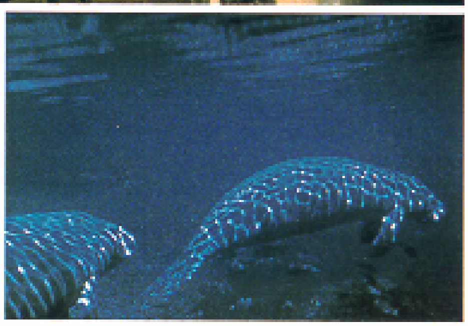
Water Resources Management Plan



CANAVERAL

National Seashore • Florida

WATER RESOURCES MANAGEMENT PLAN

CANAVERAL NATIONAL SEASHORE
FLORIDA

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LIST OF ACRONYMS

ACOE	Army Corp of Engineers
ATU	Aerobic Treatment Units
BMP	Best Management Practice
BOD	Biological Oxygen Demand
CANA	Canaveral National Seashore
CARL	Conservation and Recreation Lands Trust Fund
CCP	Comprehensive Conservation Plan
CWA	Clean Water Act
COD	Chemical Oxygen Demand
DACS	Department of Agriculture and Consumer Services
DER	Department of Environmental Regulation
DO	Dissolved Oxygen
DRI	Development of Regional Impact
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EVMCD	East Volusia Mosquito Control District
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FDER	Florida Department of Environmental Regulation
FFWCC	Florida Fish and Wildlife Conservation Commission
FIND	Florida Inland Navigation District
FMRI	Florida Marine Research Institute
FS	Florida Statues
GIS	Geographic Information System
HUC	Hydrologic Unit Code
ICW	Intracoastal Waterway
IRL	Indian River Lagoon
IRLNEP	Indian River Lagoon National Estuary Program
IRL-PLR Model	Indian River Lagoon-Pollutant Load Reduction Model
IRL-WQMN	Indian River Lagoon – Water Quality Monitoring Network
KSC	Kennedy Space Center
MINWR	Merritt Island National Wildlife Refuge
MPN	Most Probable Number
MRGIS	Marine Resources Geographic Information System
MTGW	Modified Tide Gate Weirs
NASA	National Atmospheric and Space Administration
NEP	National Estuary Program
NEPA	National Environmental Policy Act
NGVD	National Geodetic Vertical Datum
NPDES	National Pollution Discharge Elimination System
NPS	National Park Service
NSSP	National Shellfish Sanitation Program
OFW	Outstanding Florida Water

OMWM	Open Marsh Water Management
OSDS	On-Site Sewage Disposal Systems
PLRG	Pollutant Load Reduction Goals
PLRT	Pollutant Load Reduction Targets
PSM	People per Square Mile
RIM	Rotational Impoundment Management
SAV	Submerged Aquatic Vegetation
SFWMD	South Florida Water Management District
SJRWMD	Saint Johns River Water Management District
STORET	Storage and Retrieval Database
SWIM	Surface Water Improvement and Management Program
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorous
TTS	Total Suspended Solids
UCF	University of Central Florida
USFWS	United States Fish and Wildlife Service
WAM	Wildlife Aquatic Management
WRMP	Water Resources Management Plan

EXECUTIVE SUMMARY

Canaveral National Seashore (CANA) consists of approximately 58,000 acres within the Mosquito Lagoon watershed. This National Park unit represents an excellent example of a relatively stable barrier beach backed by a productive lagoon system. Mosquito Lagoon is the northernmost part of the Indian River Lagoon (IRL) system, which contains the highest species diversity of any estuary in North America (see references in 1995 special issue of *Bulletin of Marine Science*, Vol. 57) and provides critical habitat for 14 federally listed threatened and endangered species, including green sea turtles, loggerhead turtles, and West Indian manatees. The far-reaching, ecological importance of this area has been demonstrated by the EPA in listing it as an Estuary of National Significance and by the state of Florida in classifying it as a Florida Outstanding Waterway and Aquatic Preserve, the highest level of state protection. Under this designation, ambient water quality must be maintained and protected, and any degradation must be short-term or temporary.

CANA was established in 1975 by federal legislation to, "… preserve and protect the outstanding natural, scenic, scientific, ecologic, and historic values of certain lands, shoreline, and waters of the State of Florida, and to provide for public outdoor recreation use and enjoyment of the same…" (Public Law 93-626). This is an extremely complex task as numerous anthropogenic influences impact CANA's water resources including:

> ***Mosquito Control –*** In the designation of lands for NPS management, both NASA and the State of Florida stipulated that CANA must cooperate with the local mosquito control districts to control salt marsh mosquitoes. The influence of various mosquito control techniques (e.g., impoundments, larvicides, etc.) and impoundment restoration measures on CANA's water resources are not fully understood.
>
> ***Atlantic Intracoastal Waterway –*** A survey by the Florida Inland Navigation District (FIND) in 1996 revealed significant shoaling of the Intracoastal Waterway (ICW), which is adjacent to or within CANA boundaries. FIND estimates that approximately 529,000 yds^3 of material will be dredged from the ICW in this area over the next 50 years. A 91.8-acre dredged material management area, 0.3 miles west of Mosquito Lagoon's western shoreline, is where the dredged material will be piped in from the ICW and hauled away. A monitoring program is to be in place at all times, since the release of pollutants (e.g., heavy metals) into local waters is potentially high during active dredging operations.
>
> ***Aquaculture and Shellfish Harvesting –*** There has been an increase in aquaculture and commercial shellfish harvesting activities in Mosquito Lagoon since the 1995 gill net ban went into effect in all Florida waters. The recreational harvest of clams, oysters and crabs that occur in CANA waters is not adequately monitored and the Park needs to ensure that these populations can sustain this harvest pressure. In addition, the Park is concerned with harvesting methods on associated fauna and flora, especially seagrasses.

On-Site Sewage Disposal Systems – Many residents along Mosquito Lagoon are being served by On-Site Disposal Systems (septic tanks). Research has shown that up to 77% of the soils in Volusia County are rated as severely limited for septic system use. In addition, areas along Mosquito Lagoon have a very shallow water table. Virtually all potable water in the area comes from groundwater wells. Proper permitting, installation, inspection and maintenance of septic tank systems are critical to the protection of CANA's water resource, including the drinking water supply.

Biological Resource Impacts – Disease and contaminant accumulation are present in several species within the waters of the Indian River Lagoon system, including CANA. Papillomatosis (or fibropapilloma) is a disease of unknown origin, which appeared in the Indian River Lagoon in the last ten years and affects a substantial portion of the marine turtle population. In the summer of 1999, there was a mass mortality event of the horseshoe crab *Limulus polyphemus*; the cause of this rapid die-off remains unknown. There have been indications that these diseases are connected to water quality.

Recreational Activities - There is a growing concern that continued increases in boat traffic will have severe impacts to CANA's aquatic resources. Aerial observations in the Park have identified scaring from boat propellers in the submerged aquatic vegetation (i.e., seagrass beds). The slow-moving, endangered West Indian manatee is vulnerable to boat collisions. Boat wakes also cause erosion problems along the shoreline of the shallow lagoon system. Unfortunately, there is little data that evaluates the full impact boating and other recreational activities have on the park's natural resources.

The primary purpose of this water resources management plan is to provide information on potential threats to CANA resources and guidance on actions that can assist with the prevention or mitigation of water resource degradation. It is important to recognize that CANA's water-related issues extend beyond the Park's boundary. Thus, multi-agency communication and coordination are essential to successfully manage the Park's watershed. Natural resources in the region, including CANA's watershed, are monitored and managed by numerous Federal and State regulatory and non-regulatory programs. The potential for the Park to develop strong cooperative monitoring and rehabilitation programs is high.

Units of the National Park System are not required to develop a Water Resources Management Plan. However, where water resource issues or management constraints are particularly numerous, complex or controversial, a water resources management plan is useful in providing identification and analysis of water-related information and issues, and presenting a coordinated action plan to address them. The Water Resources Management Plan is complimentary to and consistent with the General Management Plan for the Park unit. The water resources management plan is similar to the Park's resources management plan, but includes a more thorough review of existing water resources information, an in-depth analysis of water resources issues, and the development of a plan to address them.

Water resources issues identified as most pressing for CANA based on an interagency scoping meeting include: 1) completing an aquatic species inventory, 2) determining if oysters, clams and blue crabs are harvested at sustainable levels and if harvesting alters aquatic biodiversity, 3) completing a water quality assessment and long-term monitoring scheme, 4) understanding if and how mosquito impoundment reconnection and restoration changes aquatic biodiversity, 5) determining the primary use areas of the endangered West Indian manatee, 6) determining the status of boat propeller scarring on seagrass beds, 7) determining if critical finfish spawning and nursery areas require additional protection, and 8) developing a spill contingency plan and protocols for regulating waste management.

Management recommendations, in the form of project statements, have been developed to address these water resources issues. Project statements are standard National Park Service programming documents that describe a problem or issue, discuss actions to deal with it, and identify the additional manpower and/or funds needed to carry out the proposed actions. They are planning tools used to identify problems and needed studies, and programming documents used to compete with other projects and Park units for support.

CANAVERAL NATIONAL SEASHORE'S WATER RESOURCES MANAGEMENT PLAN AND THE NATIONAL ENVIRONMENTAL POLICY ACT

The National Environmental Policy Act (NEPA) mandates that federal agencies prepare a study of the impacts of major federal actions having a significant effect on the human environment and alternatives to those actions. The adoption of formal plans may be considered a major federal action requiring NEPA analysis if such plans contain decisions affecting resource use, examine options, commit resources or preclude future choices. Lacking these elements, CANA's Water Resources Management Plan (WRMP) has no measurable impacts on the human environment and is categorically excluded from further NEPA analysis.

According to Director's Order (DO) #12 Handbook (section 3.4), water resources management plans normally will be covered by one or more of the following Categorical Exclusions:

- 3.4.B (1) Changes or amendments to an approved plan when such changes have no potential for environmental impact.
- 3.4.B (4) Plans, including priorities, justifications, and strategies, for non-manipulative research, monitoring, inventorying, and information gathering.
- 3.4.B (7) Adoption or approval of academic or research surveys, studies, reports and similar documents that do not contain and will not result in NPS recommendations.
- 3.4.E (2) Restoration of non-controversial native species into suitable habitats within their historic range.
- 3.4.E (4) Removal of non-historic materials and structures in order to restore natural conditions when the removal has no potential for environmental impacts, including impacts to cultural landscapes or archeological resources.
- 3.4.E (6) Non-destructive data collection, inventory, study, research, and monitoring activities.
- 3.4.E (7) Designation of environmental study areas and research natural areas, including those closed temporarily or permanently to the public, unless the potential for environmental (including socioeconomic) impact exists.

These Categorical Exclusions require that formal records be completed (Section 3.2, D0-12 Handbook) and placed in Park files.

INTRODUCTION

Canaveral National Seashore (CANA) is located on the east coast of central Florida, covering both southeast Volusia and northeast Brevard counties (Figure 1). This National Park Service (NPS) unit encompasses a relatively stable barrier island backed by a productive lagoon system. A majority of CANA acreage consists of Mosquito Lagoon, the northernmost water body of the Indian River Lagoon (IRL) system (Figure 1). This estuary system contains one of the highest species diversities of any estuary in North America (Provancha et al. 1992). Congress authorized Canaveral National Seashore on January 3, 1975 through Public Law 93-626. It was established to, "…preserve and protect the outstanding natural, scenic, scientific, ecologic, and historic values of certain lands, shoreline, and waters of the State of Florida, and to provide for public outdoor recreation use and enjoyment of the same…" (Public Law 93-626). Commercial harvesting in these waters predates the establishment of CANA and commercial collection of fish, shellfish, crabs, and shrimp has been allowed to continue within Park boundaries with proper licensing. Being designated as an Outstanding Florida Water (OFW), providing a home to 14 federally-listed threatened and endangered species, and hosting over 1.5 million visitors in 1999, indicates how critical a Water Resources Management Plan is to help protect the diverse aquatic ecosystems of CANA for many years into the future.

CANA is comprised of approximately 58,000 acres of barrier island, lagoon, coastal hammocks, pine flatwoods, and offshore waters (National Park Service 1997). This includes the longest stretch of undeveloped beach (24 miles) on Florida's east coast. Mosquito Lagoon comprises the majority (⅔) of the area within CANA boundaries. The northernmost boundary of the Park is adjacent to the town of Edgewater and runs south to State Road 402. The westernmost boundary runs along State Road 3 in the lower section of the Park and follows the Intracoastal Waterway (ICW) in the upper section. The east boundary of CANA runs 0.5 miles offshore, parallel to the beach for a length of 24 miles (Figure 1).

Mosquito Lagoon is one of the richest, most diverse estuaries in North America, in large part because it is located in a transition zone between tropical and temperate climates (see references in 1995 special issue of *Bulletin of Marine Science*, Volume 57). In fact, the 10-year freeze line in Florida (1982 – 1993) bisects the northern section of CANA (Figure 2, J. Weishampel, pers. comm., UCF, 2000). Thus, the species composition varies greatly during the year; in the summer months subtropical and tropical species dominate the waters, while in the winter temperate species take up residence (L. Walters, unpublished data). Additionally, Mosquito Lagoon is dominated by shallow flats (average depth: < 1.5 m) that support dense growths of submerged aquatic vegetation.

The only present day connection between Mosquito Lagoon and the Atlantic Ocean is through Ponce de Leon Inlet near the northern end of CANA boundaries (Figure 1). Because of the narrow width and shallow depths of Mosquito Lagoon, ocean water entering through the inlet does not travel far into the Lagoon during the astronomical tidal

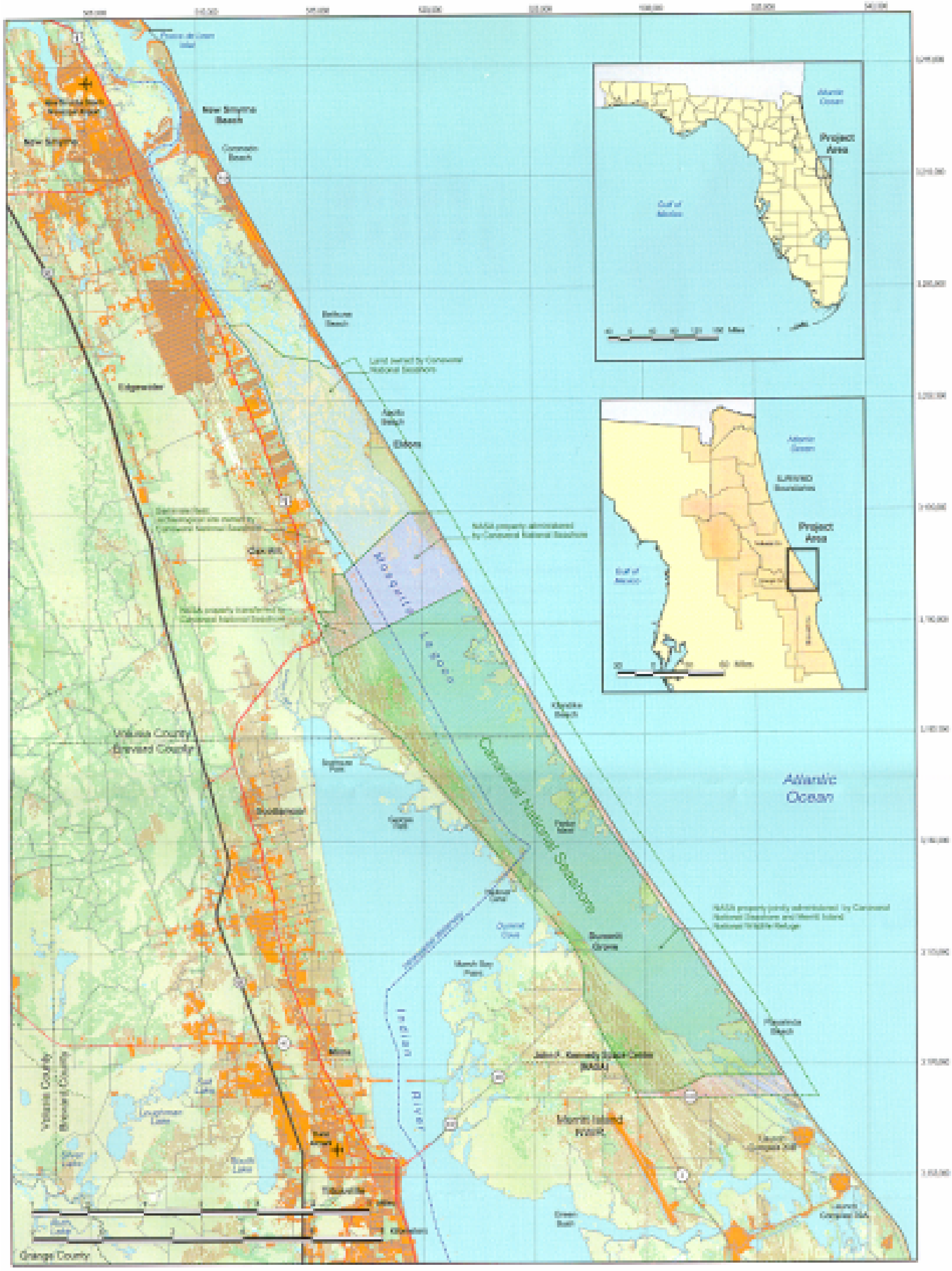

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Figure 1. Boundaries of CANA

Legend:

- NASA property administered by Canaveral National Seashore
- NASA property jointly administered by Canaveral National Seashore and Merritt Island National Wildlife Refuge
- Land owned by Canaveral National Seashore
- NASA property transferred to Canaveral National Seashore

- Interstate
- Jeep trail
- Local road
- State road
- US Highway
- County boundaries
- CNS boundaries
- Intracoastal Waterway

