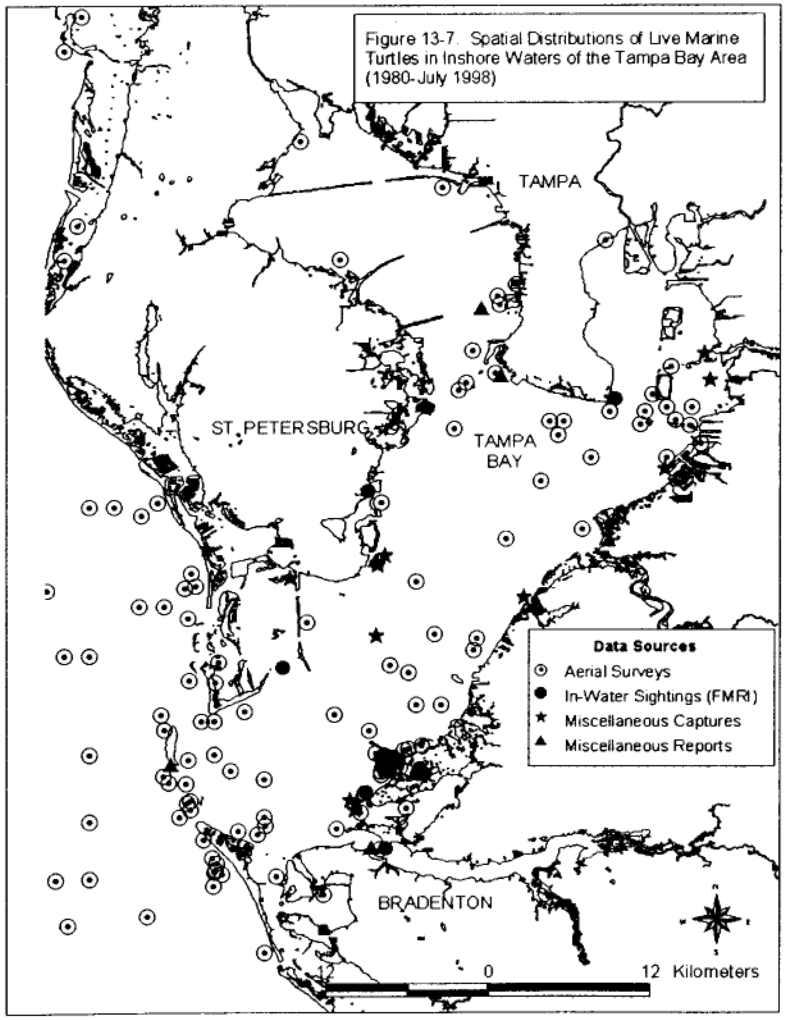


Figure 13-7. Spatial Distributions of Live Marine Turtles in Inshore Waters of the Tampa Bay Area (1980-July 1998)

Many of the live sightings were ancillary to other studies and the turtles were not identified to species. Interpretation of these survey data with regard to marine turtle distributions is also complicated by differences in data collection methods (aerial sightings, in-water sightings, and netting), behavioral differences among species (some are more cryptic than others), and the occurrence of smaller size classes in some species (which may cause them to go unnoticed).

In addition, marine turtles spend most of their lives submerged and thus not visible. Renaud (1995) reported an average submergence time of 89% for ridleys, and Renaud et al. (1995) reported a 91% average submergence time for green turtles. An additional bias is created by the fact that aerial surveys concentrated on shorelines, boat channels, and bridges.

CONCLUSIONS

Our compilation of data from various sources (stranding records, aerial surveys, incidental captures, etc.) on the occurrence of marine turtles in the TBEP area suggests that turtles are common, although perhaps inconspicuous, inhabitants of the bay. Their great mobility and tendency to remain submerged most of the time contribute to their cryptic nature. Four species are represented, with the following apparent order of abundance: loggerheads, Kemp's ridleys, green turtles, and hawksbills. During the 1980s, Kemp's ridley was listed as one of the twelve most endangered animals in the world by the International Union for the Conservation of Nature.

Although data on the seasonality of the various species in the bay are limited, it appears that at least the loggerhead and ridley are year round residents; this may eventually prove to be the case for the green turtle, as well. The hawksbill, a more tropical species than the others, appears to be very rare in the bay.

The bay serves as habitat for several life history stages of marine turtles, including foraging adults, foraging juveniles and subadults, and nesting females: The Gulf waters adjacent to Anna Maria Island, Egmont Key, and all of Pinellas County can be expected to be visited by both reproductive males and females during the mating and nesting season.