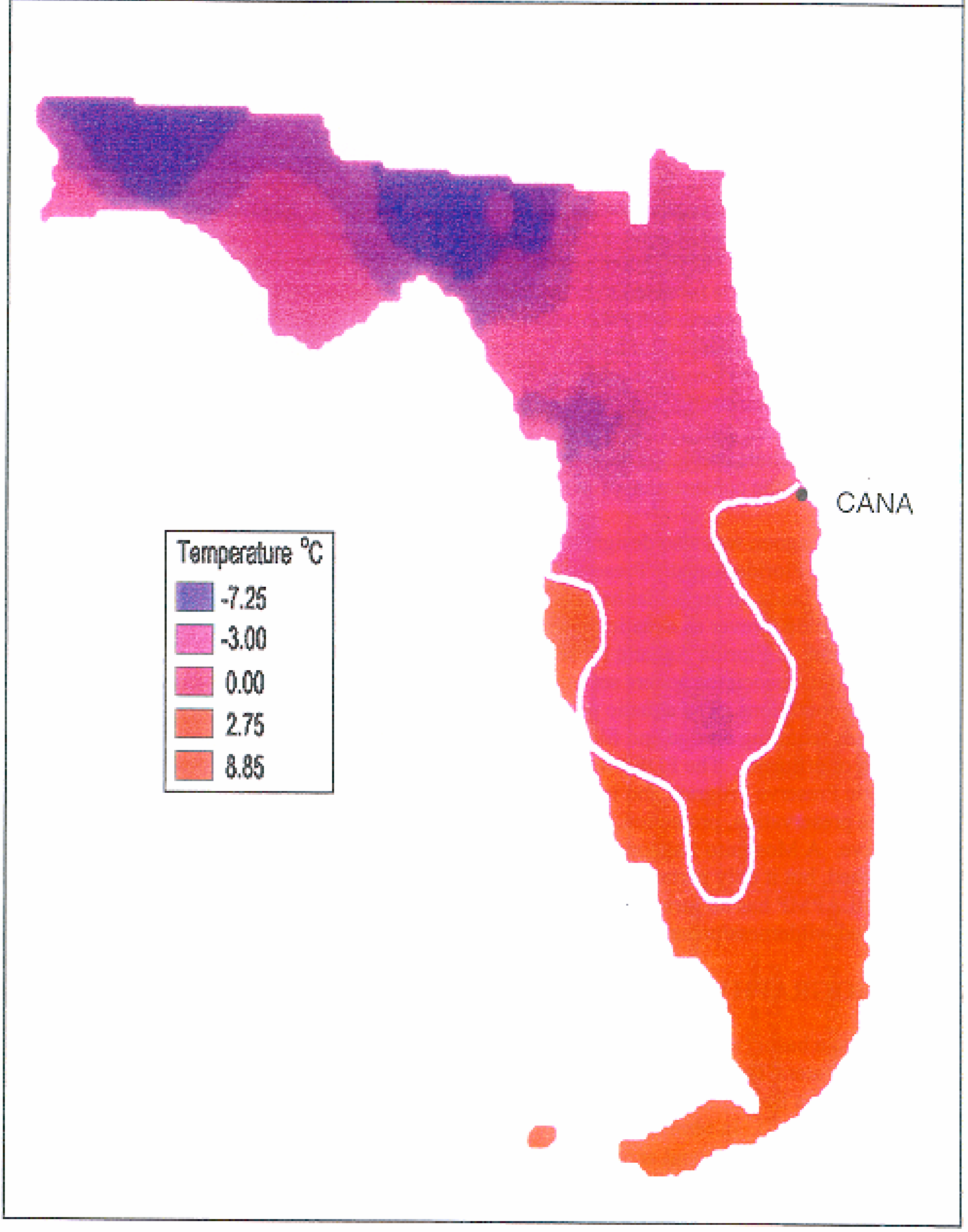
Digitalized from Canaveral National Seashore Master Plan maps (figure 3.3)

UTM Zone 17
5,000 meters grid

11-2000

1:165,000

Figure 2: Map of Annual Freeze Line Through Central Florida
(Average annual minimum temperature for 1982-1993; excluding 1985)



currents (Woodward-Clyde 1994a). This makes Mosquito Lagoon especially sensitive to sudden influxes of pollutants or materials resulting from increasing urbanization, industrialization and agriculture in the watershed (Woodward-Clyde 1994a). Near its southern end, Mosquito Lagoon has been connected to the Indian River proper since construction of the old Haulover Canal in 1854 (Snelson 1983).

The far-reaching, ecological importance of this area has been demonstrated by the variety of agencies that presently protect the waters and biodiversity of Mosquito Lagoon. In April of 1990, the U.S. Environmental Protection Agency (EPA), through the National Estuary Program (NEP), designated Mosquito Lagoon, along with the rest of the Indian River Lagoon complex, as an Estuary of National Significance. The State of Florida also has declared Mosquito Lagoon and the upper Indian River proper as Outstanding Florida Waters (Chapter 17-302.700, Section 403.061, F.S.). An Outstanding Florida Water (OFW) designation is intended to preserve the exceptional ecological or recreational significance of these waters by allowing no action that causes degradation of water quality as defined by a certain baseline period in these areas. The OFW designation supersedes other surface water classifications and water quality standards. With regard to dredge and fill permitting, any project within OFW must demonstrate that it is in the public interest and satisfies OFW regulations before a permit will be issued. Other restrictions include increased requirements for non-point source runoff control and limitations on the construction of non-water dependent structures.

Mosquito Lagoon was also designated as an Aquatic Preserve by the State of Florida through the Florida Aquatic Preserve Act of 1975. This act requires state-owned, submerged lands, in areas that have exceptional biological, aesthetic, and scientific value, to be set aside forever as aquatic preserves or sanctuaries for the benefit of future generations. A Florida Aquatic Preserve is defined as an exceptional area of submerged lands and its associated waters set aside to be maintained essentially in its natural or existing conditions. The aquatic preserve designation substantially restricts or prohibits activities requiring dredge and fill permits, drilling gas or oil wells, and the discharge of wastes or effluents. The FDEP is the agency responsible for the administration of the Aquatic Preserve Program and is required to develop and implement management plans for the preservation, protection, and enhancement of the natural resources of each aquatic preserve. A Mosquito Lagoon Aquatic Preserve Management Plan (MLAPMP) has been published, but it only pertains to the northern lagoon area outside of CANA boundaries. The MLAPMP has no jurisdiction in CANA waters as long as the area is managed for its intended wilderness/preservation purposes (Gardner 1991).

DEMOGRAPHY

A drainage basin (watershed) incorporates the total land area that drains into a common body of water. The Mosquito Lagoon drainage basin includes all or part of the cities of New Smyrna Beach, Edgewater, Oak Hill, and the unincorporated community of Bethune Beach (Figure 3). In terms of area, the Mosquito Lagoon drainage basin covers 168.3 km^2 (42,000 acres) of land area (Woodward-Clyde 1994b). Total surface water area in

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Figure 3. Drainage Sub-Basins in Southeastern Volusia County and Northern Brevard County 1995

Legend:

- Banana River Unit
- Deep Creek Unit
- Halifax River Unit
- Mosquito Lagoon Unit
- North Indian River Lagoon Unit
- Puzzle Lake Unit
- Tosohatchee Unit

- Interstate
- Jeep trail
- Local road
- State road
- US Highway
- County boundaries
- CNS boundaries
- Intracoastal Waterway

Source:
SJRWMD
St. Johns River
Water Management District

UTM Zone 17
5,000 meters grid

11-2000

1:165,000

Mosquito Lagoon is 37,853 acres, almost equivalent to its drainage basin area (Woodward-Clyde 1994b). The Mosquito Lagoon basin has the smallest population size of the three bodies of water that form the IRL system. This has been the case historically and is projected to continue into the future (Woodward-Clyde 1994a). However, this area has had one of the highest historic growth rates in the state, increasing 188% from 1970 to 1990 (Figures 4, 5; Woodward-Clyde 1994a). Rapid growth is projected to continue, with an estimated growth rate of 58% from 1990 through 2010 (Woodward-Clyde 1994a). Table 1 shows population counts by city and Table 2 shows population densities for Mosquito Lagoon compared to the entire IRL system from 1970 through 2010.

Table 1. Populations (# of people) for the major cities in the Mosquito Lagoon drainage basin

City/Community	1990	1997	1999
Edgewater	15,351	18,077	18,507
New Smyrna Beach	16,549	18,425	18,603
Oak Hill	917	1,104	1,432
Ponce Inlet	1,704	2,408	2,525
Total	**34,521**	**40,014**	**41,067**

Table 2. Past, Present, and Future Populations in Mosquito Lagoon Drainage Basin Compared to the Entire IRL System

Year	Mosquito Lagoon Population	Mosquito Lagoon Density (people/square mile)	IRL System (Regional Total)
1970	11,905	183	301,978
1990	34,521	531	678,763
1999	41,067	632	
2010(estimate)	54,520	839	1,082,853

The urban areas are almost exclusively at the northern end of Mosquito Lagoon, with mostly undeveloped land at the southern end (Figures 4, 5). The majority of the undeveloped land in this southern portion is federal property, operating as Kennedy Space Center, Merritt Island National Wildlife Refuge, and Canaveral National Seashore (Figures 4, 5). Note that almost 40% of the total 65 square mile land area of the Mosquito Lagoon basin is owned by the federal government and is unavailable for population growth. When only the available (non-federal) land is considered, the population density in 1990 was closer to 851 people per square mile (psm) and the estimated 2010 density will be 1,353 psm. On this basis, the population density around the northern end of Mosquito Lagoon will be among the greatest along the IRL system (Woodward-Clyde 1994e).

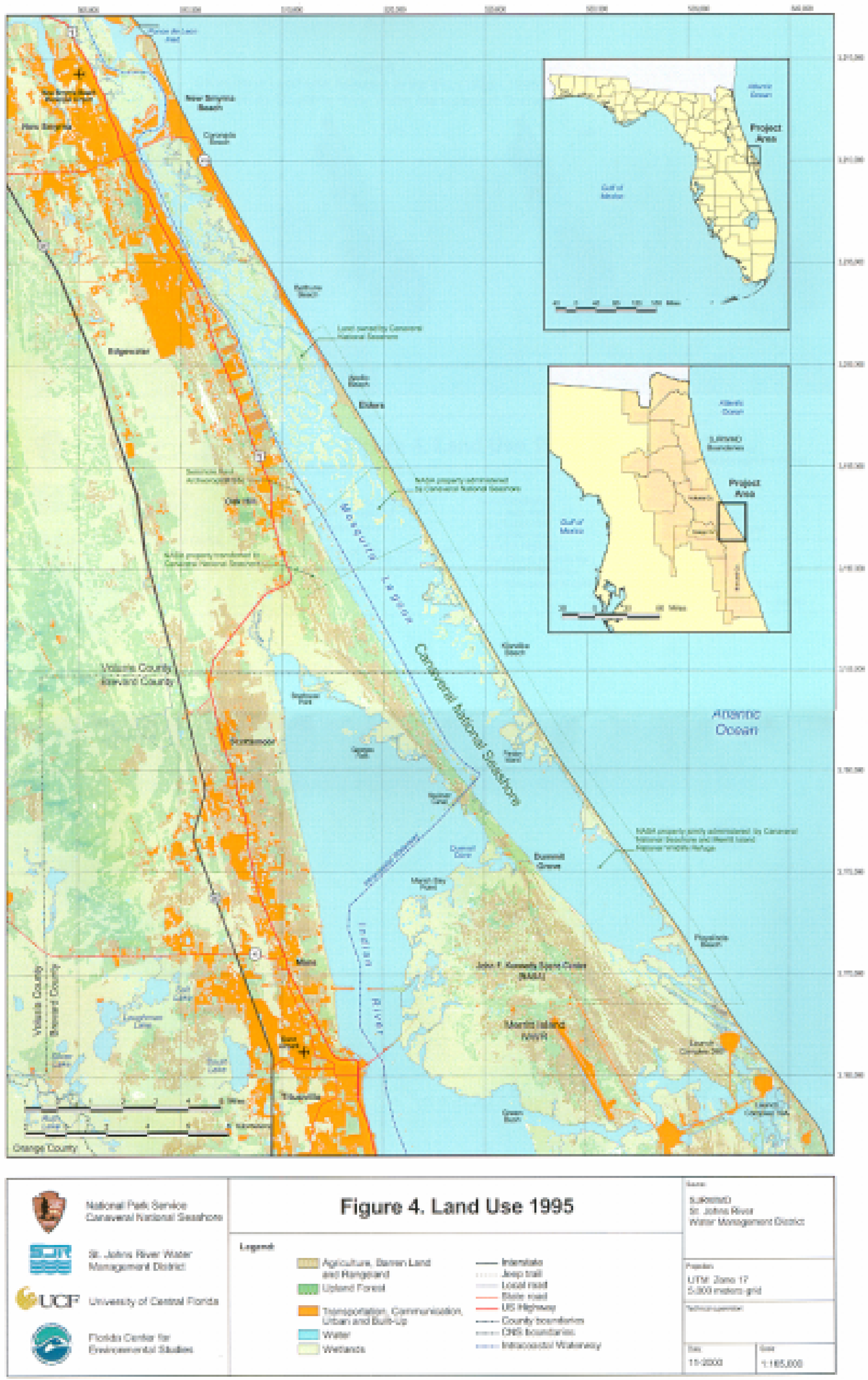
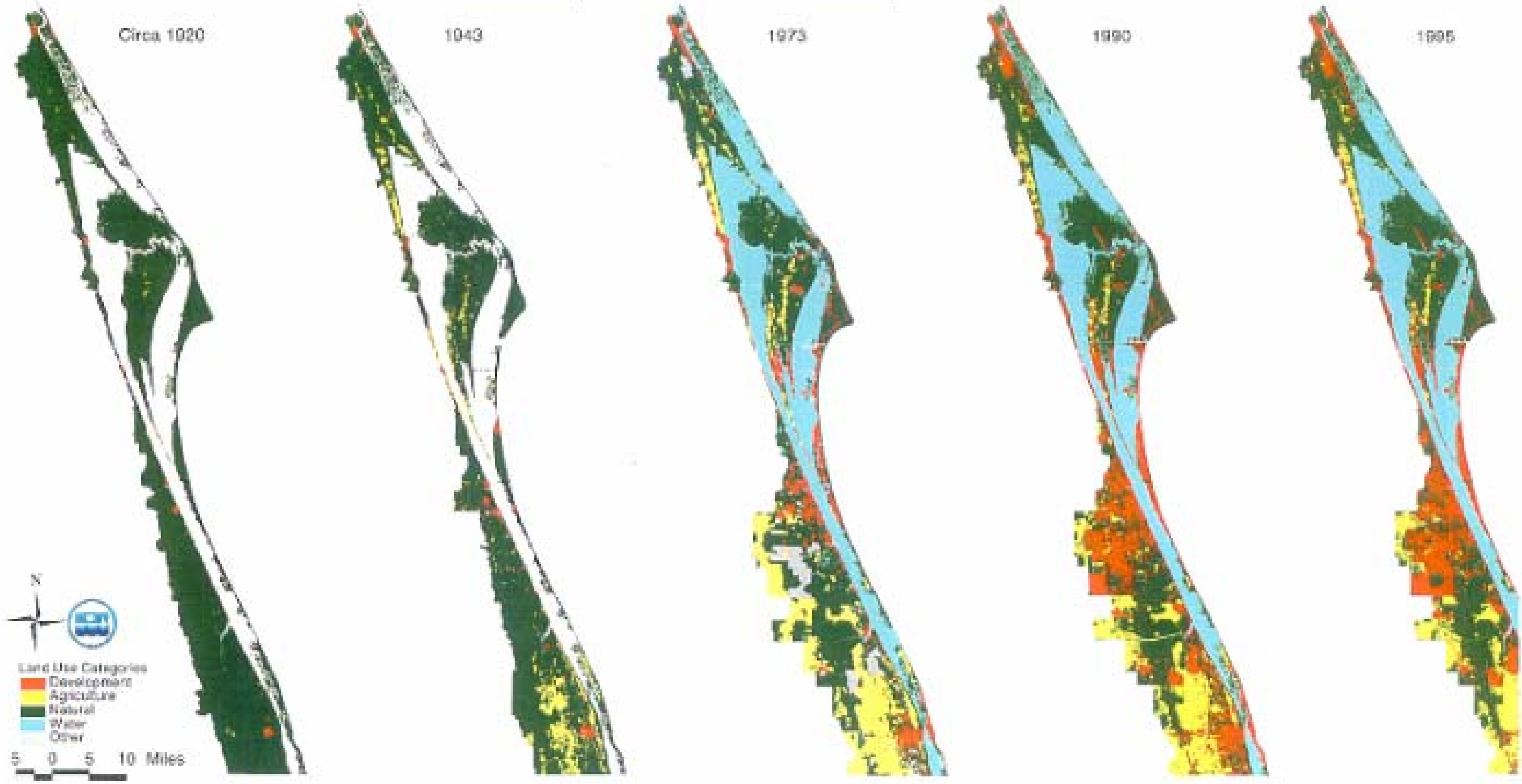


Figure 4. Land Use 1995

Figure 5
Changes in Land Use Adjacent to the IRL (1920 - 1995)
Produced by St. Johns River Water Management District



LAND OWNERSHIP AND LAND USE

The southern two-thirds (about 40,000 acres) of the 58,000 acres in Canaveral National Seashore is owned by NASA (National Atmospheric and Space Association, Kennedy Space Center) (Figure 1). The majority of this area is jointly managed with the United States Fish and Wildlife Service (USFWS) through a cooperative agreement. The adjacent Merritt Island National Wildlife Refuge (MINWR) manages natural resources in the joint area while the National Park Service (NPS) is responsible for interpretation and protection of archeological and historic sites (Interagency Agreement Between NPS and USFWS 1990). The remaining one-third of CANA is owned and managed by the NPS (Figure 1).

CANA and MINWR work closely together to manage the contiguous and overlapping ecosystems. While the missions of the National Park Service and U.S. Fish and Wildlife Service are not identical, they are compatible. MINWR was established in 1963 "for use as an inviolate sanctuary, or for any other management purpose, for migratory birds" as stated in the Migratory Bird Conservation Act of 1929 (16 U.S.C. 715 d). The mission statement provides more detail and adds threatened and endangered species, public use and environmental education. It reads: "to protect, enhance, and manage wetlands and uplands for biodiversity and for the benefit of all species native to Merritt Island National Wildlife Refuge; provide feeding, resting, and wintering habitat for waterfowl and other migratory birds; protect and manage threatened and endangered species and their habitats; and provide opportunities for compatible public recreation and environmental education".

The Park maintains a number of facilities to accommodate approximately 1.5 million visitors per year (Figure 6). CANA headquarters is located in downtown Titusville. There is a visitor information center in the North District of CANA. The Merritt Island National Wildlife Refuge is accessible to the general public from the southernmost region of CANA (Figure 6). To provide the opportunity to experience an uncrowded, undeveloped beach, the number of parking spaces has been limited and the beach is closed to public vehicles. Five public boat launches are available (Figure 6). From north to south, the first boat launch is at Shipyard Island (approximately 500 yards south of the north Park entrance, accessible via Route A1A). Two launches are located along the central, mainland side of Mosquito Lagoon (off of S.R. 3). The fourth is adjacent to Haulover Canal (off S.R. 3) and the fifth is at Eddy Creek near Playalinda Beach (off S.R. 402). Other public launches are located just outside the park at Edgewater, Bethune Beach, and Oak Hill. Other popular attractions at CANA include Eldora House, Turtle Mound, walking trails, campgrounds on some of the small barrier islands (accessible only via boat), fishing, and horseback riding during the winter months (Figure 6). Fellers House Field Station, maintained jointly by CANA and the Biology Department at the University of Central Florida, is located directly south of Eldora House on the Lagoon and is used by university faculty and their students to better understand biodiversity within the Park.

Figure 6. Facilities of CANA

In contrast to the minimal development of the southern portion of Mosquito Lagoon, the northern 1/3 of these waters are bordered by several cities on the east and west shores, and trailer parks with septic tanks in the unincorporated areas of the western shore. Because of the proximity of these communities to the Park, the State of Florida specified, in the deed transferring lands to the NPS, that the Park would cooperate with the local mosquito control districts to control mosquitoes. A cooperative agreement between CANA and the East Volusia Mosquito Control District allows the application of larvicides when necessary and maintenance of existing mosquito control ditches. These two agencies and SJRWMD are also working to utilize non-chemical methods of mosquito control and to restore wetlands through the removal and breaching of dikes that surround mosquito impoundments.

The Intracoastal Waterway (ICW), whose maintenance and operation is under the jurisdiction of the U.S. Army Corps of Engineers (ACOE) and the Florida Inland Navigation District (FIND), forms the northwestern boundary of CANA for a distance of 8 miles (Figure 6). It then extends into the Park for another 10 miles before exiting through Haulover Canal (Figure 6). The ICW was dredged to its present size of 125 feet wide by 12 feet deep in 1952. Since then, the ICW in the vicinity of CANA has not been maintenance dredged and will be re-dredged only when and where it is needed. The section of the ICW within CANA boundaries is scheduled for maintenance dredging sometime after 2005 (D. Roach, pers. comm., Florida Inland Navigation District, 2000). Dredging and the environmental monitoring of the dredging activity will be overseen by the ACOE and FIND. Dredged material from the next ICW dredging within CANA, the central portion of Mosquito Lagoon, will be pumped to an upland dredged material management site in Oak Hill, just west of the northernmost mainland boundary of CANA (Figure 7).

There are about 150 acres of non-active orange groves near Haulover Canal (Figure 6). These groves have been inactive since the early 1990's but are still managed by the U.S. Fish and Wildlife Service (USFWS). In 2008, pending funding, USFWS plans to phase out the citrus groves and restore the areas to their natural state (F. Adrian, pers. comm., MINWR, 2001).

A Boston Whaler plant, located between Edgewater and Oak Hill, is currently the only boat manufacturer along Mosquito Lagoon. Volusia County has been working with the Volusia County Business Development Corporation to obtain suitable property and attract boat manufacturers and other water-related industries to the area. In the future, a 60-acre site (formerly a concrete plant) adjacent to Boston Whaler could become a commerce park for marine-related industries.

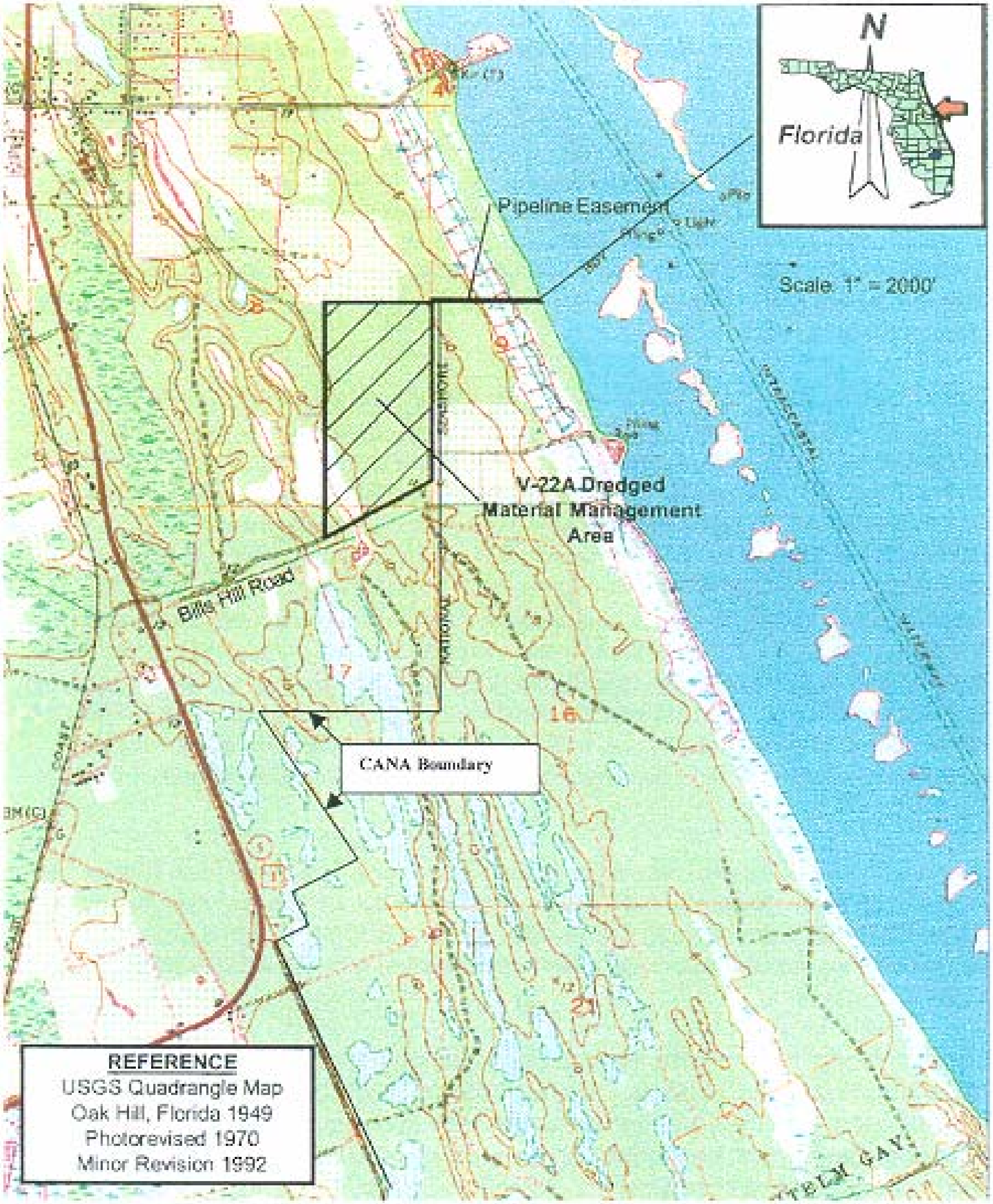


Figure 7. Location of V-22A Dredged Material Management Area, Volusia County.

(From Management Plan V-22A Dredged Material Management Area prepared for FIND by Taylor Engineering, Inc., Jacksonville, FL, June 1997. Used with permission of FIND).

Park boundary has been added and is approximate.

PURPOSE OF WATER RESOURCES MANAGEMENT PLAN

Whether in support of natural systems or providing recreational opportunities for visitors, water is a very important resource in National Park Service units. Consistent with its fundamental purpose, the National Park Service seeks to perpetuate surface and ground waters as integral components of park aquatic and terrestrial ecosystems by carefully managing its consumptive use of water. It also strives to maintain the natural quality of surface and ground waters in accordance with all applicable federal, state, and local laws and regulations. In addition, water-based recreation such as swimming, fishing, and boating, as well as the health of the estuarine ecosystem, are dependent upon the maintenance of adequate water quality.

The enabling legislation of CANA calls for the National Park Service to protect and interpret the ecological and historic resources. At the same time, the National Park Service must facilitate public use, both now and in the future. In order to achieve these goals, National Park Service policies require that each unit of the National Park System develop and implement a General Management Plan. The Canaveral National Seashore General Management Plan, adopted in 1981, provides the overall basis for managing recreational usage, resource protection, and Park development (National Park Service 1981). This General Management Plan recognizes that management of CANA's resources must involve coordination among numerous landowners, as well as participation by all concerned individuals and special interest groups. Due to its age, a major revision of this General Management Plan is in order. However, to date, no time frame for this revision has been determined.

Water resources planning for a unit of the National Park System typically involves several steps. The planning starts with consideration of the reasons for the Park's establishment, identification of the exceptional water-related resource values of the Park, and articulation of management objectives. These have been identified in CANA's General Management Plan (National Park Service 1981). The Resource Management Plan for Canaveral National Seashore (National Park Service 1997) then expands on the Park's cultural and natural resources presented in the General Management Plan. The Resource Management Plan summarizes Park resources, available baseline information, current resource management programs, and resource issues. It also contains project statements to address specific problems.

Because Canaveral National Seashore is a water-dominated system, numerous water-related issues naturally exist. For this reason, land use within and adjacent to Mosquito Lagoon, or anywhere in the watersheds, connected by either groundwater or surface water, has the potential to affect CANA's natural resources. This Water Resources Management Plan provides resource-specific information to support the decision-making process related to the protection and management of CANA's water resources and water-dependent environments. This plan also includes a review of available information on CANA's water resources and water-dependent environments and descriptions of significant water resources management issues, including constraints on water management brought about by Canaveral National Seashore's enabling legislation.

Finally, the plan provides a recommended strategy for water resources, including recommended actions for inventory, monitoring, and research. These recommendations are identified as water-related project statements, consistent with guidelines of the National Park Service, and are designed to be incorporated into the Canaveral National Seashore Resource Management Plan (National Park Service 1997). These actions address the water resource issues within the context of the management objectives. The common thread between management actions, issues, and management objectives is the cornerstone of issue-driven planning.

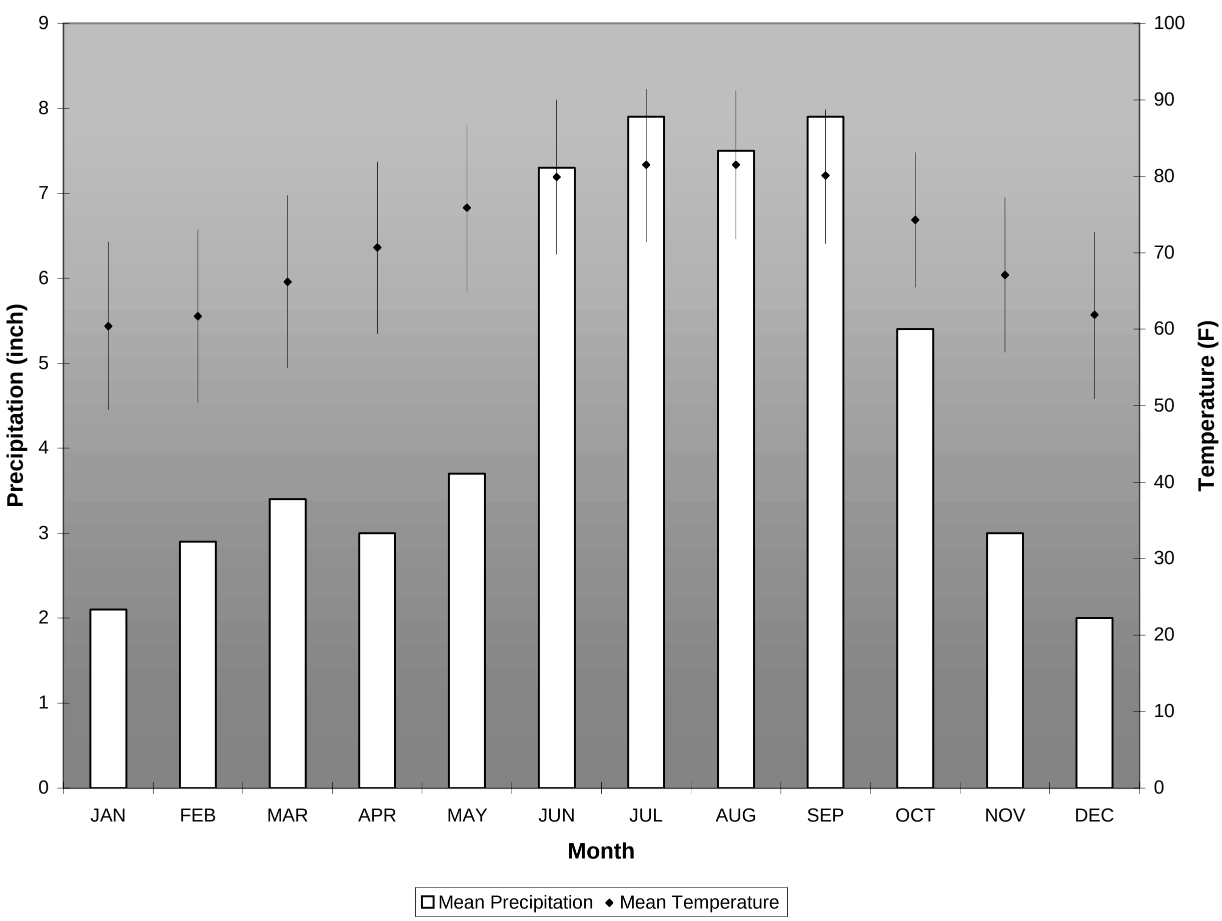
CANA's General Management Plan addresses the need for specific action-oriented resource management plans and research for long-term preservation of Canaveral National Seashore. This Water Resources Management Plan is such an action plan, designed to guide Canaveral National Seashore's water-related research activities over the next 5 to 10 years. It provides information on potential threats to water resources and guidance on immediate research actions that can lead to prevention or mitigation of water resource degradation. It must be complimentary to, and consistent with, other existing Park management documents, including the General Management Plan (National Park Service 1981) and the Resource Management Plan (National Park Service 1997). Information included in this Water Resources Management Plan will be used to steer some of the water resource sections when the General Management Plan is revised.

DESCRIPTION OF WATER RESOURCES

CLIMATE

CANA is situated between 28°38' and 28°58' north latitude on the east coast of Florida (Figure 1). This region lies within a transition zone of warm temperate to subtropical climates (Figure 2). The summers are very hot and humid, and the winters are generally mild. However, freezes lasting several days are occasionally recorded (Doehring and Barile 1988). These freezes can have severe impacts on the biota and economy of the region. For example, the January 1985 freeze (19 degrees F in Titusville) resulted in the death of mangrove forests, Australian pines, juvenile sea turtles and fish in CANA. Mean monthly temperatures between 1901 and 1996 are presented in Figure 8.

Figure 8. Monthly mean precipitation (1931 – 1995) and air temperature range (1901 – 1996), Titusville, FL (National Climatic Data Center 2000).



The relatively stable climate of CANA is influenced by the fact that: 1) it is part of the Florida Peninsula, 2) it is directly adjacent to the Atlantic Ocean, and 3) it has the warm Gulf Stream of the Atlantic Ocean passing close offshore (Woodward-Clyde 1994b). The proximity of Mosquito Lagoon to this large body of water keeps this east coastal region of Florida slightly warmer in the winter and slightly cooler in the summer than the inland areas. This is due to the predominantly easterly winds blowing inland from the ocean (Woodward-Clyde 1994b). A comparison of 40 years of daily temperature data from Merritt Island and Titusville, a few miles inland and the location of CANA headquarters, found 30 freezing days at Merritt Island versus 121 days in Titusville (Provancha et al. 1992).

Rao (1987) collected data on rainfall between 1951 and 1980 in Mosquito Lagoon and found 48-56 inches (122-142 cm) annually and, on average, there are 148 days per year with measurable rainfall. The NOAA rainfall station in New Smyrna Beach has recorded the most rainfall for 24 hours during this period in the IRL region with 21.98 inches (Rao 1987). Regionally, however, there is slightly less rainfall in Mosquito Lagoon than in the Banana River or Indian River (Provancha et al. 1992). The distribution of rainfall is bimodal, with approximately 65% of the precipitation falling between May and October as a result of convection cells and tropical storms. Winter and spring rainfall generally results from passage of frontal systems. Figure 8 presents the average monthly rainfall from 1931 to 1995 for the region. In general, little rainfall is recorded from November to May of each year and moisture surpluses occur annually between June and October. However, recent global climatic events (e.g. El Nino, La Nina) have extended the drought period, while concurrently increasing salinity and water temperatures. For example, during the summer of 1998, severe fires burned throughout central Florida and salinities as high as 45 ppt and water temperatures greater than 95 degrees F were reported in the northern sections of CANA (L. Walters, unpublished data). In the southern reaches of Mosquito Lagoon, recent summer salinities have reached 55 ppt for extended periods of time (G. Ehlinger, pers. comm., Florida Tech, 2000). These extremely high temperatures suppress dissolved oxygen levels and accelerate the rate at which sediments become anoxic or anaerobic (Windsor 1988). This in turn kills many organisms, especially sessile invertebrates and submerged aquatic vegetation (L. Walters, unpublished data).

Evapotranspiration values at nearby Cape Canaveral averaged 37 inches (94 cm) per year (Mailander 1990). May was the month with the highest insolation due to the low number of convective thunderstorms, while December was the month with lowest insolation (Mailander 1990). Solar elevation ranges from a maximum of 85.5 degrees above the horizon on June 21 to a minimum of 38.5 degrees on December 21 (the longest and shortest days of the year, respectively). During the summer wet season, wind is predominately from the east (Mailander 1990). Winter (dry season) winds are predominately from the north and north-northwest. Relative humidities are consistently above 75% in the Mosquito Lagoon region.

Intense storms can impact CANA throughout the year, as the entire Park is located within the 100-year flood plain (Figure 9). In the winter/spring months, northeasters of temperate origin occur; in the summer/fall months, tropical depressions, tropical storms and hurricanes dominate the weather. Northeasters typically cause heavy erosion on the barrier island with heavy rains and gale force winds. Hurricanes (> 73 mph) have high winds, extremely high tides, large waves and often very large amounts of rain. Thirty-four systems (tropical storms + hurricanes), including 1999 Hurricanes Dennis, Floyd, and Irene, have struck within a 50-mile radius of Melbourne, Florida between 1871 and 1999. Tropical depressions (winds < 39 mph) and tropical storms (39 – 73 mph) may also cause flooding and some wind and wave related damage. High winds and waves associated with these storms increase water turbidity by entraining bottom sediments. Turbidity adversely impacts shellfish, seagrass and other biological resources. Wind-driven currents may also increase the dispersion of nutrients and contaminants throughout the Lagoon (Windsor 1988).