Historical literature suggests that marine turtle populations in the Tampa Bay area were once more robust, but became depleted at the end of the last century. Their current population status remains unknown, but there is no current evidence that densities are high. Although they are all now protected by law from harvesting, it is clear from stranding records that numerous mortality factors are still operating. Many are human-related, such as boat collisions, entanglement, and incidental catch. For green turtles, fibropapilloma disease is a major mortality factor. It has been suggested that environmental conditions such as pollution may play a part in the etiology of this disease, but this hypothesis remains unproven. A herpes virus is suspected to be the pathologic agent.

Current monitoring efforts of nesting beaches in the TBEP area are adequate. With the exception of Passage Key and some small islands in the Ft. DeSoto area, nearly all nesting beaches are monitored daily throughout the nesting season. Given the small number of nests believed to be deposited in the unmonitored areas, and the potential disturbance to seabirds on Passage Key, we would not recommend extending surveys to these areas.

Monitoring of strandings of marine turtles in the bay has improved dramatically in recent years, but there is no question that marine turtle carcasses sometimes go unreported. A campaign to inform the public of the importance of reporting sightings of dead turtles would be helpful in this regard. A further enhancement of STSSN activities would be support for professional necropsies of selected carcasses to better investigate mortality factors.

Perhaps the most neglected aspect of sea turtle monitoring in the bay has been that of assessing the distribution, abundance, and seasonality of live turtles. Our study will hopefully bring together a body of data that has heretofore existed in widely scattered places. However, our knowledge of these topics remains preliminary. Understanding the biology and ecology of the bay's turtles will take a concerted, long-term effort. The rewards will be improved management of these species, and a better understanding of the marine ecosystems of which they are a vital part.

RECOMMENDATIONS

1. Maintain the quality and quantity of existing nesting and foraging habitats of marine turtles in Tampa Bay. Address issues such as artificial lighting, coastal construction, beach armoring, beach nourishment, and human use of beaches, which can negatively impact marine turtles and their habitats.

2. Continue monitoring of nesting activity on. bay area beaches.

3. Improve stranding response for marine turtles in the bay through a public awareness campaign. Enhance assessment of mortality factors by providing for professional necropsies of selected carcasses.

4. Promote basic research on the distribution, abundance, seasonality, population structure, habitat usage, growth rates, and migrations of marine turtles. Encourage research on the cause of fibropapillomatosis.

5. Maintain and update GIS coverages of marine turtle distributions in the bay area; overlay turtle distributions with habitat and other coverages.

ACKNOWLEDGMENTS

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Table 13-1. Nesting activity of marine turtles, by location, in the Tampa Bay area (from 27" 22'07" N to 28'07'05" N), 1982-1997. IRR=irregular survey. All nests are those of loggerheads *(Caretta caretta)* unless otherwise noted. (Data source: Florida Statewide Nesting Survey Database).

Beach length (km)	Year	# Days per week	Survey start date	Survey end date	# of Nests
(Pinellas) County Beaches					
	1982	IRR			5
--	1983	IRR	--	--	17
--	1984	IRR	--	--	19
--	1985	IRR	--	--	25
--	1986	IRR	--	--	27
--	1987	IRR	--	--	50
Mid County Beaches (One Kemp's ridley nested on Madeira Beach in 1989)					
15.0	1988	7	05/01	10/01	7
15.0	1989	7	04/11	11/30	35
15.0	1990	7	04/01	10/31	57
22.4	1991	7	04/01	10/15	29
15.0	1992	7	--	--	59
6.8	1993	7	05/01	10/31	41
6.8	1994	7	05/01	10/31	33
6.8	1995	7	05/01	10/31	77
6.8	1996	7	05/01	10/07	56
6.8	1997	7	05/01	10/05	61
St. Pete Beach					
6.4	1988	7	04/01	10/---	7
9.7	1989	7	04/01	10/31	5
6.4	1990	7	05/01	10/10	8
6.5	1991	7	05/01	11/01	19
6.5	1992	7	04/01	08/15	11
6.7	1994	7	04/01	10/31	12
6.4	1995	7	04/15	11/15	29
6.4	1996	7	04/15	11/15	32
6.4	1997	7	04/15	10/15	14
8.0	1988	7	05/15	08/10	11
8.8	1989	7	01/01	12/31	8
8.4	1990	7	01/01	12/31	23
10.4	1991	7	02/01	12/31	22
8.9	1992	7	01/01	12/31	15
9.7	1993	7	02/01	12/31	24
9.7	1994	7	05/01	10/15	15
9.7	1995	7	01/01	12/31	50
9.7	1996	7	01/01	12/31	25
9.7	1997	7	04/15	10/15	26
Egmont Key					
4.8	1982	3	06/01	10/01	17
4.8	1984	4	06/01	10/01	6
4.0	1988	3	--	09/06	11
6.4	1989	3	05/25	10/01	40
8.8	1990	7	05/01	07/30	14
6.4	1991	7	05/01	09/05	16
6.4	1992	7	05/30	09/07	22
6.4	1993	7	05/01	09/30	31
6.4	1994	7	05/01	10/16	31
6.4	1995	7	04/01	10/10	56