In addition to the land-based stations, there are several weather buoys off the east coast of Florida. The closest one to Mosquito Lagoon is 20 nautical miles east of Cape Canaveral (28º30'01"N, 80º10'03"W). This weather buoy records air temperature, wind speed and direction, sea temperature, barometric pressure, and wave height. Recent data from these buoys can be retrieved from the National Data Buoy Center station information website at: http://www.ndbc.noaa.gov/.

PHYSIOGRAPHY

The entire state of Florida is located on the Floridian Plateau (Fernald and Patton 1984). The plateau is approximately 500 miles in length and between 250-400 miles in width (Fernald and Patton 1984). The plateau includes both emergent land and submerged continental shelf. This plateau has existed for millions of years and has been alternately covered by seawater and exposed as dry land many times. This has created areas where marine and terrestrial deposits have been deposited one on top of the other.

The barrier island complex, including the Mosquito Lagoon sub-basin, has taken an estimated 240,000 years to form and is the result of multiple rises and falls in sea level (Fernald and Patton 1984). More specifically, the east coast of Florida is formed mainly by eroded relict dune lines and broad marine terraces, as well as the present barrier islands and lagoon system. Terraces were formed during the high stillstands, which allowed erosion by waves and currents to form flat plains that emerged as flatlands when the sea level subsided (Brooks 1982; Glatzel 1986). The lowest terrace in the Mosquito Lagoon watershed is called the Silver Bluff Terrace. As the sea level receded, dune ridges, including the Atlantic Coastal Ridge, formed on this terrace (Schnable and Goodell 1968). The Mosquito Lagoon drainage basin is bordered by the Atlantic Coastal Ridge on the west and the Atlantic Beach Ridge (Barrier Islands) on the east.

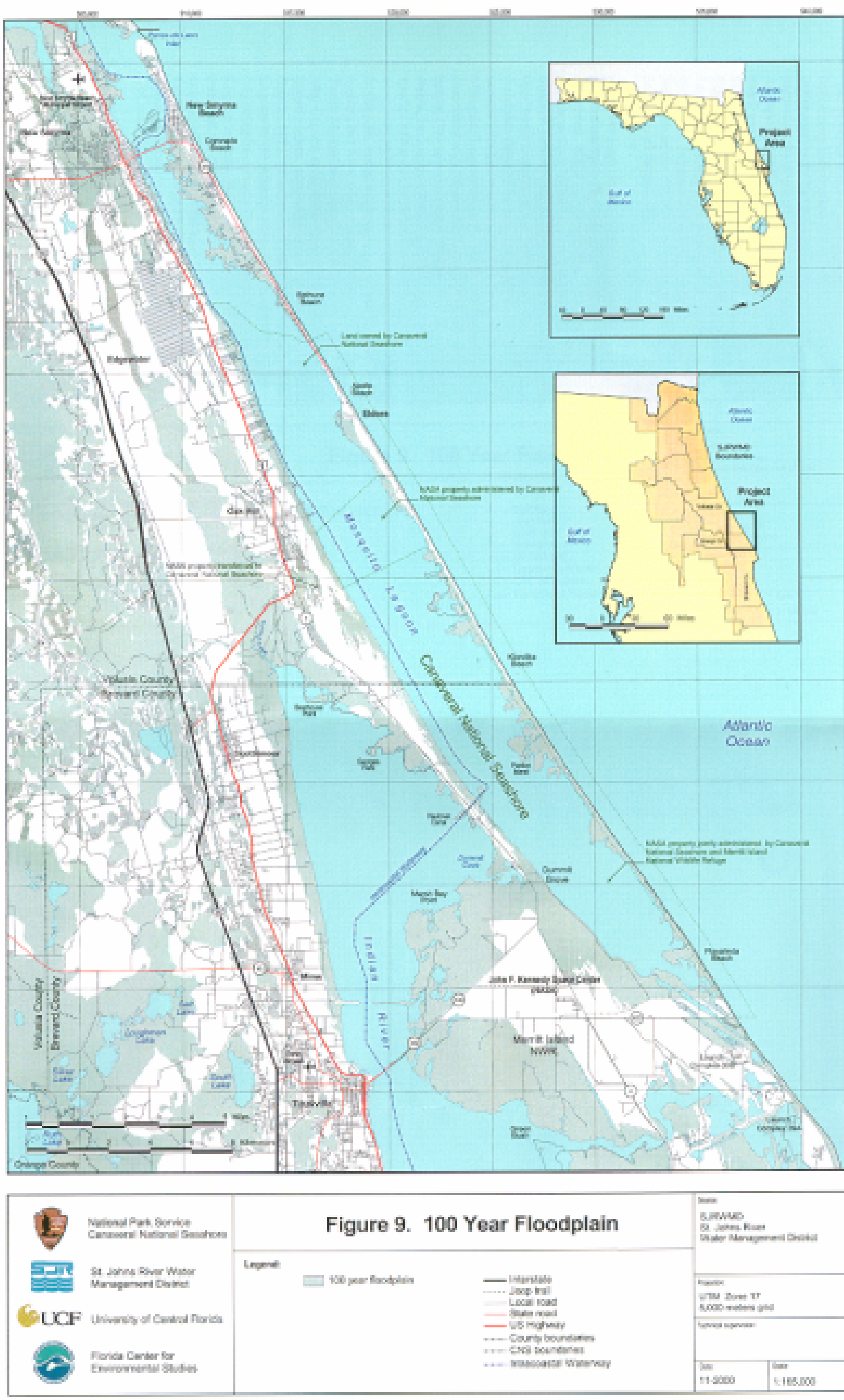


Figure 9. 100 Year Floodplain

The physical features presented here represent a compilation of existing information concerning the physical characteristics of the Mosquito Lagoon sub-basin. An understanding of these features is critical since they determine the ecosystem. In particular, the physical features determine biological habitats, define the sources and transport of pollutants, and outline human usage. For over a century, many large and small projects have been carried out throughout the IRL to aid navigation, drain floodwaters, control mosquitoes, provide access to the barrier islands and stabilize tidal inlets. These projects have substantially changed many of the physical features of the Lagoon, including infiltration, runoff, shallow-aquifer storage and land drainage capacities. In some cases, such as the mosquito impoundments, where the natural functions of the IRL have been degraded, efforts are presently underway to return the habitat to its natural state.

Mosquito Lagoon was created by a small number of physiographic features. A predominant physiographic land feature of the barrier island system in this area is Cape Canaveral. Cape Canaveral was described by Stauble (1988) as a "cuspate foreland" similar to Cape Hatteras in North Carolina, in which a sandy cape has developed where offshore currents meet. The Mosquito Lagoon barrier islands were created, in part, by this "cuspate foreland" of Cape Canaveral (Stauble 1988). Additionally, to the north, the flood tide delta of the migrating (until stabilized) Ponce de Leon Inlet and a now-closed second inlet that was located near Bethune Beach influenced the physiography of Mosquito Lagoon (Stauble 1988). Unlike many barrier islands, the barrier islands associated with Mosquito Lagoon have only a single dune ridge averaging 12 feet in height (Woodward-Clyde 1994b). For the vast majority of its length, the dune is quite stable, backed by a dense growth of saw palmetto (*Serenoa repens*) and several other species of hardy shrubs and grasses (National Park Service 1997).

In the past, many inlets have been formed across the Mosquito Lagoon barrier island system, but have since naturally closed. The most recent of these inlets was located near Turtle Mound and closed around 500 AD (Mehta and Brooks 1973). Vegetated flood-tidal (lagoon side) deltas and oyster beds in the geological strata are remnants of these historic inlets, suggesting that these areas were once open to tidal flushing (Mehta and Brooks 1973; Woodward-Clyde 1994b). The only present-day connection of Mosquito Lagoon to the Atlantic Ocean is through Ponce de Leon Inlet (Figure 1). This naturally migrating inlet marks the northern end of both Mosquito Lagoon and the Indian River Lagoon system. Because of the dynamic behavior of the shoreline on both sides of the inlet and the shoaling of its mouth, a stabilization project by means of jetties was conducted between 1968 and 1972 (Woodward-Clyde 1994b). Presently, the direction of longshore currents and associated erosion and deposition associated with the stabilized Ponce de Leon Inlet is not well understood and differs between models (e.g. Stauble and DeCosta 1987; Taylor et al. 1991).

Some areas along the barrier island of Mosquito Lagoon are very narrow, which makes them susceptible to over-wash and likely spots for inlet formation. In the fall of 1999, small, "temporary inlets" were formed from over-wash at several spots along the barrier island during storms associated with the hurricane season. These overwashes may become larger and more frequent if hurricane intensity and frequency increase. Also, if global warming continues as predicted, sea level rises will acerbate these impacts.

The only direct hydraulic link between Mosquito Lagoon and the Indian River proper is through Haulover Canal, a man-made canal constructed to replace an overland system of transporting boats (Figure 1). The original Haulover Canal was excavated in 1854 but is no longer in use (Hutchinson 1987). In 1887, a larger canal was built approximately one-half mile to the north through the Cape Canaveral Complex Ridge and is still used today. In the past, Mosquito Lagoon may have been connected to the rest of the IRL system to the south by channels north and west of Cape Canaveral (Mehta and Brooks 1973; Almasi 1983).

ESTUARINE SETTING

The Indian River Lagoon (IRL) System stretches 156 miles from Ponce de Leon Inlet at the northern end to Jupiter Inlet at the southern end and covers a full 40% of Florida's east coast (Figure 1). Despite its name, the Indian River Lagoon is not a river. It is an estuary – a water body in which the mixing of fresh and salt water occurs. Ocean water enters the IRL system through inlets, while freshwater enters the Lagoon through rainfall, groundwater seepage, and as discharge from streams, creeks, rivers and canals. The salinity profile of a particular segment of the Lagoon depends on its proximity to inlets and freshwater inputs and the specific physical and geographic features of the area.

Estuarine communities cover much of the Atlantic and Gulf coasts of the United States and are characterized by both high productivity and high biodiversity (Provancha et al. 1992). In fact, estuaries are among the most productive ecosystems on earth (Bertness 1999). High primary productivity of estuaries reflects their nutrient-rich conditions and the presence of many primary producers, including micro- and macroalgae, seagrasses and emergent grasses, scrub, and trees. These primary producers in turn provide important spawning and nursery habitat for many species of fish and invertebrates. Approximately 72% of commercial and 74% of sport species of fish and invertebrates must spend all or part of their lives in or associated with an estuarine system (Durako et al. 1988).

Estuaries serve as buffers between the oceans and the land, providing an important ameliorating zone for storms and floods. For example, a fringe of salt marsh only 8 feet wide can reduce wave energy by over 50%. Estuaries also serve as important sinks for materials (nutrients and contaminants) that flow from the land, catching pollutants before they reach the ocean (Durako et al. 1988). Additionally, estuaries can be very important to the recreational and tourism industries and serve as important transportation routes (i.e. ICW).

Three distinct bodies of water make up the IRL system: the Indian River, the Banana River and Mosquito Lagoon. Mosquito Lagoon is the northernmost sub-basin of the IRL system and is a bar-built type estuary occupying 152.8 km^2 (Clapp 1987). Canaveral National Seashore is responsible for maintaining and protecting a large portion of Mosquito Lagoon. Unfortunately, as the background information in this Water Resources Management Plan will point out, many aspects of the biology and geology of Mosquito Lagoon have not yet been adequately addressed. Issues deemed most critical by scientists and CANA Resource Managers will be addressed in the final section of this report as project statements.

SOILS

The soils comprising the Indian River Lagoon watershed are characterized by location-specific geologic, hydrologic and biological factors. Soil surveys of this region are currently being conducted by the State of Florida. Overall, in the Mosquito Lagoon region, four types of landforms and associated soils can be found (Woodward-Clyde 1994b). Barrier island sands are sandy throughout, frequently contain shell fragments, and are classified as either well drained or excessively drained (Figure 10). Well-drained soils are defined as soils that are very permeable and have high infiltration rates. Excessively drained soils have a wet season water table greater than six feet deep and are generally permeable. Soils from the mainland coastal ridge vary from excessively drained to poorly drained. Some mainland coastal ridge soils have weakly cemented, sandy subsoil that is underlain by loam. Soils of the flatwoods are very level and poorly drained. Most have a sub-soil that is sandy in the upper layers and loamy in the lower portions. Flatwood sub-soils also frequently contain organic matter or iron. Finally, tidal marsh soils are nearly level and range from poorly to very poorly drained. Some tidal marsh soils are organic throughout, while others have stratified layers of sand and clay. Soil types are very important due to the presence of septic tanks along the edge of Mosquito Lagoon.

DRAINAGE PATTERNS AND WATERSHED BOUNDARIES

The present-day Mosquito Lagoon drainage basin boundaries are much the same as the natural boundaries that existed prior to the permanent arrival of Europeans in the 1700's (Table 3; Woodward-Clyde 1994b). The drainage basin is defined as the total land area that drains into the body of water, whereas the watershed includes the land area as well as the water body.

TABLE 3: Drainage Basin and Watershed Areas

Mosquito Lagoon		Drainage Basin		Total Watershed	
km^2	Acres	km^2	Acres	km^2	Acres
159	37,853	168	42,000	327	79,422

The Mosquito Lagoon watershed is located entirely within Volusia and Brevard Counties (Figure 3). The Mosquito Lagoon drainage basin consists of at least two, and possibly five sub-basins. The largest is the Mosquito Lagoon sub-basin (38,183 acres). It includes the area draining to the Lagoon by direct overland flow, sub-surface flow and

National Park Service Canaveral National Seashore
St. Johns River Water Management District
University of Central Florida
Florida Center for Environmental Studies

Figure 10. Infiltration Rates

Legend:
High infiltration rate
Moderate infiltration rate
Moderate or very low infiltration
Low infiltration rate
Low to very low infiltration rate
Very low infiltration rate
Urban
Interstate
State road
US Highway
County boundaries
Intracoastal Waterway

drainage ditches (Woodward-Clyde 1994b). The smaller basin is a well-defined area called the Florida Shores sub-basin (3,386 acres), located within the city of Edgewater. There are several minor man-made drainage ditches that extend the natural watershed to the west and discharge into the Lagoon as well as a few very small (< 5000 feet) natural creeks (Figure 3). One area of concern is a large man-made canal that drains the city of Oak Hill. This drainage canal empties untreated water into two mosquito impoundments, which eventually spills over into Mosquito Lagoon. The limits of the natural and artificial sections of the watershed have not been thoroughly mapped in the northernmost portion of the Indian River Lagoon. Thus, the relative effects of each drainage basin on the Lagoon and the influence of specific drainages cannot be presently assessed (Woodward-Clyde 1994a, b).

SURFACE WATERS

COASTAL HYDROLOGY

Volusia County is home to some of the world's most popular beaches. It is an area with a huge tourism industry that frequently pushes the limits of coastal development. Houses and condominiums are built right near dune edges and these structures often require protection from dune retreat. Most commonly, seawalls are built to combat the power of the waves. The overall impact of seawalls on the surrounding area is mostly negative and permits are only issued as a last resort.

There are several important studies that help describe the hydrology along the southeast Atlantic coast (e.g. Mehta and Brooks 1973; Dolan 1982). The most recent coastal study was by Allen (1991) who helped determine the impact of a revetment in Bethune Beach, immediately north of CANA's boundary. This six-year monitoring program (1984-1989) found that shoreline retreat only occurred during intensive storms and little erosion was conclusively linked to revetment. The data suggested, however, that an increase in sea level or storm frequency will accelerate dune erosion, especially near the revetment (Allen 1991). Overall, it was shown that the high fore dune ridge has undergone sporadic retreat during the past 40 years and, despite interludes of stability, net erosion is the present trend. Comparison of accurately mapped Mean High Water shorelines for the years 1874 and 1979 indicated net erosion north of Turtle Mound and net accretion southwards.

This study also found that the revetment has added to an amplification of the offshore sand-bar/trough morphology. This change in offshore topography could have an affect on rip currents, placing Park bathers in danger. Additionally, it negatively impacts beaches associated with seawalls.

The regional longshore sediment transport system does not appear to be a simple net movement from north to south (Walton 1976), and may consist of a series of cells with convergent and divergent points along the shore (Stapor and May 1983). In general, the longshore current of Volusia County is primarily southward (Allen 1991).

ESTUARINE HYDROLOGY

Mosquito Lagoon is the northernmost segment of the IRL system. Approximately one half of the area is located in Volusia County, while the southern half is in Brevard County (Figure 1). The Lagoon is 34 miles long, accounting for 22% of the length of the entire IRL system. The average depth of Mosquito Lagoon is 1.3 meters, while the surface area is 37,853 acres (Mendonca 1983; Woodward-Clyde 1994b). The volume of Mosquito Lagoon is approximately 2.3×10^8 m^3 of water (Provancha et al. 1992). Natural and spoil islands are very abundant in the northern section of Mosquito Lagoon. The high number and density of these islands form many constricting channels which results in limited tidal flushing between the inlet and the southern reaches of the Lagoon. The southern section of Mosquito Lagoon is mostly open water with fewer islands.

The tides along the east coast of central Florida are classified as semi-diurnal. The only regular exchange of water with the Atlantic Ocean is via the twice-daily tidal flushing through Ponce de Leon inlet at the northern end of the Lagoon. The spring tide range at this inlet is approximately 0.82 meters (NOAA 1993). The distance that a water molecule moves on either the flood or ebb portion of the tidal cycle is called the excursion distance (Smith 1988). The long, narrow shape of Mosquito Lagoon, in combination with its shallow depths and intricate set of islands, results in short excursion distances (Woodward-Clyde 1994a). As the flood tide enters Mosquito Lagoon, increased bottom friction of this shallow system causes a steady reduction in the height of the tide and the resultant tidal currents (Smith 1990). As a result, the excursion distance into Mosquito Lagoon only reaches points just south of Edgewater (Woodward-Clyde 1994a). According to Taylor et al. (1991), tidal excursion from the inlet may extend as far south as Oak Hill, about 15 miles from the inlet. This means that the ocean water entering the Lagoon is not carried far by the direct effects of the astronomical tide currents (Woodward-Clyde 1994b). Therefore, the central and southern portions of the Lagoon are subject to very poor circulation and flushing with ocean waters.

A study by Taylor et al. (1991) indicated that the water level variations south of the Volusia County line were not due to the astronomical tide currents from Ponce Inlet, but rather due to the effects of wind. Because Mosquito Lagoon is long and narrow, wind can have significant effects on water levels (Woodward-Clyde 1994b). The long, shallow stretches of Mosquito Lagoon provide suitable time and space for wind stress to blow water away from the windward shore and decrease the water level while accumulating it up on the leeward shore and raising the water level (Woodward-Clyde 1994b). Strong, north winds are most frequent in winter months and may cause a decrease in water level in the northern section of the Lagoon. Strong southeast and east winds may cause a decrease in water level in the southern sections of the Lagoon. These wind effects do not have the predictable periodicity of astronomical tides. However, these weather-related non-periodic water level changes are often equal, or sometimes greater, in height to astronomical tides, and they are often referred to as meteorological tides.

Meteorological currents are thought to be the only significant currents capable of moving water throughout most of Mosquito Lagoon (Woodward-Clyde 1994b). The semi-diurnal characteristic tide of Florida's east central coast was not seen at the tide station in the southern part of Mosquito Lagoon (Taylor et al. 1991). A single daily high and low water level, with a range of only 0.15 meters was observed at this station. This single diurnal tide pattern demonstrated that in the southern, open portion of Mosquito Lagoon, wind driven currents and associated water level changes dominate the hydrodynamics (Woodward-Clyde 1994b). This is important because, under certain conditions, there can be virtually no mass flow or mixing of water in the central and southern portions of the Lagoon and consequently no flushing of nutrients or pollutants from the estuary (Woodward-Clyde 1994b).

The rise and fall of the ocean tide is the predominant driving force of water and pollutant flushing into and out of the estuary through Mosquito Lagoon's only inlet. In general, marked differences exist between offshore and estuary tidal ranges, especially in Mosquito Lagoon. Offshore, the average range from high water to low water is about 4.0 feet. Moving into the estuary, the tidal range begins to drop. At Edgewater (approximately 9 miles south of Ponce Inlet) the range is 2.1 feet, while the range drops to 0.5 feet at the south Volusia County line, 13 miles farther south (Table 4).

Table 4. Observed Tidal Range, Phase, and Distance from North Offshore Station

	Offshore	**Edgewater**	**South County Line**
Distance (miles)	0	6	19
Mean Range	4.0 ft	2.1 ft	0.5 ft
Phase Difference			
• **High Water**	0	+1.3 hrs	--
• **Low Water**	0	+1.0 hrs	--

An exception to the semi-diurnal tidal pattern normally observed in other areas is the diurnal pattern in the southern portion of Mosquito Lagoon (South Volusia County Line). Since the range diminished somewhat during neap (minimum tidal range) conditions, around June 10, some astronomical influence may have been responsible. However, wind records revealed the occurrence of significant east winds during the 23-day sampling period. The effect of this was to push water toward the western half of the Lagoon, thereby lowering the water level in the eastern half, where the tide gauge was located. Thus, observed diurnal tidal patterns in this area can be attributed to wind effects.

Current measurements can reveal several significant characteristics of an estuarine system, including the magnitude of flood and ebb currents, the total volumes of water transported by the flood and ebb tides (tidal prisms), the net differences in these volumes, and the vertical and horizontal distributions of water flow. Measurement from June 1 and 2, 1989 showed that 612.6 million cubic feet of ocean water flooded into Mosquito Lagoon, while 804.3 million cubic feet ebbed out of the Lagoon. This means that there was a net flow of 191.7 million cubic feet of water out of Mosquito Lagoon recorded during this tidal cycle.

Evink (1980) studied the effect of wind on the circulation patterns. Wind strength and direction are seasonal in the Indian River Lagoon region. During the dry winter season, wind direction is predominantly from the north and north-northwest. During the wet summer season, wind direction is predominantly from the east and southeast (Woodward-Clyde 1994b). Generally, it can be stated that the summer winds move Lagoon water to the north through the shallow portions of the Lagoon, with a southerly return through the Intracoastal Waterway. The winter winds generally move surface waters south, with a northerly return via the ICW.

SURFACE WATER QUALITY AND MONITORING

Management

Monitoring of living resources, sediments, and surface water quality in Mosquito Lagoon provides important sources of information that can be useful to resource managers and decision makers (Sigua et al. 1999). The significance of water resource monitoring in the Lagoon is: 1) to develop water quality management priorities and plans that direct pollution control resources toward point and non-point sources, 2) to implement water quality management programs, such as establishing permit limits for point and non-point sources, 3) to define the naturally occurring variability in the physical, chemical, and biological systems, and 4) to establish the extent, magnitude, and significance of any environmental problems (Sigua et al. 2000).

Surface Water Management

The Florida Water Resource Act (Chapter 373 F.S.), enacted in 1972, created six water management districts. The districts were assigned to the major watersheds within the state and were provided with the authority to manage and regulate surface waters. Regulated activities include any construction, alteration, maintenance or operation of any dam, impoundment, reservoir or works including ditches, canals, conduits, channels, culverts, pipes and other construction that connects to, draws water from, drains water into, or is placed in or across open waters or wetlands. Each water management district has established thresholds that trigger permit application requirements.

CANA is located within the watershed area administered by the Saint Johns River Water Management District (SJRWMD). The SJRWMD has a comprehensive surface water management-permitting program in place. A Surface Water Improvement and Management (SWIM) Plan has been developed for the Indian River Lagoon by SJRWMD and the South Florida Water Management District (SFWMD). The SWIM plan was developed in compliance with the SWIM Act (Chapter 373.451-373.4595, FS and 62-43.035 FAC) and passed in 1987, which designated the Indian River as an area of special concern. The SWIM Plan has coordinated many sampling programs throughout the IRL system by development of consensus of the existing monitoring programs on comparable and compatible parameters and laboratory analysis methodologies. The SWIM plan is currently being updated by SJRWMD and will be ready in 2002. Water resource management objectives for the revised SWIM plan and this plan were shared during a meeting between SJRWMD and CANA in September 2000. Under the SWIM program, CANA is working closely with SJRWMD to monitor seagrass in Mosquito Lagoon, collect meteorological data, and restore impounded areas to functioning wetlands.

The EPA regulates the discharge of pollutants into navigable waters of the United States under the Federal Clean Water Act of 1977 (CWA), as amended by the Water Quality Act of 1987. Their regulatory authority is vested in the National Pollution Discharge Elimination System (NPDES) permit program. NPDES permits are operating permits that ensure compliance with state and federal water quality standards. The EPA has adopted numerous regulations to implement the CWA found in Title 40 CFR. Chapter 373 Florida Statutes (FS) authorizes FDEP to administer regulation of use, management and storage of surface waters. The FDEP has delegated authority to SJRWMD to administer permitting and enforcement programs under The Florida Water Resources Act. The SJRWMD has also been delegated responsibility for regulation of storm water discharges under Chapter 403 F.S./Rule 40C-4 FAC and Wetland Resource permitting (dredge and fill) under Chapter 403 FS.

<u>Water Quality Standards</u>

The Clean Water Act (CWA) required each state to adopt water quality standards. These standards are established on the use and values of waters for public water supplies, propagation of fish and wildlife, recreation, agriculture, industry, and navigation. The State of Florida classifies its surface waters according to instructions in the Federal Water Pollution Control Act (Section 303). The most recent assignment and description of classifications are given in Chapter 62-302 of the Florida Administrative code. State compliance with the CWA has been delegated to the FDEP. Today, Florida surface waters are designated according to five classifications based on their potential use and value:

Class I	Potable Water Supplies
Class II	Shellfish Propagation and Harvesting
Class III	Recreation and Fish and Wildlife Propagation
Class IV	Agricultural Water Supplies
Class V	Navigation and Utility and Industrial Use

Details of these classifications are provided in Appendix A. Most of Mosquito Lagoon (from KSC north to Edgewater) and the northern-most segment of the Indian River proper (north of the NASA Railway spur crossing) are designated as Class II, allowing shellfish harvesting and aquaculture to occur. Class II waters establish more stringent limitations on bacteriological and fluoride pollution than Classes III - V. Discharge of treated wastewater effluent into Class II waters is prohibited. Dredge and fill projects in Class II waters require a plan of procedure to adequately protect the project area from significant damage.

Outstanding Florida Waters

The surface waters of Canaveral National Seashore and Mosquito Lagoon are designated as Outstanding Florida Waters (Rule 62-302.700(9) F.A.C.). This is a state designation under the Clean Water Act, intended to afford the highest level of protection to existing high quality waters. Designated waters are to be preserved in a non-degraded state and protected in perpetuity for the benefit of the public. As a result, no degradation of water quality, other than that allowed in Rule 62-4.232(2) and (3) F.A.C. is to be permitted in CANA's surface waters. The last day for the baseline year for defining the existing ambient water quality at CANA was March 1, 1979. See the *State of Florida Statutes and Designations* section (*Outstanding Florida Waters*) in this report for additional information.

Shellfishing Standards and Regulations

The Florida Department of Agriculture and Consumer Services (DACS) manages and classifies shellfishing areas to protect shellfish consumers from shellfish-borne illnesses and to maximize the harvest of shellfish resources. Shellfish are defined in this section as oysters, clams, and mussels. Florida is a member of the Interstate Shellfish Sanitation Conference (ISSC), a voluntary, cooperative association of states, the U.S. Food and Drug Administration (FDA), National Marine Fisheries Service (NMFS), Environmental Protection Agency (EPA) and the shellfish industry. State responsibilities include adopting laws and regulations for the sanitary control of the shellfish industry, formulating comprehensive shellfish harvesting area surveys and adopting control measures to ensure that shellfish are grown, harvested and processed in a safe and sanitary manner. DACS is authorized by Chapter 370.071 FS to establish regulations, specifications, and codes relating to sanitary practices for catching, handling, processing, preserving, canning, smoking, and storing shellfish. The FDA reviews methods for classification and management of shellfish areas proposed by the ISSC, and incorporates those methods consistent with standard health practice into the National Shellfish Sanitation Program (NSSP) Manual of Operations.

Classifications are based on pollution source, hydrographic, meteorological and bacteriological surveys to identify where sanitary conditions are suitable for the harvest of wholesome shellfish. Criteria for classification are contained in Ch. 5L-1 FAC, which incorporates by reference the NSSP Model Ordinance.

The sanitary control of the shellfish industry is necessary since shellfish harvested from polluted waters that may cause human illnesses. Many pathogens associated with fecal material are discharged into coastal waters. Sources of pollution include failing septic systems, stormwater runoff, wastewater treatment plant outfalls, and discharges from boats. Because monitoring for all human pathogens is not feasible, an indicator group of bacteria (fecal coliforms) is used to assess the likelihood that human pathogens are present. Few fecal coliform bacteria are directly pathogenic. However, the presence of fecal coliform bacteria in coastal waters indicates that feces from warm-blooded animals is present and that human pathogens are likely to also be present.

DACS routinely monitors fecal coliform and water quality parameters at established stations in each of Florida's shellfish harvesting areas. The NSSP has established bacteriological standards for shellfish harvesting area classification. For areas to be classified as Approved or Conditionally Approved, the level of fecal coliform in sub-surface water samples must meet the NSSP 14/43 standard. For areas to be classified as Restricted or Conditionally Restricted, the level of fecal coliform in sub-surface water samples must meet the NSSP 88/260 standard.

> *NSSP 14/43 standard*: The fecal coliform median or geometric mean must not to exceed 14 MPN/100 ml, and not more than 10 percent may exceed 43 MPN/100 ml.
>
> *NSSP 88/260 standard*: The fecal coliform median or geometric mean must not exceed 88 MPN/100 ml, and not more than 10 percent may exceed 260 MPN/100 ml.

Shellfish may only be harvested from approved or conditionally approved areas, unless under special permit and supervision. Conditionally approved areas in CANA are closed for harvesting when rainfall exceeds 0.3 inches in a 24-hour period. Shellfish areas are reopened for harvest when waters meet appropriate NSSP standards and adequate time has elapsed for shellfish to purify. No shellfish may be harvested from prohibited and unclassified areas. Shellfish harvesting classifications for Mosquito Lagoon are presented in Table 5.

Table 5. Shellfish Harvesting Classifications

<u>Approved</u>	Normally open to shellfish harvesting and are temporarily closed only under extraordinary circumstances such as red tides, hurricanes, or sewage spills.
<u>Conditionally Approved</u>	Periodically closed to shellfish harvesting based on pollution events such as rainfall or increased river flow.
Restricted	Normally open to *relaying* or *controlled purification*, allowed only by special permit and supervision; may be temporarily closed under extraordinary circumstances, such as red tides, hurricanes, or sewage spills.
Conditionally Restricted	Periodically, *relay* and *controlled purification* activity is temporarily suspended based on pollution events, such as rainfall or increased river flow.
Prohibited	Shellfish harvesting is not permitted due to actual or potential pollution.
Unclassified (Unapproved)	Shellfish harvesting is not permitted pending bacteriological and sanitary surveys.

- Classifications from Florida Department of Agriculture and Consumer Services

A comprehensive report is written for each shellfish harvesting area to document the methods and findings of the surveys, as well as proposed changes in classification and management. In 1996, some “Approved” areas of Mosquito Lagoon were reclassified as “Conditionally Approved” for shellfish harvesting. Figures 11a-c and Appendices A and B show the most recent shellfish harvesting classifications for Mosquito Lagoon and the upper Indian River proper.

Commercial shellfish harvesting is allowed in CANA under a provision in the Park's enabling legislation which states that fishing will be permitted in accordance with state laws, although designated zones may be closed for certain reasons and established periods, but only after consultation with the appropriate state agency. To commercially harvest shellfish within CANA, a license is required from the State of Florida and a permit is required from CANA. Information on permits can be obtained from CANA headquarters. The open or closed status of shellfish areas is updated daily on a statewide toll-free telephone line at 1-877-304-4024 or at: www.floridaaquaculture.com. The Florida Wildlife Conservation Commission (FWCC), Bureau of Marine Enforcement (formerly Florida Marine Patrol) is responsible for enforcement of shellfish regulations. Within the Park, the FWCC, CANA rangers, and the Volusia County Sheriff’s Department all enforce shellfishing regulations. Information on licenses required to engage in commercial harvesting, harvesting seasons, and gear or bag limits may be obtained from FWCC offices.

Section 305(b) Water Quality Assessment

The Clean Water Act requires each state, including Florida, to conduct water quality surveys to determine whether or not its waterways are healthy enough and of sufficient quality to meet their designated uses. The U.S. EPA uses this information to prepare a biennial report to Congress for the National Water Quality Inventory. This is the principal means by which the U.S. EPA, Congress, and the public can evaluate existing water quality and track progress in cleaning up pollution. The section of the Clean Water Act requiring this process is 305(b).

In response to this mandate, the State of Florida prepares a section 305(b) report every two years for submission to the U.S. EPA. It is divided into a main report and technical appendices. The main report provides a summary of water quality, and identifies sources and causes of pollution, for each water body type. The technical appendices summarize water quality by individual water bodies. Information on non-point source pollution and data on fish consumption advisories are combined with the water quality and biological data to assess the health of each watershed. The section 305(b) report lists the water segments that fully support (good water quality), partially support (fair water quality), or do not support (poor water quality) their designated uses described by Florida’s surface water quality standards and criteria. The findings of 305(b) reports are used to develop a list of priority water bodies requiring Total Maximum Daily Load (TMDL) development.