Table 13-1 (continued). Nesting activity of marine turtles, by location, in the Tampa Bay area.

Beach length (km)	Year	# Days per week	Survey start date	Survey end date	# of Nests
5.2	1996	7	05/01	10/02	37
4.8	1997	7	05/01	10/19	72
Anna Maria Island					
7.4	1982	7	05/07	08/31	21
8.6	1983	7	05/16	08/13	23
8.6	1984	7	05/15	08/16	36
8.8	1985	7	05/18	08/01	23
9.7	1986	7	05/12	08/15	70
11.3	1987	7	05/15	08/15	59
9.7	1988	7	05/13	08/20	25
9.2	1989	7	05/07	08/21	106
9.6	1990	7	05/08	08/22	100
11.2	1991	7	05/04	08/21	96
11.3	1992	7	05/01	08/25	102
11.3	1993	7	05/01	09/30	155
11.3	1994	7	05/10	08/25	136
11.3	1995	7	05/09	10/10	214
11.7	1996	7	05/11	08/25	171
11.7	1997	7	05/01	10/16	161

Table 13-2. Strandings of dead or injured marine turtles in inshore waters of the Tampa Bay area (from 27°22'07"N to 28°07'05"N), 1980-1997 (Data source: Florida Sea Turtle Stranding and Salvage Network Database).

Year	Species					
	Caretta caretta	***Chelonia mydas***	***Lepidochelys kempii***	***Eretmochelys imbricatu***	**Unknown**	Total
1980	0	0	0	0	0	0
1981	1	0	0	0	0	1
1982	3	0	0	0	0	3
1983	3	0	0	0	0	3
1984	2	0	0	0	0	2
1985	2	0	0	0	1	3
1986	11	0	0	0	0	11
1987	9	0	4	0	0	13
1988	9	1	3	0	2	15
1989	21	1	3	1	0	26
1990	14	0	3	0	0	17
1991	8	0	3	0	1	12
1992	8	1	1	0	1	11
1993	4	0	8	0	2	14
1994	5	3	4	0	1	13
1995	4	9	11	2	1	27
1996	7	9	6	3	0	25
1997	9	4	6	0	1	20
Total	120	28	52	6	10	216

Table 13-3. Occurrence of carcass anomalies reported for marine turtles stranded in inshore areas of the Tampa Bay area (from 27°22'07"N to 28°07'05"N), 1980-1997. (Data source: Florida Sea Turtle Stranding and Salvage Network Database.) Carcass anomaly catagories are not mutually exclusive (individual turtles may have exhibited more than one carcass anomaly.)

Carcass anomaly	***Caretta caretta*** (n=120)	***Chelonia mydas*** (n=28)	***Lepidochelys kempi*** (n=52)	***Eretmochelys imbricata*** (n=6)	Unknown species (n=10)	Total
Boat related injuries	33	0	5	1	2	40
Emaciated	2	8	0	0	0	10
Fibropapillomas	0	18	*0*	0	0	18
Fishing gear entanglement*	2	1	2	2	0	7
Shark bites	3	0	2	0	0	5
Deliberate mutilations	1	0		0	1	3

*Incidental captures are included.

H. Greening (Tampa Bay Estuary Program)

Introduction

Goals adopted to restore and protect the living resources of Tampa Bay and results from the 1993-1998 Baywide Environmental Monitoring Report are collated here to provide a synthesis of current status and trends for goals and the resources they are designed to protect and/or restore. In addition, specific "flags" (indicating that additional attention and action may be needed) are highlighted, along with a brief description of recently initiated actions to address these areas of potential concern.