Figure 11A - SHELLFISH HARVESTING AREA CLASSIFICATION MAP #80 (Effective: December 28, 1997)
Body A (#80) Shellfish Harvesting Area in Brevard County

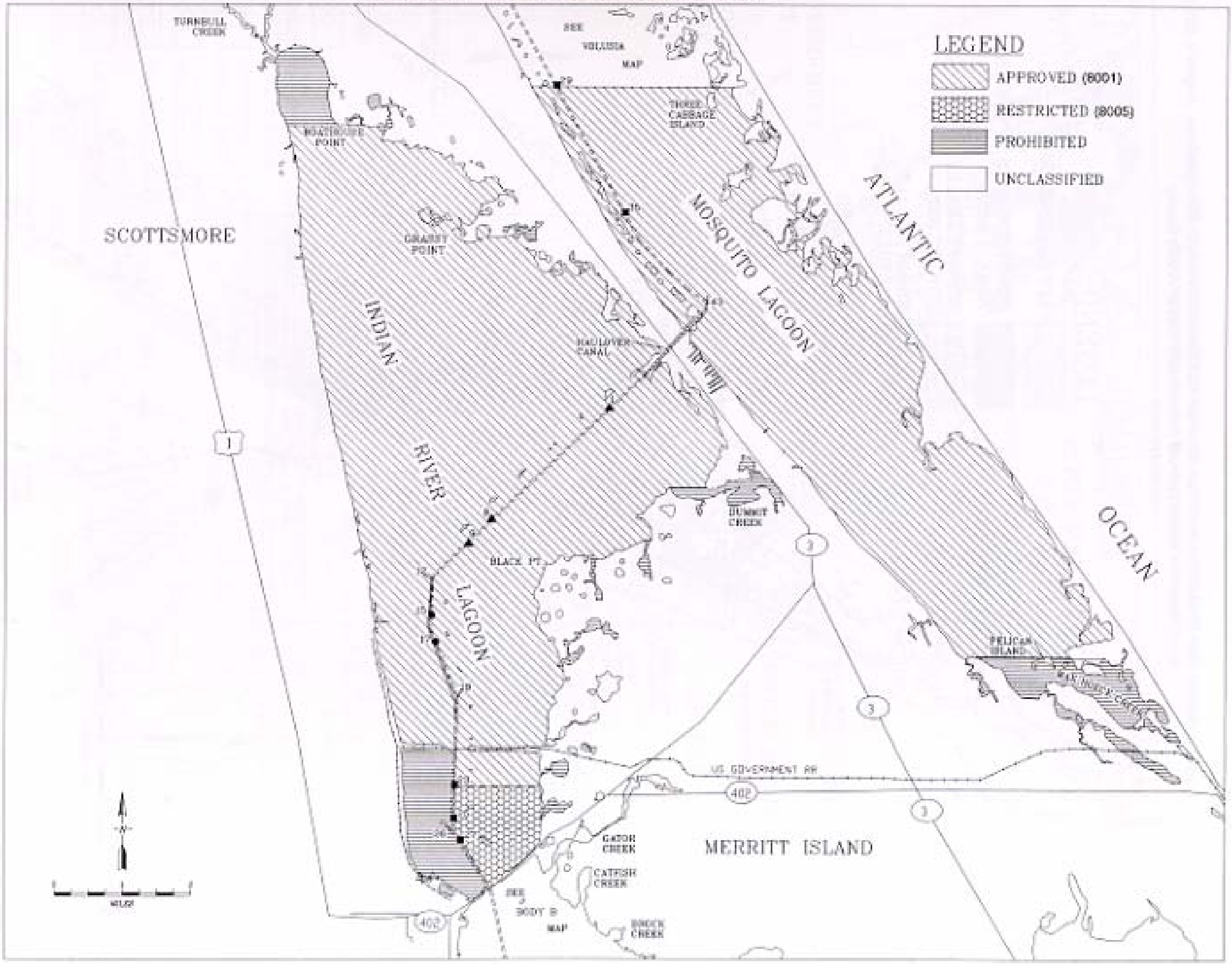


Figure 11B - SHELLFISH HARVESTING AREA CLASSIFICATION MAP #82A (Effective: August 9, 2000)
South Volusia (#82) Shellfish Harvesting Area in Volusia County

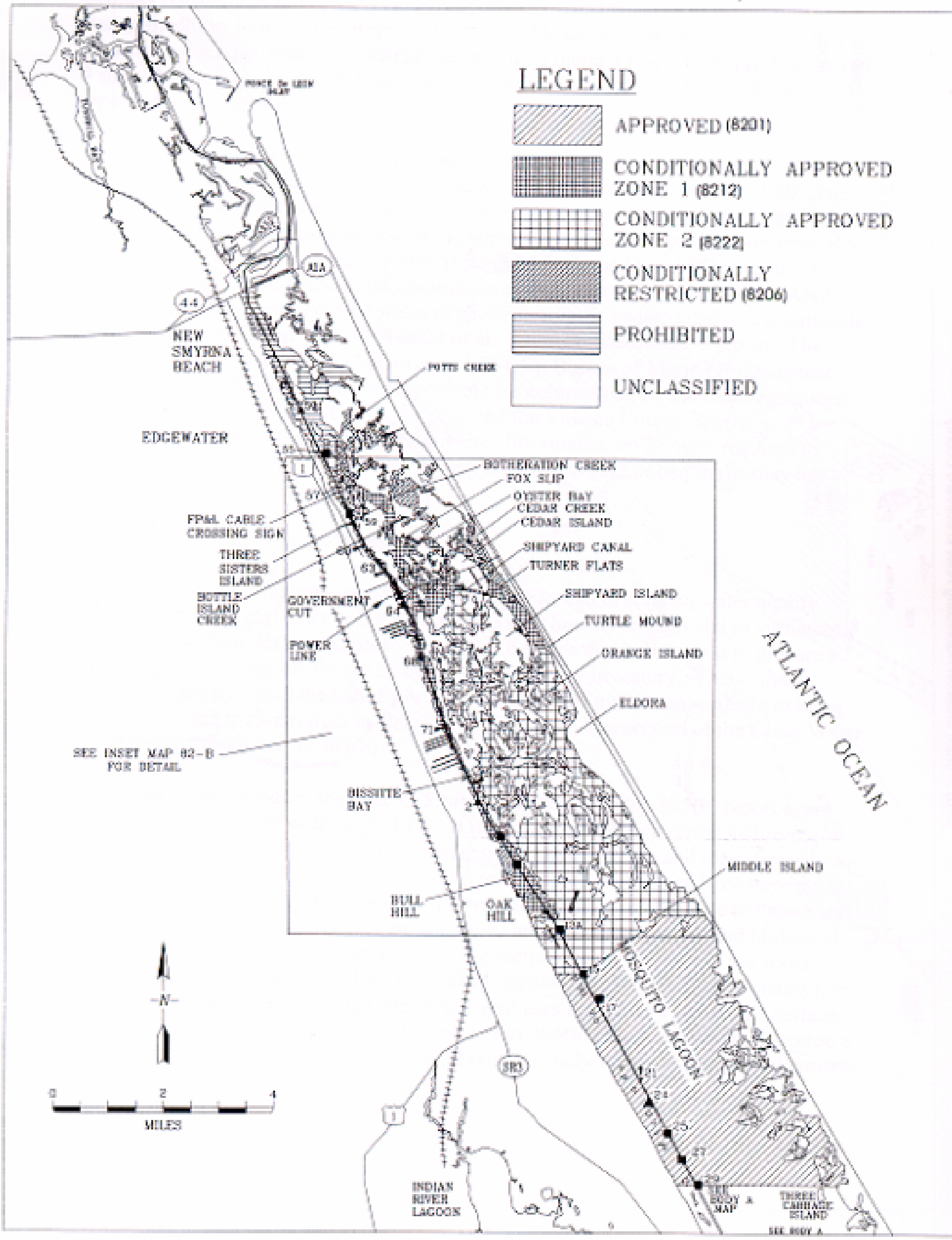
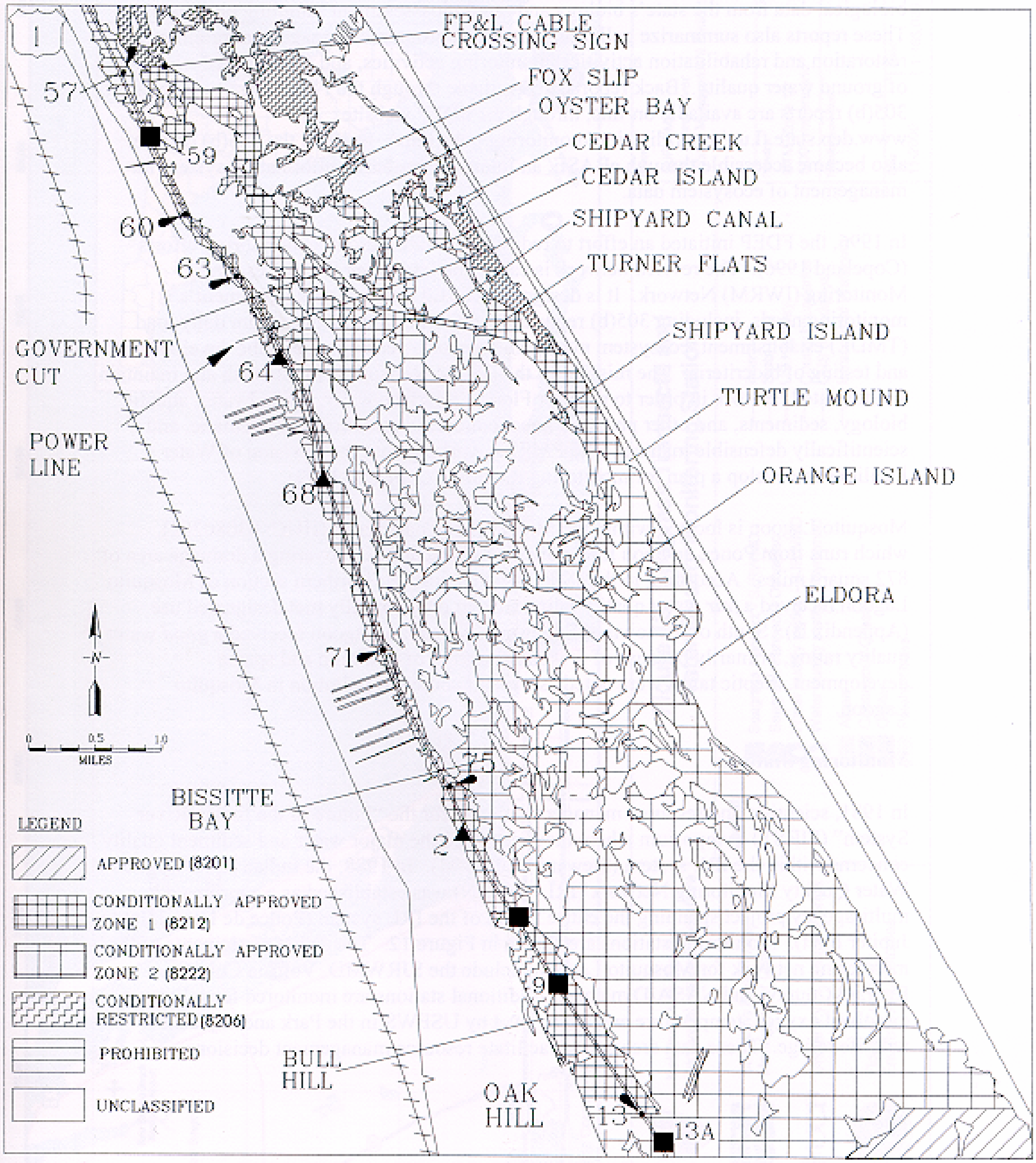


Figure 11C - SHELLFISH HARVESTING AREA CLASSIFICATION MAP #82B (Effective: August 9, 2000)
South Volusia (#82) Shellfish Harvesting Area in Volusia County
Inset of Map 82A



The Florida 305(b) reports are prepared by the Basin Planning and Management Section of the FDEP. The 305(b) report utilizes the storage and retrieval (STORET) database and biological data from the state's biology and rapid bioassessment sampling programs. These reports also summarize pollution prevention programs, management programs, restoration and rehabilitation activities, monitoring activities, and provide an evaluation of ground water quality. Back reports are available through the FDEP library. The latest 305(b) reports are available on-line, through the FDEP website: www.dep.state.fl.us/water/division/monitoring/pubs.htm/. In 1998, the 305(b) data set also became accessible through eBASE, an Internet map-based information system for management of ecosystem data.

In 1996, the FDEP initiated an effort to redesign its water resource monitoring efforts (Copeland 1996). The revised network is called the Integrated Water Resource Monitoring (IWRM) Network. It is designed to fulfill many of the Department's monitoring needs, including 305(b) reporting requirements, total maximum daily load (TMDL) establishment, ecosystem management needs, permitting, and the development and testing of biocriteria. The mission of the IWRM Network is to establish and maintain an integrated network in order to monitor Florida's surface water, groundwater, aquatic biology, sediments, and other pertinent aquatic media in an efficient, systematic, and scientifically defensible manner. The FMRI is working with the Division of Water Facilities to develop a plan for monitoring estuaries (Copeland 1999).

Mosquito Lagoon is located within the Middle East Coast Basin (HUC: 03080202), which runs from Ponce de Leon Inlet down to Sebastian Inlet, covering a drainage area of 872 square miles. According to the 1996 305(b) report, the northern section of Mosquito Lagoon received a *fair* water quality rating since it only partially met designated use (Appendix B). South of the town of Edgewater, Mosquito Lagoon received a *good* water quality rating, primarily because of few point sources of pollution and sparse development. Septic tanks were noted as a major source of pollution in Mosquito Lagoon.

Monitoring Stations

In 1981, scientists and resource managers gathered for the "Future of the Indian River System" (FIRST) Symposium where they identified the major water and sediment quality concerns within the IRL system (Steward et al. 1994). In 1988, the Indian River Lagoon-Water Quality Monitoring Network (IRL-WQMN) was established as a coordinated multi-agency project spanning the entire length of the IRL system (Ponce de Leon Inlet to Jupiter Inlet). Monitoring stations are shown in Figure 12. The active participants of the monitoring network for Mosquito Lagoon include the SJRWMD, Volusia County, Brevard County, and NASA/Dynamac. Additional stations are monitored for salinity, dissolved oxygen, temperature and water level by USFWS in the Park and adjacent wildlife refuge. These data are used to facilitate resource management decisions.

Figure 12. Seagrass Transects and Water Quality Monitoring Stations

The IRL-WQMN has the task of generating information on the physical and chemical conditions of the IRL and to infer from this data the well-being or biological integrity of the Lagoon. The goals of the IRL-WQMN are to:

- characterize the IRL over the long term - assess the status and trends in estuarine water chemistry in relation to primary producers as indicators of biological integrity, especially seagrasses, the key macrophytes.
- identify problem areas (via indicators of biological integrity and destabilization, e.g. trends toward phytoplankton dominance over macrophytes).
- measure the effectiveness of management objectives and actions intended to remedy the problem areas.
- provide current information to redirect or refocus management plans.
- provide accountability to the public by relating progress toward restoration and protection of the IRL.

Before 1996, the IRL-WQMN monitored 22 surface water-sampling sites along the 57 km of Mosquito Lagoon. NASA/KSC sampled an additional 11 sites away from major facilities and operational areas once every two months. Water quality samples taken from sites V01 to V20 were collected and analyzed by the Volusia County Environmental Management Department or their subcontractors following the Volusia County quality assurance plan (Gately 1991) and the IRL-WQMN Quality Assurance/Quality Control Manual (Steward and Higman 1991). Water quality samples from sites ML01 and ML02 were collected and analyzed by the Brevard County Office of Natural Resource Management Division (ML02 is currently measured by NASA/Dynamac, Inc.). Both physical and chemical parameters have been sampled monthly since 1988.

In 1996, SJRWMD proposed a selective reduction in the number of sampling stations in the IRL-WQMN to eliminate statistically unnecessary sampling, resulting in a more cost-efficient sampling effort in the IRL system (Sigua et al. 1996a). The Stations that were retained for Mosquito Lagoon and upper Indian River proper (V02, V11, V17, ML02, I02, and I07) will continue to provide information on the long-term spatial and temporal trends of water quality and help discern the covariant causal link between seagrass coverage (distribution and density) and water quality. Active station locations are shown in Figure 12. All Mosquito Lagoon water quality data is sent to the EPA's Office of Water and the database is accessible on STORET at www.epa.gov/storet/.

In addition to the selective reduction of sampling stations within the IRL system, proposed modifications also included: 1) the selection of existing sampling stations based on their proximity to seagrass transects, 2) an increase in the sampling frequency at each station to three times per station during a tidal cycle each month followed by dropping back to one sampling per station per month after three years, 3) the inclusion of near-bottom nutrient samples to be collected at each station, at least once during a tidal cycle (~12 hr) each month, to help calibrate the PLR Model, 4) the measurement of the separate organic and inorganic fractions of total suspended solids, and 5) the centralization of laboratory analyses to reduce potential analytical errors, which can occur when several laboratories are involved in a monitoring program. By streamlining the WQMN, staff and laboratory resources are now used more efficiently and place less budgetary demand on the participating agencies (Sigua et al. 1996b). Both near-surface and near-bottom, physical water quality parameters are measured *in situ*. Physical parameters (near-surface) are listed in Table 6 (Sigua et al. 2000). Chemical parameters are listed in Table 7 (Sigua et al. 2000). Strict quality assurance and quality control procedures are followed for data validation and data reporting.

Table 6. Water Column (near-surface) physical parameters for the IRL-WQMN

Physical Parameters	Unit
Water Temperature	Degrees Celsius
pH	PH units
Dissolved Oxygen (DO)	Mg/L
Conductivity	Mmhos/cm
Salinity	parts per thousand
Secchi Depth	meters
Depth of Collection	meters
Depth of Sample Site	meters
Air Temperature	degrees Celsius
Wind Direction	degrees
Wind Velocity	miles per hour
Cloud Cover	percent

Table 7. Water column (near-surface) chemical parameters for the IRL-WQMN
(* = added in 1996)

Near-Surface Chemical Parameters	Unit	Analytical Method
Color♦	PCU	EPA 110.2
Turbidity♦	NTU	EPA 180.1
Total Suspended Solids (TSS)	mg/L	EPA 160.2
Total Inorganic Suspended Solids*	mg/L	
Chlorophyll *a*	µg/L	SM17-10200H
Chlorophyll *b*	µg/L	SM17-10200H
Chlorophyll *c*	µg/L	SM17-10200H
Pheopigments	µg/L	SM17-10200H
Chlorophyll *a* corrected	µg/L	SM17-10200H
Chlorophyll *a* / Pheopigment Ratio		
Total Organic Carbon as C*	mg/L	
Total Kjeldahl Nitrogen as N	mg/L	EPA 351.2
Nitrate + Nitrite as N	mg/L	EPA 353.3
Dissolved Kjeldahl Nitrogen as N*	mg/L	
Total Phosphorus as P	mg/L	EPA 365.1
Total Orthophosphorus as P	mg/L	EPA 365.1
Dissolved Phosphorus as P*	mg/L	
Silica as SiO2-D*	mg/L	

Coastal Water Quality and Testing

Managers of public-access beaches around the globe must be concerned with the water quality and the safety of beach visitors. To date, only a limited amount of testing has occurred in Florida. For example, as soon as testing began in the Florida Keys in the late 1990's, many beaches were immediately closed. Oceanic water testing in CANA began in July 2000 (J. Stiner, pers. comm., CANA, 2000). In July, water from Parking Areas 1 – 5 in the northern section of CANA and from Parking Area four in the southern section were tested for *Enterococcus* sp. by Volusia County Department of Health. *Enterococcus* sp. is a group D streptococci bacteria that are transmitted via human and animal feces and are environmentally persistent (web site: www.enterococcus.ouhsc.edu). Infections generally occur via mucusal surfaces and symptoms range from urinary tract infections to heart problems. Bacteria levels were low at CANA in the initial samples. The Park has continued to sample monthly at North District Parking Areas 1 and 5, and Brevard County Department of Health is sampling bi-monthly at South District Parking Area 4. The greater frequency of sampling in the South District is due to a Brevard County requirement to sample twice a month. The results at both districts have been good (0-34 *Entrococci* per 100 milliliters seawater) with the exception of one sample taken at South District Parking Area 4 on August 29, 2000. This sample registered 42 *Enterococci* per 100 ml of water (State of FL, Dept. of Health and Volusia County Environmental Health Laboratory Ocean Sampling Reports).