Overall, for the period 1993-1998, Tampa Bay is showing good progress towards goals adopted by the Tampa Bay Estuary Program partners for nitrogen management, acres of seagrass, and restoration/creation of low-salinity habitats (Chapter 1). Results also indicate the following:

Water and sediment quality:

- The large water quality improvements realized in the early to mid-1980s (water clarity, nutrients, chlorophyll-a) have been maintained throughout the 1990s. All segments of Tampa Bay have shown long-term improvements in chlorophyll-a concentrations (Chapter 6).

- Chlorophyll-a concentrations have fluctuated above and below the bay segment-specific targets (Chapter 1), which indicates that particular attention to ensuring that proposed nitrogen management actions are fully implemented is critical to maintain steady progress towards long-term seagrass restoration goals.

- The baseline conditions for trace metal contaminants of Tampa Bay (Chapter 8) suggest that approximately 6% (24 square miles) of bay sediments are of "marginal" quality, and approximately 1% (4 square miles) are "subnominal". Hillsborough Bay shows the greatest degradation, with approximately 33% (13 square miles) of "marginal" quality and almost 8% of "subnominal" quality.

Nutrient loading:

- Based on a dilution method (Chapter 4), estimates of Tampa Bay freshwater inflow and estimated total nitrogen and total phosphorus loadings do not indicate any obvious trends over 1985-1998. Variability between years for TN loadings appears to be greatly affected by rainfall.

- Total annual TN atmospheric deposition averaged over the period August 1996 through July 1998 to the surface of the bay represented approximately 24% of the 1985-1991 total nitrogen loads to the bay (Chapter 5). Previous estimates suggested that direct atmospheric deposition provided about 29% of the total nitrogen load.

Habitats:

- Mapping indicates net increases in seagrass coverage at a rate of about 2% per year between 1988 and 1994 (Chapter 7). However, trends in seagrass bed density appear to be declining during this same period.

Animal populations:

- Hillsborough Bay shows lowest benthic organism species richness and diversity; both Terra Ceia Bay and Boca Ciega Bay showed relatively high diversity (Chapter 9). Salinity appears to be the most important factor affecting benthic community structure throughout the bay. In general, the benthic community is "healthier" in areas of higher dissolved oxygen and lowest percent silt + clay.

- In the years 1989-1997, 199 taxa (fish and selected macroinvertebrates) have been collected and released (Chapter 10). Juvenile red drum recruitment peaked in 1991 and 1995 and was relatively lower in 1997. Juvenile sheepshead recruitment peaked in 1991, 1994, and 1997, and young-of-the-year spotted seatrout recruitment was highest in 1989 and 1991, with fairly constant recruitment since 1991.

- Wintering and summering manatee populations in Tampa Bay have increased from 60 in 1983 to 190 in 1994 in winter, and from 70 to 100 animals in summer (Chapter 11). However, annual manatee deaths have increased three-fold from the period 1976-1984 to 1985-1997. Bottlenose dolphin population size appeared to be stable over the period 1988-1998.

- The Tampa Bay area is home to approximately 28 species of colonial waterbirds, numbering more than 200,000 individuals. Collectively, the Tampa Bay waterbird population is among the state's largest. Populations of most coastal species are increasing, while many species that forage in freshwater wetlands are declining.

- Loggerhead, green and Kemp's ridley sea turtles have been observed nesting on beaches in the Tampa Bay area (Chapter 13). An average of 35 loggerhead nests have been documented on Egmont Key annually from 1989-1997. While loggerheads most often are found in Tampa Bay as adults, Kemp's ridley, green and hawksbill sea turtles that frequent the bay are primarily juveniles or immatures.

Areas of potential concern

One of the most important functions of monitoring programs is to provide an indication of potential degradation in condition or change in trends. Although many of the 1993-1998 monitoring results continue to indicate improving conditions in Tampa Bay, several areas indicate the need for careful consideration and action. These areas of potential concern and actions which have been recently initiated to address these areas as identified during this monitoring period, include the following:

1. **Chlorophyll-a concentrations in all bay segments continue to fluctuate around the target levels.** Continuation of the management strategy adopted by the Tampa Bay Nitrogen Management Consortium will be critical to maintain steady progress toward maintaining water quality goals.

2. **Seagrass density appears to be declining in established beds.** The initiation in 1998 of a more intensive seagrass conditions monitoring program, including approximately 50 transects, will provide more detailed evaluation of seagrass condition. In addition, monitoring for the presence of the *Labyrinthula* organism (associated with seagrass disease) will be initiated in fall 1999.