Water Quality Characteristics and Trends

SWIM Water Quality Assessment (1990-1999)

The following excerpts are taken directly from the 2001 SWIM plan update (Steward, Brockmeyer, and Virnstein, in progress, November 2001) and the water quality report from NASA (Dynamac, Inc.) produced in cooperation with the NPS (Hall et al. 2001). Within Mosquito Lagoon, salinity drops as distance from Ponce de Leon Inlet increases. Mosquito Lagoon receives inputs of salt water from the ocean through the inlet and receives freshwater from precipitation, groundwater seepage, surface runoff, and discharges from a small number of tributaries, man-made canals, and wastewater treatment plants. Compared to other segments of the IRL system, Mosquito Lagoon's watershed is small and discharges are minimal. Most of the freshwater input comes from direct precipitation and runoff (Sigua et al. 1999). Mean monthly fluctuations ranged from 28 to 34 ppt. A salinity gradient of 2-3 ppt was observed between the northern and southern sections of the Lagoon. Because of the low freshwater inputs, Mosquito Lagoon, along with the South IRL, exhibited the highest 10-year average salinities (31-33 ppt) of any area in the IRL system (Figure 13). Over this period, Mosquito Lagoon exhibited relatively strong temporal stability in salinity. There was a slight decline in salinity that did occur from 1994 to 1996, but it was probably a response to the unusually high rainfall levels during that time (Figure 13).

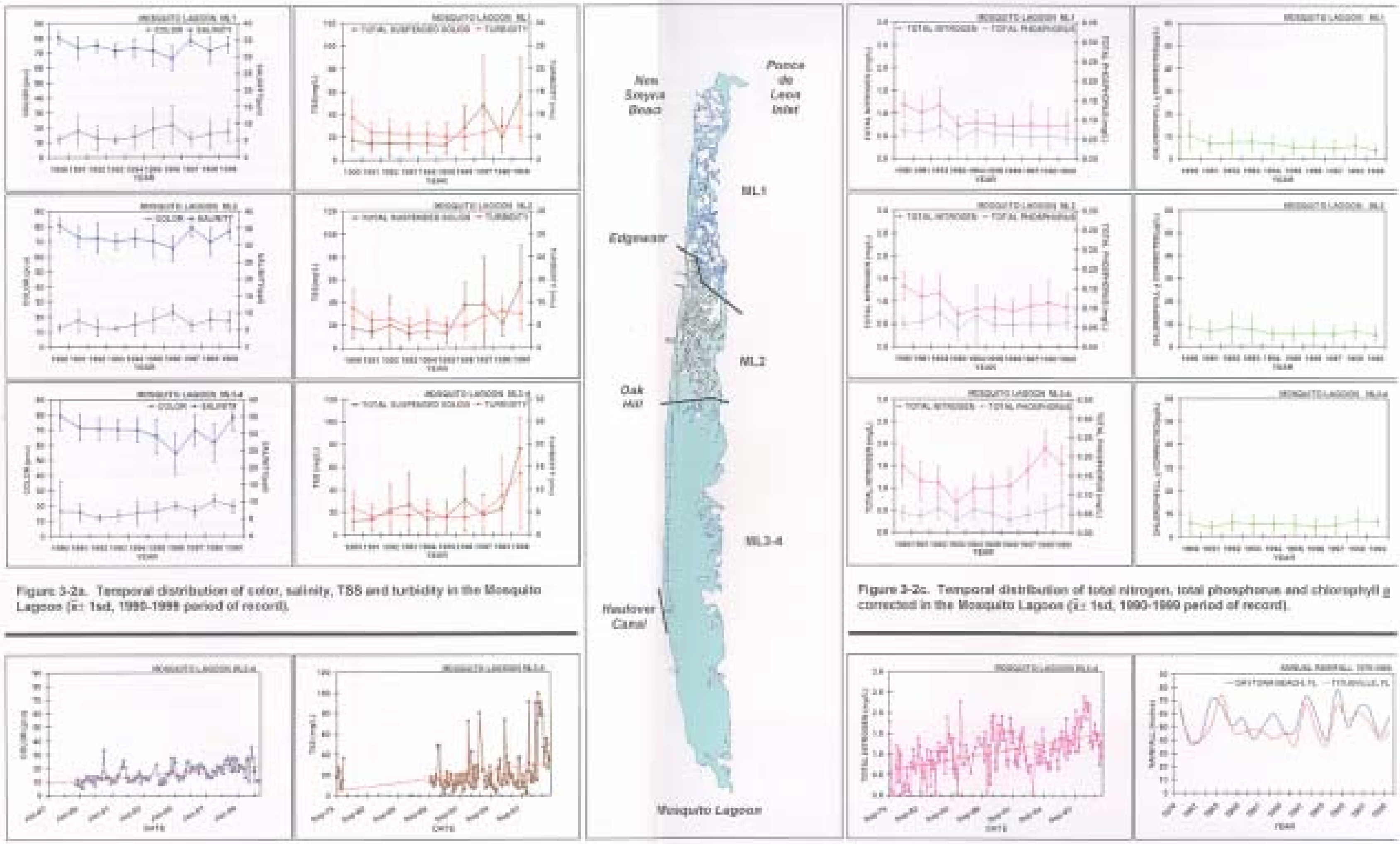


Figure 3-2a. Temporal distribution of color, salinity, TSS and turbidity in the Mosquito Lagoon ($\bar{x}$± 1sd, 1990-1999 period of record).

Figure 3-2b. Increasing trends in color and TSS in the southern reach of Mosquito Lagoon (monthly data).

Figure 3-2c. Temporal distribution of total nitrogen, total phosphorus and chlorophyll a corrected in the Mosquito Lagoon ($\bar{x}$± 1sd, 1990-1999 period of record).

Figure 3-2d. Increasing trend in TN in the southern reach of Mosquito Lagoon (monthly data).

Figure 3-2e. Annual Rainfall since 1970 near the Mosquito Lagoon.

Figure 13: SWIM Results
(Figure produced by St.Johns River Water Management District)

The 10-year average color for most of the IRL system ranges between 15 and 20 pcu (platinum-cobalt units), with the Central IRL having a high average of 20 to 30 pcu. Color in Mosquito Lagoon has been gradually increasing over the years (Figure 13). The most noticeable increase occurred between 1994 and 1996 (Figure 13). This can be explained by the higher than average rainfall levels during this period, causing increased land runoff into the Lagoon. Since 1996, color levels in ML3-4 have been above 20 pcu nearly as often as they have been below that level (Figure 13). The implications of this trend with respect to light limitation may be as important as for other optical pollutants.

Most of Mosquito Lagoon is considered pristine habitat, except for occasional turbidity resulting from storms and wind suspending bottom sediments (Section 305(b) Report 1996). Mosquito Lagoon's shallow depth (average: 1.3 m or 4 ft) may make it susceptible to elevated turbidities, maybe even more than other IRL system segments. Turbidity is an important light-limiting factor in Lagoon waters. Turbidity is a result of the combination of organic suspended solids (living and detrital, both algal and non-algal) and inorganic (mineral) suspended solids in the water column. Mosquito Lagoon's 10-year average turbidity is > 6 ntu, higher than most other areas in the IRL system. Clarity decreased with increased distance from Ponce De Leon Inlet (Sigua et al. 1999). Additionally, clarity is greatest in the winter and early spring and decreased significantly in summer/fall months (Sigua et al. 1999). Turbidity appears to be strongly influenced by total suspended solids (TSS). If TSS levels can be kept low, turbidity levels should also remain low. Unfortunately, since 1995, TSS levels have generally increased, along with turbidity (Figure 13). In 1999, the average TSS levels in Mosquito Lagoon increased to > 50 mg/L, about three times the pre-1996 levels.

There has been a troubling increase in Total Nitrogen (TN) over the past 20 years, especially in the southern segment (ML3-4) (Figure 13). In each of the last three years, mean annual TN concentrations in ML3-4 exceeded the provisional IRL system threshold of 1.1 mg/L (Figure 13). Even so, these TN levels have not promoted a similar phytoplankton (chlorophyll *a*) response. It is fortunate that chlorophyll *a* levels have remained relatively low and stable over the last 10 years (mean annual concentrations are ~5 to 6 µg/L; below the 6.7 µg/L provisional mean annual threshold) (Figure 13). Considering that annual TN levels are increasing and that chlorophyll *a* (phytoplankton) concentration is a light-limiting co-factor with turbidity, better nutrient management in Mosquito Lagoon is warranted. It is also noted that the large accumulations of unattached macroalgae (seaweed) in Mosquito Lagoon may also be an indication of excess nutrients (e.g. nitrogen).

The algal blooms reported in 1990 and 1996 for the southern IRL were attributed to several conditions, which include sufficient light, waters temperatures > 18 degrees C, low salinity and a low TN/TP ratio (low N and abundant P) (Sigua et al. 2000). Thus, it may be the P levels that need to be monitored because Mosquito Lagoon may be sensitive to elevated inputs of phosphorus (e.g. pulsed loadings that occur after high rainfall). Total phosphorus loadings also come from runoff, wind re-suspension, and increased wastewater volumes. Low phosphorus levels are generally found in Mosquito Lagoon; the average value was 0.1 mg/L (Sigua et al. 1999). Seasonally high total phosphorus concentrations have been recorded during winter months, when tourism in central Florida is highest. Chlorophyll *a* levels may have remained low, despite elevations in TN, because there were no increased phosphorus inputs sufficient to trigger higher phytoplankton densities.

The average dissolved oxygen (DO) value for Mosquito Lagoon was 6.47 mg/L (Sigua et al. 2000). The state standard is 4.0 mg/L or greater in estuarine waters, so these values for CANA waters are well within the acceptable range. However, DO values collected at the northern district boat dock were highly variable; values ranged from a low of 0.04 mg/l to a high of 15.3 mg/l (Hall et al. 2001). Ratings below the state standard were observed for extended periods during the fall and spring months, suggesting high system respiration and oxygen demand. The pH for 22 test sites in Mosquito Lagoon averaged 7.9 and ranged from 6.5 to 8.5 (Sigua et al. 2000). All of these values are within state standards. PH appears to be slightly higher in wet summer months and positively correlated with distance from Ponce de Leon Inlet (Sigua et al. 2000).

Overall, Mosquito Lagoon exhibits good water quality, which can be attributed to low urbanization and negligible amounts of agricultural discharges (Sigua et al. 1996a, 1999). Enrichment of nutrients is a special concern in the southern reaches of Mosquito Lagoon where the residence time may be on the order of 2 to 3 months, whereas the northern section may have a residence time of less than 1 month. Evidence of water quality decline is demonstrated by increases of TN, TSS, and color over the last 5 years. It is difficult to discern whether or not this is beginning to have a major impact on seagrass. We must assume, though, that the increased loadings are nearing the threshold of impact (SWIM Plan update; in progress, November 2001).

Metals

Metals are naturally occurring elements that have the potential to be harmful to organisms in elevated concentrations. Biological effects of exposure can include altered metabolic and physiological rates, reduced fecundity, increased risk of tumors and cancers, reduced survival of larval, juvenile and/or adult forms and altered mental capacity. In an effort to minimize human and ecosystem risks, the State of Florida DEP has established concentration criteria for metals for different surface water quality classifications or uses (Appendix C).

Scientists at NASA are presently completing a study of metal concentrations in surface waters of Mosquito Lagoon. They are comparing surface water concentrations of metals in Mosquito Lagoon from two sampling periods (1992-1993 and 1998). For State regulation purposes, they used the Class II: Shellfish propagation and harvesting water quality criteria. Preliminary results from their study are presented in Table 8.

Table 8: Metal Concentrations in Surface Waters of Mosquito Lagoon

Metal	1992-1993	1998	State Limits
Aluminum	0.54 mg/L	0.31 mg/L	1.5 mg/L
Cadmium	< 0.0093 mg/L	<0.0093 mg/L	0.0093 mg/L
Chromium	6 of 54 samples > 0.05 mg/L	not detected	0.05 mg/L
Copper	14 of 54 samples > 0.0029 mg/L	not detected	0.0029 mg/L
Iron	0.5 mg/L	<0.3 mg/L	0.3 mg/L
Lead	0.0080 mg/L	0.0065 mg/L	0.0056 mg/L
Magnesium	972.9 mg/L	1267 mg/L	not listed
Nickel	0.10 mg/L	not detected	0.0083 mg/L
Potassium	402 mg/L	523 mg/L	not listed
Silver	1.07 μg/L	not detected	0.05 μg/L
Zinc	0.025 mg/L	not detected	0.086 mg/L

1992-1993 results are based on 54-72 samples; 1998 results are based on 6 samples (Hall et al. 2001).

The mean total lead values in 1992/1993 and 1998 slightly exceeded the state criterion 0.0056 mg/l. However, the 1992/1993 mean was based on 19 samples of out of 72 which registered lead; no lead was detected in the other 53 samples. Averaging those in would reduce the overall lagoon-wide concentration to below the state limits (C. Hall, pers. comm., NASA, 2001). The 1998 mean was based on only 6 samples (C. Hall, pers. comm., NASA, 2001).

The data suggest that, overall, metal concentrations in Mosquito Lagoon have declined from 1992/93 to 1998. However, managers must be cautious with this apparent data trend due to the very small sample size (n=6) in 1998. Additionally, techniques for metal detection have likely changed during this interval and the 1998 results may reflect improved techniques or overall analytical capabilities. Mercury was not listed in the results by Hall et al. (2001). Fish consumption advisories are in effect for mercury for the Indian River Lagoon and all coastal water bodies in Florida (US EPA 1999).

Pollutant Load Reduction Targets

There is growing evidence that the ecological and biological integrity of the IRL system has declined during the last 50 years (e.g. Sigua and Steward 2000). There are three major types of impacts responsible for this decline: 1) pollution from point and non-point sources, 2) disruption in the natural patterns of water circulation in the Lagoon, and 3) alterations in freshwater inflows, especially augmentation of wet season discharges.

Increased anthropogenic activities have altered hydrologic and hydrodynamic patterns and increased the loading of pollutants, especially of nutrients and suspended solids (Steward et al. 1994). These pollutants are transforming the IRL system from a macrophyte-based system to a phytoplankton and/or algal-based system (Sigua and Steward 2000). The primary indicator of this transformation is the loss of seagrass near urbanized areas, where water quality has declined.

The St. Johns River Water Management District (SJRWMD) is in the process of developing Pollutant Load Reduction Targets (PLRT) or Pollutant Load Reduction Goals (PLRG) based on the environmental requirements for seagrass growth and expansion (Steward 2001). In the IRL system, seagrasses are indicators of water quality and ecological integrity (Sigua and Steward 2000). Establishment of seagrass-based PLRTs is a major objective of water quality management in the IRL system. It is believed that the primary factor controlling the growth of seagrass is the amount of sunlight that reaches seagrass blades (Kenworthy and Haunert 1991; Dennison et al. 1993; Morris and Tomasko 1993). Light penetration is strongly affected by water clarity, which can be monitored using indicators such as suspended solids, color, and phytoplankton density. Thus, targeted reductions of nutrients (e.g. nitrogen and phosphorus) dissolved organic matter and/or suspended sediments should achieve desired seagrass coverage goals. Most of the loadings are stormwater-generated (Sigua and Steward 2000). Therefore, implementation of this plan will focus on major urban and agricultural areas.

The process of developing PLRTs uses two different but complementary approaches (Steward 2001). One approach depends on the use of a 3-D mechanistic model of the IRL that should be fully developed by 2002. The second approach is an inference method (a basin spreadsheet model) that can be used to estimate pollutant loads based on land use and other relevant characteristics that affect loading rates. Areal coverage of seagrass is the key metric involved in the inference methods approach. Light penetration is the metric of focus for the 3-D model. Combined, the two methods will converge on a meaningful set of defensible, resource-based PLRTs.

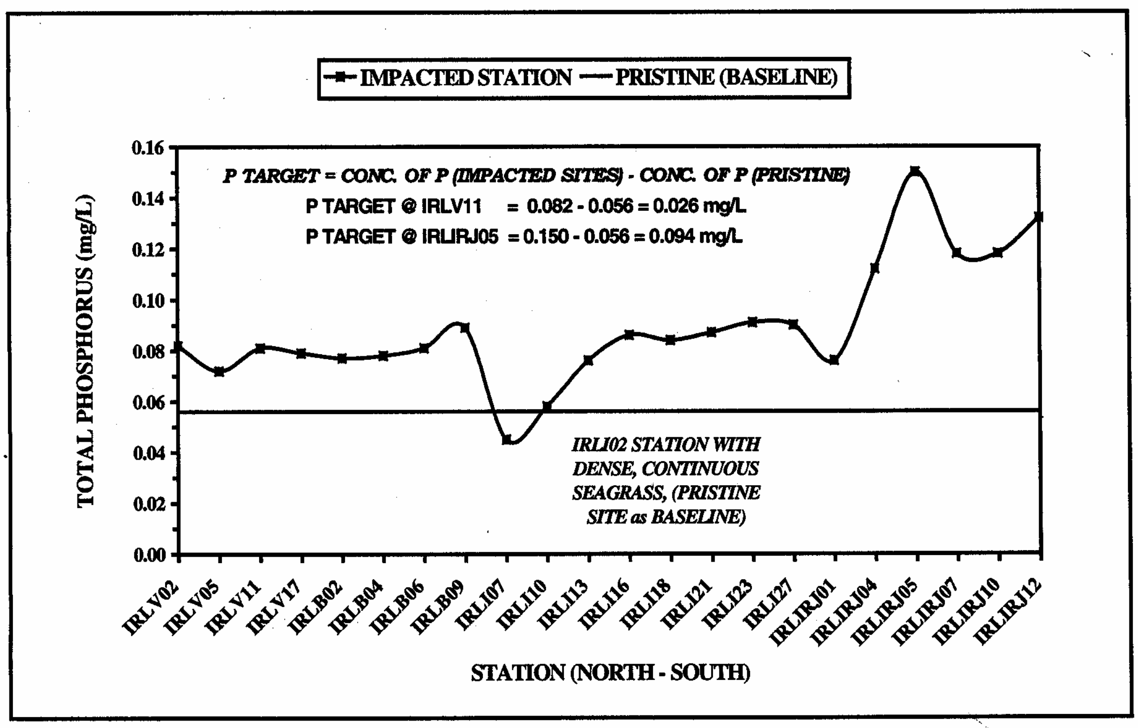
The Florida Legislature, Florida Department of Environmental Protection (FDEP), and SJRWMD under the State of Florida Water Policy (Chapter 62-40) acknowledge that the setting of PLRTs should be done in a scientific manner to be reasonably assured that the targeted resources can be restored or protected. A key strategy is to pursue reductions in nutrients and dissolved and/or suspended matter loadings that will allow sufficient penetration of sunlight for the expansion of seagrass to pre-defined depths and aerial coverages (Sigua and Steward 2000). The preliminary goal is to extend and maintain seagrass beds in water depths up to 1.7 m. This goal is based on the maximum depth of seagrass in undisturbed, healthy areas (Virnstein and Morris 1996).