3. **High levels of some contaminants have been found in river sediments.** More intensive monitoring, initiated in 1998 within the rivers, will determine the extent and severity of these contaminated areas.

4. Although manatee populations have increased in Tampa Bay, **annual manatee deaths have increased three-fold since 1976-1984.** The initiation of the Tampa Bay Manatee Watch Program in 1999 is aimed at educating boaters about manatees and the need to reduce speeds in shallow seagrass areas. In addition, a research project comparing boater behavior in regulated and unregulated areas was initiated in 1999, with the objective of examining the effectiveness of signage and education in implementing manatee protection strategies.

5. **Wading bird species populations which nest on bay islands but forage in freshwater wetlands have declined.** A Tampa Bay Estuary Program 1999 mini-grant project is mapping the location of freshwater wetlands important to nesting wading birds as forage areas, and will be developing information for distribution to landowners explaining the importance of these small wetland areas. The maps will be available to regulatory and planning agencies for their use in permitting and land use decisions.

APPENDIX A

Freshwater Inflow and Nutrient Loadings to Segments of Tampa Bay

Freshwater Inflow and Nutrient Loadings to Segments of Tampa Bay

AD = Atmospheric Deposition

DPS = Domestic Point Sources

GW = Ground Water

IPS = Industrial Point Sources

NPS = Non-Point sources

FML = Fertilizer Material Loss

SPR= Springs

FRESHWATER INFLOW (million m3/year)

Segment	Source	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
OLD TAMPA BAY	AD	277.5	288.7	314.3	344.3	258.1	217.5	274.5	245.2	239.7	276.2
	DPS	37.9	37.9	36.6	39.2	38.9	37.7	38.8	40.8	48	48.7
	GW	54.0	54.0	54.0	54.0	54.0	54.0	54.0	54	54	54
	IPS	0.2	0.2	0.2	0.4	0.2	0.2	0.2	0.2	0.1	0
	NPS	143.7	134.5	189.0	256.8	107.9	85.5	151.0	123.5	103	131.4
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	513.3	515.3	594.1	694.7	459.1	394.9	518.4	463.7	444.7	510.3
HILLSBOROUGH BAY	AD	131.5	138.9	146.4	161.1	123.3	103.2	127.1	125.5	115.4	138.7
	DPS	100.0	100.0	100.0	100.0	104.4	99.9	100.2	90	87.1	94.6
	GW	49.6	49.6	49.6	49.6	49.6	49.6	49.6	49.6	49.6	49.6
	IPS	47.9	46.2	46.9	53.0	47.2	43.4	48.0	39.6	78.6	71.2
	NPS	321.2	473.8	668.6	746.3	256.0	142.0	559.7	376.7	399.9	760.3
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	57.0	71.7	75.6	66.5	61.6	60.9	55.0	60.9	64.6	62.6
	TOTAL	707.2	880.2	1087.0	1176.5	642.1	499.0	939.5	742.3	795.1	1177
MIDDLE TAMPA BAY	AD	364.5	425.3	418.6	485.4	335.1	284.4	353.6	358.1	322.8	352.9
	DPS	13.3	13.3	13.3	13.3	13.1	13.2	13.4	14.4	16	15.7
	GW	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
	IPS	17.2	17.6	17.1	16.7	17.8	16.8	19.7	24	21.3	49.5
	NPS	157.1	202.5	228.7	520.3	193.4	130.5	210.6	261.2	164	325.9
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	564.7	671.3	690.3	1048.4	571.9	457.5	609.8	670.3	536.7	756.7
LOWER TAMPA BAY	AD	312.0	354.8	356.8	413.7	311.9	256.8	299.5	347.8	297.8	325.3
	DPS	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.4	1.8	1.7
	GW	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
	IPS	2.1	2.1	1.7	2.6	1.7	2.2	2.2	0.2	0	0
	NPS	32.1	29.8	31.5	70.3	35.8	21.0	28.6	41.1	26.4	35.2
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	359.0	399.5	402.8	499.4	362.1	292.8	343.1	402.3	337.6	373.9
BOCA CIEGA BAY	AD	113.6	135.4	132.6	154.3	104.0	89.7	111.4	111.1	100.4	106.1
	DPS	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.5	2.9	2.8
	GW	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2	2	2
	IPS	0	0	0	0	0	0	0	0	0	0
	NPS	52.6	70.2	50.4	251.3	39.4	32.8	47.4	33.4	31.5	43
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	170.6	210.0	187.3	410.0	147.8	126.8	163.2	149	136.9	154
TERRA CIEA BAY	AD	20.2	22.4	23.2	26.5	21.6	17.3	19.6	24.9	20.8	23
	DPS	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.5	1.6	1.5
	GW	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1	1	1
	IPS	0	0	0	0	0	0	0	0	0	0
	NPS	6.6	7.1	7.1	17.4	8.3	4.9	6.6	10.3	5.9	8.5
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	29.6	32.4	33.1	46.7	32.7	25.1	29.1	37.8	29.3	34
MANATEE RIVER	AD	50.9	58.2	60.1	68.0	56.7	45.9	51.0	66.7	54.7	59.2
	DPS	8.6	8.6	8.6	8.6	8.6	8.6	8.6	9.8	9.4	9.9
	GW	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
	IPS	3.7	3.7	2.4	4.4	4.1	3.6	4.0	1.4	1.6	1.9
	NPS	192.8	216.2	254.2	393.8	190.6	90.1	256.8	243.6	175	188.3
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	258.8	289.5	328.1	477.5	262.7	151.0	323.2	324.3	243.5	262.1

TOTAL NITROGEN LOADING (UStons/year)

Segment	Source	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
OLD TAMPA BAY	AD	149.3	219.0	264.5	217.0	268.8	206.7	247.5	178.7	221.5	279.9
	DPS	73.9	73.9	71.4	76.4	60.5	57.9	65.3	71.6	77.1	77.9
	GW	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
	IPS	0	0	0	0	0	0	0	0	0	0
	NPS	195.1	184.1	270.6	390.9	163.4	120.6	205.9	183.5	145.3	193.7
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	419.1	477.8	607.3	685.1	493.5	386.0	519.5	434.6	444.7	552.2
HILLSBOROUGH BAY	AD	70.8	106.6	124.2	102.5	136.3	99.8	115.5	93.7	107.7	142.1
	DPS	379.3	379.3	379.3	379.3	308.5	264.9	237.8	229.9	211.3	225
	GW	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	IPS	68.9	69.3	68.3	94.4	60.3	45.1	60.6	64.8	86.2	89.2
	NPS	514.5	696.3	1563.6	1215.5	403.6	231.3	982.3	623.6	535.1	1154.1
	FML	195.9	150.7	189.1	198.8	233.0	263.5	272.1	250.8	213.8	235.5
	SPR	90.6	113.0	129.0	109.4	93.6	104.8	99.1	190.1	200.6	194.5
	TOTAL	1320.9	1516.1	2454.4	2100.8	1236.2	1010.3	1768.3	1453.8	1355.6	2041.3
MIDDLE TAMPA BAY	AD	204.0	329.3	357.1	292.5	360.3	292.3	309.6	267.6	302.5	345.7
	DPS	18.2	18.2	18.2	18.2	17.5	17.8	19.1	22.7	21.5	17.9
	GW	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	IPS	3.7	4.0	4.0	3.6	4.5	3.4	4.5	17	10	146.7
	NPS	234.2	326.9	478.6	899.7	311.5	232.2	340.2	505	234.4	524.2
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	460.7	679.0	858.5	1214.6	694.4	546.3	674.0	812.9	568.9	1035.2
LOWER TAMPA BAY	AD	175.0	272.0	303.5	254.4	351.6	261.7	265.2	267.3	281.2	313.1
	DPS	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.2	1.5	1.5
	GW	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
	IPS	13.0	13.0	12.3	14.8	13.1	13.2	11.4	0.4	0	0.1
	NPS	34.3	33.6	37.0	76.6	45.0	24.8	33.4	42	27.9	39
	FML	69.1	59.2	25.0	21.2	33.1	16.6	19.2	30.6	15.7	25.7
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	293.0	379.4	379.4	368.6	444.4	317.9	330.8	342.2	327.2	380
BOCA CIEGA BAY	AD	64.1	104.5	113.0	91.6	109.7	92.6	96.5	82.6	94	102.8
	DPS	3.1	3.1	3.1	3.1	3.1	3.1	3.1	4	3.8	3.2
	GW	0	0	0	0	0	0	0	0	0	0
	IPS	0	0	0	0	0	0	0	0	0	0
	NPS	101.3	135.2	96.8	484.1	76.1	63.2	91.5	64.1	60.7	83.1
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	168.5	242.8	212.9	578.8	188.9	158.9	191.1	150.7	158.5	189.1
TERRA CIEA BAY	AD	11.3	17.0	19.7	16.8	25.1	17.3	17.7	19.5	19.7	22.1
	DPS	6.5	6.5	6.5	6.5	6.5	6.5	6.5	5.1	4.3	3.9
	GW	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	IPS	0	0	0	0	0	0	0	0	0	0
	NPS	9.0	9.9	9.9	24.1	12.2	6.9	9.2	13.9	8.2	12
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	26.9	33.5	36.2	47.5	43.9	30.8	33.5	38.6	32.2	38
MANATEE RIVER	AD	28.9	44.0	50.7	43.1	66.1	45.4	45.8	52.5	52.2	56.8
	DPS	20.6	20.6	20.6	20.6	20.6	20.6	20.6	17.5	12.1	17.1
	GW	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	IPS	42.8	42.8	17.6	39.6	36.8	49.9	70.0	15.4	12.4	5.3
	NPS	255.4	289.1	343.1	579.2	344.7	149.9	495.3	488.8	303.9	473.6
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	347.8	396.6	432.1	682.6	468.3	265.9	631.8	574.2	380.8	552.9

TOTAL PHOSPHORUS LOADING (UStons/year)

Segment	Source	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
OLD TAMPA BAY	AD	181.0	188.2	205.0	224.5	168.3	141.8	179.0	159.9	156.3	180.1
	DPS	46.1	46.1	44.9	47.3	44.8	45.4	47.2	47.4	50.8	50.3
	GW	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9
	IPS	0	0	0	0	0	0	0	0	0	0
	NPS	48.2	45.5	65.1	117.9	32.5	25.1	42.8	41.8	31.4	41.4
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	284.2	288.7	323.9	398.6	254.5	221.2	277.9	257.9	247.4	280.7
HILLSBOROUGH BAY	AD	85.7	90.5	95.4	105.0	80.4	67.3	82.9	81.9	75.2	90.4
	DPS	588.8	588.8	588.8	588.8	529.1	475.5	456.2	341.6	331.5	304.8
	GW	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11	11	11
	IPS	257.2	246.4	252.0	325.7	259.0	210.2	240.7	57.6	90.6	81.8
	NPS	318.2	303.2	719.5	775.7	200.4	57.5	490.4	360.5	474.1	336.2
	FML	287.6	222.0	277.5	291.5	341.0	384.3	396.4	352.6	314.4	326.8
	SPR	5.9	7.5	7.8	6.9	6.6	6.3	5.6	4.3	4.6	4.4
	TOTAL	1554.4	1469.4	1952.0	2104.6	1427.5	1212.1	1683.2	1209.5	1301.4	1155.5
MIDDLE TAMPA BAY	AD	237.7	277.3	272.9	316.5	218.5	185.5	230.6	233.5	210.5	230.1
	DPS	3.3	3.3	3.3	3.3	3.2	3.2	3.3	2.5	2.3	2.3
	GW	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3	3	3
	IPS	9.4	10.2	10.2	9.5	5.2	12.2	13.8	17	21.3	55.6
	NPS	62.8	84.4	108.2	214.7	84.7	48.5	96.2	141.3	69.8	159.3
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	316.2	378.2	397.6	547.0	314.6	252.4	346.9	397.2	306.9	450.3
LOWER TAMPA BAY	AD	203.5	231.3	232.6	269.8	203.4	167.5	195.3	226.8	194.2	212.1
	DPS	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2
	GW	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	IPS	13.8	13.8	10.7	40.4	4.0	8.4	5.6	0.3	0	0
	NPS	13.7	12.7	13.4	30.0	15.3	8.9	12.2	13.7	8.8	11.9
	FML	99.7	85.4	36.0	30.6	47.7	23.9	27.8	35.8	18.5	30
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	333.2	345.7	295.2	373.3	272.9	211.2	243.4	279	223.9	256.6
BOCA CIEGA BAY	AD	74.1	88.3	86.5	100.6	67.8	58.5	72.7	72.4	65.5	69.2
	DPS	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4
	GW	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	IPS	0	0	0	0	0	0	0	0	0	0
	NPS	16.9	22.5	16.1	81.0	12.7	10.5	15.2	10.7	10.1	13.8
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	91.7	111.5	103.3	182.3	81.2	69.7	88.6	83.7	76.2	83.6
TERRA CIEA BAY	AD	13.2	14.6	15.1	17.3	14.1	11.3	12.8	16.3	13.5	15
	DPS	1	1	1	1	1	1	1	0.4	0.7	0.3
	GW	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	IPS	0	0	0	0	0	0	0	0	0	0
	NPS	2.1	2.3	2.2	5.6	2.7	1.6	2.1	3.2	1.9	2.7
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	16.5	18.1	18.5	24.1	18.0	14.1	16.1	20.2	16.4	18.2
MANATEE RIVER	AD	33.2	37.9	39.2	44.3	36.9	29.9	33.3	43.5	35.7	38.6
	DPS	4.2	4.2	4.2	4.2	4.2	4.2	4.2	3.3	2.3	3.6
	GW	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	IPS	0	0	0	0	0	0	0	0	0	0
	NPS	67.3	83.2	98.2	165.6	82.6	41.0	103.7	96.3	64.8	124.2
	FML	0	0	0	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0	0	0	0
	TOTAL	105.1	125.7	142.0	214.5	124.1	75.5	141.6	143.5	103.2	166.9

TOTAL SUSPENDED SOLIDS LOADING (UStons/year)

Segment	Source	1985	1986	1987	1988	1989	1990	1991
OLD TAMPA BAY	AD	0	0	0	0	0	0	0
	DPS	41.9	41.9	39.7	44.0	40.4	38.3	33.4
	GW	0	0	0	0	0	0	0
	IPS	0.5	0.5	0.5	0.8	0.4	0.4	0.5
	NPS	5131.0	4657.9	6334.0	9248.3	4035.8	3218.7	5385.2
	FML	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0
	TOTAL	5173.4	4700.3	6374.2	9293.1	4076.6	3257.4	5419.1
HILLSBOROUGH BAY	AD	0	0	0	0	0	0	0
	DPS	402.9	402.9	402.9	402.9	235.4	266.3	245.1
	GW	0	0	0	0	0	0	0
	IPS	1064.3	940.0	828.3	1126.8	996.5	964.7	956.9
	NPS	13849.9	14208.4	19333.1	21565.6	10831.5	9819.4	15446.7
	FML	0	0	0	0	0	0	0
	SPR	0.6	0.8	0.8	0.7	0.7	0.7	7.1
	TOTAL	15317.7	15552.1	20565.1	23096.0	12064.1	11051.1	16655.8
MIDDLE TAMPA BAY	AD	0	0	0	0	0	0	0
	DPS	2.1	2.1	2.1	2.1	2.0	2.0	2.0
	GW	0	0	0	0	0	0	0
	IPS	202.4	204.6	203.9	201.7	157.8	210.7	248.7
	NPS	3443.2	5140.8	4318.7	15741	3500.3	2526.3	3855.3
	FML	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0
	TOTAL	3647.7	5347.5	4524.7	15945.2	3660.1	2739.0	4106.0
LOWER TAMPA BAY	AD	0	0	0	0	0	0	0
	DPS	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	GW	0	0	0	0	0	0	0
	IPS	53.0	53.0	48.4	73.0	61.1	45.1	37.4
	NPS	442.4	410.6	429.0	975.1	494.7	287.8	391.7
	FML	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0
	TOTAL	495.5	463.7	477.5	1048.2	555.9	333.0	429.2
BOCA CIEGA BAY	AD	0	0	0	0	0	0	0
	DPS	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	GW	0	0	0	0	0	0	0
	IPS	0	0	0	0	0	0	0
	NPS	3242.8	4318.0	3095.6	15481.7	2422.9	2018.2	2921.4
	FML	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0
	TOTAL	3243.1	4318.3	3095.9	15482.0	2423.2	2018.5	2921.7
TERRA CIEA BAY	AD	0	0	0	0	0	0	0
	DPS	4.8	4.8	4.8	4.8	4.8	4.8	4.8
	GW	0	0	0	0	0	0	0
	IPS	0	0	0	0	0	0	0
	NPS	188.0	204.4	201.4	501.4	238.8	140.0	187.6
	FML	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0
	TOTAL	192.8	209.2	206.2	506.2	243.6	144.8	192.4
MANATEE RIVER	AD	0	0	0	0	0	0	0
	DPS	18.0	18.0	18.0	18.0	18.0	18.0	18.0
	GW	0	0	0	0	0	0	0
	IPS	2649.6	2649.6	455.3	1661.5	2382.0	4400.8	4348.5
	NPS	2351.3	2766.6	2946.2	5676.6	3001.7	1645.9	2829.5
	FML	0	0	0	0	0	0	0
	SPR	0	0	0	0	0	0	0
	TOTAL	5018.9	5434.2	3419.5	7356.1	5401.7	6064.7	7196.0