The development of PLRTs requires information on water body nutrient concentrations, external nutrient loading rates, sediment nutrient flux estimates, and nutrient turnover (uptake + release) rates of the major plant communities in the IRL system. Because conditions in the IRL vary spatially (Sigua et al. 1995; Sigua et al. 1998), it is impossible to set a meaningful target for the entire IRL system. The IRL is appropriately characterized as a composite of several segments of differing hydrodynamic (Sheng 1996), water quality (Sigua et al. 1995; Sigua et al. 1996a; Sigua et al. 1998; Sigua et al. 1999), and biological features (Virnstein et al. 1987). The IRL system needs to be divided into several relatively homogeneous segments and a set of PLRTs would then be established for each segment.

Initial PLRTs will be set by comparison of loading rates and amounts for basins that have impacted and healthy seagrass beds. Current values for seagrass acreage, seagrass density, light levels at 1.7 m, and seagrass depth in Mosquito Lagoon that will be used in PLRT models are presented in Figure 14.

An example of impact analysis is shown for targeted phosphorus reduction in the north-south phosphorus distribution in the IRL system (Figure 15). The concentration of phosphorus from each impacted station was compared with the long-term mean of phosphorus concentration for the station having adjacent healthy seagrass coverage. In general, all stations (IRLV02 to IRLIRJ12) were compared with station IRLI02 to determine the absolute difference of phosphorus concentration between the sites. Next, the required reduction in phosphorus concentration, and the corresponding percent phosphorus reduction to attain the same concentration at site IRLI02 were determined. Results of these analyses are given in Table 9. Except for station IRLI07, all other stations would require reduction in phosphorus concentration to attain the same level exhibited by site IRLI02 (Figure 15). Stations in Mosquito Lagoon, Banana River, and the northern Indian River will require less phosphorus reduction than south-central IRL and southern IRL stations. The required average percent reduction for Mosquito Lagoon to attain the IRLI02 concentration is 28.5%.

Figure 15. North-south distribution of phosphorus and targeted reduction values in the IRL system.



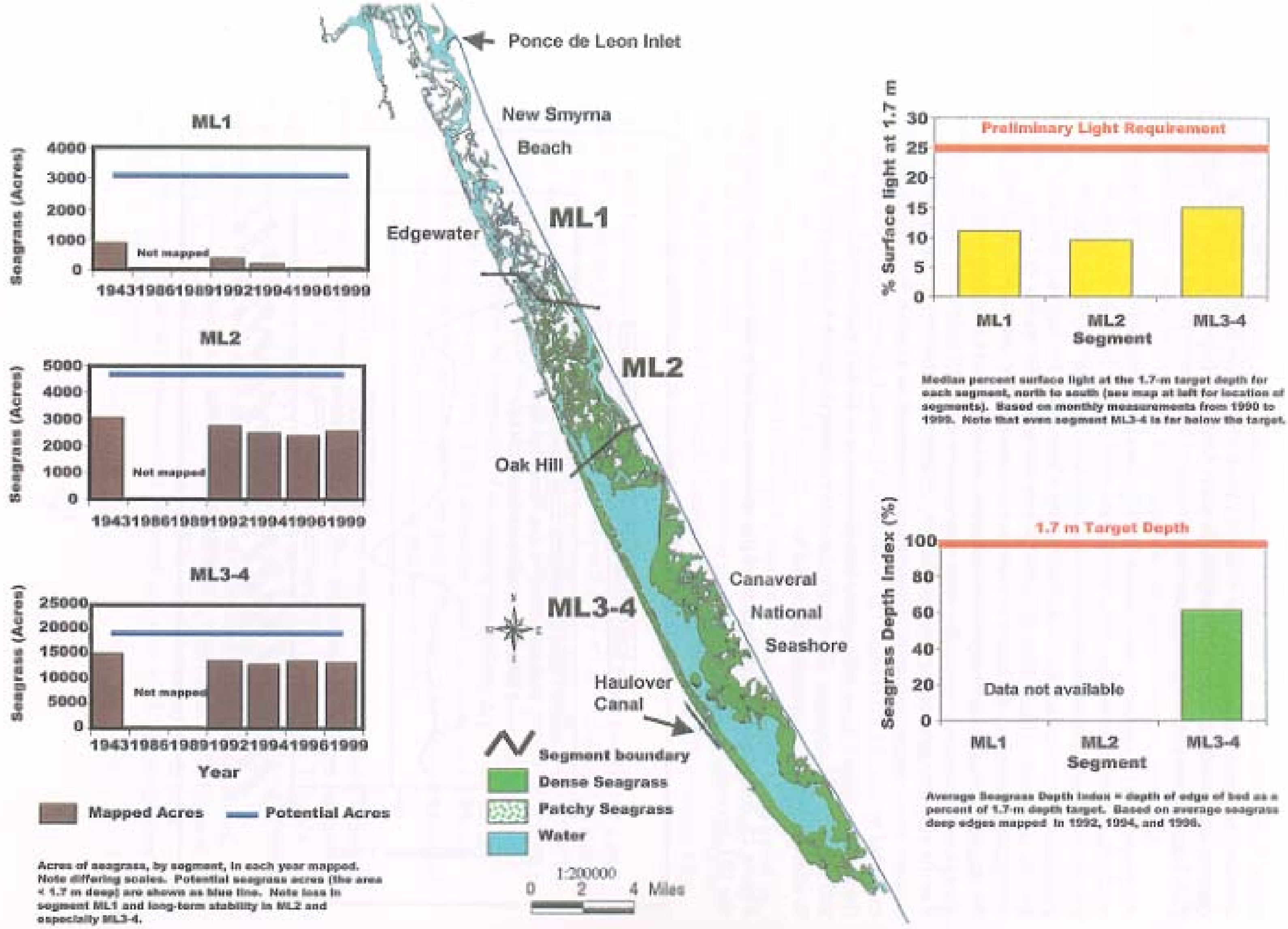


Figure 14: Mosquito Lagoon Seagrass Coverage and Associated Indices

(Produced by St. Johns River Water Management District)

Table 9. Required Reduction of Phosphorus Concentration and Estimated Percent Phosphorus Reduction for Impacted Areas to Attain Healthy Seagrass Conditions Described for Site IRLI02 (Pristine Reference Site)

Water Quality Station Near Seagrass Beds	Latitude/Longitude Coordinates (percent)	Required Reduction in P Concentration (mg/L)	% P Reduction to Attain the Site-IRLI02 Condition
IRLV02	29.03N 80.91W	0.026	31.7
IRLV05	29.01N 80.91W	0.016	22.2
IRLV11	28.95N 80.84W	0.025	30.7
IRLV17	28.88N 80.84W	0.023	29.1
IRLI10	28.50N 80.77W	0.002	3.5

The projection of nutrient loadings into the IRL system clearly indicates that storm water (urban + agricultural) contributions were unacceptably high and that measures should be taken to reduce this problem (Harper 1995). Some possible measures include:

- reduce inter-basin freshwater discharges to restore healthy salinity regimes and reduce external loadings.
- install best management practice (BMP) facilities as a retrofit strategy in existing developments (baffle box, curb inlet traps, retention and detention ponds).
- encourage the use of swales and erosion control methods that stabilize canal banks.
- encourage the establishment of local storm water utilities with runoff reduction incentives based on percent of pervious area on their property or other storm water treatment methods employed.
- fully implement Florida Law 90-262 which calls for the elimination of existing and prohibition on new domestic wastewater effluent discharge to the IRL system.

Following its development, the IRL-PLR model will be used along with optimization procedures that incorporate economic, regulatory, and other technical constraints to establish final PLRTs and allocate reduction targets among the watershed sources in an equitable manner.

HYDRODYNAMIC MODELS

Taylor Engineering Model

An increase in the population around Mosquito Lagoon has raised concerns about the degradation of water quality in this area. To address this concern, the Volusia County Council, acting through the Ponce de Leon Port Authority, authorized Taylor Engineering to develop a multi-phase program for the long-term management of Volusia's rivers. In 1989, Phase I (Program Development) was completed. It provided the Port Authority with a recommended scope of work for the program, along with associated time and cost estimates (Taylor et al. 1991).

Phase II: Rivers Baseline Evaluation, completed in 1991, was designed to develop an understanding of the physical characteristics of Volusia's estuaries as they relate to circulation and flushing, and the extent to which major, controllable factors influence these characteristics. Advanced systems analysis techniques, in the form of computer models, were used to accomplish this goal. Based on the forces of nature, these models predict the movement of water through the estuary (hydrodynamics) and the resulting impacts on flushing and water quality (transport-diffusion). Also, they allow a systematic approach in which each factor can be independently addressed, and its specific influence on circulation and flushing quantified. The Rivers Baseline Evaluation has identified and prioritized these major factors influencing Volusia's estuarine water quality (Taylor et al. 1991). The major factors include: 1) the estuary's flushing ability, 2) the impacts of bridges and causeways, 3) point source and tributary discharges, 4) deepening of the ICW, and 5) modifications to the Inlet.

The field-sampling program was a relatively short but intensive effort performed in May and June 1989. It produced four sets of valuable data that encompassed the entire estuarine system of Volusia, including: 1) continuous recordings of tides, 2) continuous recordings of channel current velocities, 3) continuous recordings of salinity, and 4) high and low water transects of salinity along the north-south axes of the Halifax River and Mosquito Lagoon. Moreover, these data were recorded concurrently so that their inter-relationships could be analyzed. The result was a comprehensive and synoptic set of data that allowed for the calibration of the hydrodynamic and transport-diffusion models, and provided an understanding of the physical characteristics of the estuary (Taylor et al. 1991).

The hydrodynamic and transport-diffusion models consist of two coupled computer algorithms, collectively referred to as TRANQUAL, originally developed by Taylor and Dean (1972). This 2-D model solves detailed formulations of the laws of physics and fluid dynamics governing the movement of water and the transport, mixing, and dispersal of substances in the water column. The calculated results reflect the influences of the complex interaction of external forces such as tide, wind, tributary flows, and point discharges upon the unique characteristics of the estuary, such as planform geometry, bathymetry, bottom roughness, submerged banks, and other flow constrictions. The hydrodynamics model mathematically simulates the movement of water and portrays the resulting changes in surface water elevation. The transport-diffusion model uses this information to simulate the transport, mixing, build-up, and decay of pollutants in the Lagoon (Taylor et al. 1991).

The model encompasses all the estuarine waters of Volusia County (i.e. from the north-east Volusia County line to the south-east Volusia county line) and covers an area of 165.9 square miles. Through the use of the hydrodynamics model, total volumes of water moving across specified planes within the estuary were computed over a 24.7-hour period (two tide cycles). The computed volumes are summarized in Table 10.

Table 10. Computed Tidal Exchange Volumes over 24.7 Hours (millions of ft^3)

Interface	Flood	Ebb	Net
Inlet Boundary	1288.00	1306.50	18.50 (out)
South Channel	528.34	540.93	12.59 (north)
Southern Boundary	142.55	154.42	11.87 (north)

The net flow to the north represents migration towards the inlet, where pollutants can exit the estuary. Net flows are caused by several factors including more efficient flow dynamics in one direction as opposed to another or large discharge volumes into the estuary from tributaries, storm water runoff, and other point sources. The net flows recorded for Mosquito Lagoon are small compared to the total flood and ebb exchange volumes of water moving through the system. It was also found that the bridges and causeways across the entrance to Mosquito Lagoon (S.R. 44 and A1A) might not be the limiting factors that control the large-scale movement of water. The primary factor is more likely the long stretches of constricting channels leading to the Lagoon (Taylor et al. 1991).

For this study, the waters within Volusia County were divided into four sub-basins. Each model application began by filling one sub-basin with a hypothetical pollutant. As the model was run, the pollutant was dispersed and transported out of the system by the flushing action of the tide and the various discharges into the estuary. Each model ran until the residual mass of pollutant in the originally tagged sub-basin dropped to 10% of its initial value. Although the "New Smyrna – Southern County Line" sub-basin was not tagged, the response of this sub-basin was monitored in all situations. According to the model, even the sub-basins that are north of Ponce de Leon Inlet can contribute a small portion of pollutants into southern Mosquito Lagoon.

SJRWMD 3-D Model

The SJRWMD entered into an agreement with the University of Florida in 1994 for the development of the Indian River Lagoon-Pollutant Load Reduction (IRL-PLR) Model. The IRL-PLR model is a 3-D process based computer simulation model that uses dynamic equations calibrated for a number of interacting processes: hydrology, hydrodynamics, salinity, water quality, and light attenuation. This model will be used by the SJRWMD as a tool for the setting and testing of PLRTs or numerical targets for the reduction of nitrogen, phosphorus, and dissolved/suspended matter loadings to the IRL. The development and use of the IRL-PLR model is based on the premise that improved water clarity will restore seagrass beds (Sigua and Steward 2000).

The model integrates various sub-models or model components, and can run in sequence with an option to omit those components not required for a specific simulation (Sigua and Steward 2000). Integration of the components will proceed in a step-wise fashion beginning with the coupling of the hydrologic, hydrodynamic, and salinity models. These models must be fully linked, and calibrated before incorporating the water quality model. Then the light attenuation model will be incorporated to produce the final quantitative link among sub-basin loadings. Once the model is calibrated and verified for the full range of expected meteorological and hydrological conditions (e.g. storms, dry periods, etc.), it will then be able to describe the Lagoon's response to any realistic combinations like land use intensification or increased nutrient loading (Sigua and Steward 2000).

It is expected that at least five years is required to set up, calibrate, and verify the model before refined PLRTs can be established. This length of time is needed because of several reasons:

- the large size of the Indian River Lagoon.
- the number of component processes (hydrology, hydrodynamics, salinity regimes, water quality, and light attenuation) that needs to be integrated.
- the number of variables associated with each component that require simultaneously collected data over a range of time scales (event, diurnal, or seasonal).

Following development, the IRL-PLR model will be used in an optimization procedure that incorporates economic, regulatory, and other technical constraints to establish final PLRTs and allocate these reduction targets among the watershed sources in an equitable manner.

SEDIMENTS

The sediments in the Indian River Lagoon are dynamic and the settling basin is constantly changing in shape and composition (Woodward-Clyde 1994a, 1994c). Sediment build-up in the Lagoon has been identified as a physical problem. Deposition and erosion interfere with navigation and can change the tidal regime within the estuary. Additionally, many aquatic organisms that have low tolerances for sediment accumulations, such as the eastern oyster *Crassostrea virginica*, are potentially being smothered by high loadings (Walters et al. 2001). It is imperative that we better understand the movements and sources of the sediment flux in the waters of CANA.

The bottom of Mosquito Lagoon contains sandy sediments, comprised mostly of quartz and shell fragments (Woodward-Clyde 1994a). The sand and shell particles that comprise these sandy sediments have relatively low affinities for particle-reactive contaminants in comparison to more fine-grained sediments (Woodward-Clyde 1994a).
Another type of sediment that can be found in the Lagoon is fine-grained, organic-rich mud commonly referred to as "muck" (Woodward-Clyde 1994a). Muck is more frequently associated with particle-reactive contaminants, including synthetic organic compounds and metals.

Muck deposits cover very little of the bottom of Mosquito Lagoon and are usually found in relatively deep or sheltered areas where wave action and current strength are limited, such as the ICW. The last IRL system-wide sediment survey found no major muck deposits between New Smyrna and Oak Hill (Trefry et al. 1990). South of Oak Hill, three minor muck deposits were found in the ICW. It is believed that the deposits may be a result of the transport of soil and organic material from the more developed northern and central regions. Where present, muck deposits can vary in thickness from less than 0.5 inch (1 cm) to greater than 6 feet (1.8 m), as has been found in central regions of the IRL system (Trefry et al. 1990).

The SJRWMD SWIM Plan is suggesting a resurvey within the next 5 years given that TSS and TN concentrations in the southern portion of Mosquito Lagoon have dramatically increased in the last few years. If the sediment survey should reveal an appreciable expansion of muck deposits, a proposal to accelerate the ICW dredging schedule can be submitted to the ACOE. Lagoon-wide investigations in sediment particle re-suspension and optical properties of suspended material may provide major clues as to what type of suspended material most influences turbidity and light penetration. A study of the composition of the sediments would also be important for identifying and controlling specific sources of TSS and TN.

SEDIMENT QUALITY

The sediment quality of most of the open water areas of the Indian River Lagoon is good and levels of metals in sediments in the IRL complex are within FDEP estimated normal loadings for estuaries (Woodward-Clyde 1994c). Trefry et al. (1989) state that land runoff (e.g. fine sediments) is the major source of muck. Large runoff events, such as summer storms, sweep muck sediments from the tributary creeks and canals into the Lagoon. Organic detritus from the land contributes directly to these deposits. Also, nutrients in this runoff can stimulate plankton, aquatic plant and algal production in Mosquito Lagoon, which in turn can contribute a significant load of dead organic material to the sediments (Woodward-Clyde 1994c).

Metal contamination (zinc, copper, mercury, lead) also appears to be associated with the muck deposits. Most of this contamination is south of the boundaries of CANA and justifies CANA's need to better understand water bodies external to CANA boundaries. Within CANA waters, contamination is predicted to occur where the Intracoastal Waterway crosses CANA boundaries. Maintenance dredging of the ICW is not scheduled to begin until at least 2005 (D. Roach, pers. comm., Florida Inland Navigation District, 2000). However, preparation of the dredged material management site in Oak Hill was initiated in 2001 (Figure 7). Debate continues as to where runoff from the dredge piles will re-enter Mosquito Lagoon and CANA must be directly involved with this process (J. Stiner, pers. comm., CANA, 2001).

In January, 1993, sediments from seven locations in Mosquito Lagoon were tested for DDT-related residues (CANA files). Such compounds may have been deposited during mosquito control activities in the 1940's through 1960's, prior to establishment of the Park (see Mosquito Control under Anthropogenic Influences, page 78). Locations included two impoundments, one spoil island, and four natural high-marsh islands. Analysis by an EPA-certified lab, with a detection limit of 1.0 part per billion (ppb), revealed no residue at six sites and 0.0044 parts per million (ppm) at the seventh (State of Florida Pesticide Analysis Reports, CANA files).

GROUNDWATER

HYDROGEOLOGY

The state of Florida has more available ground water than any other state within the United States (McGuinness 1963). Potable ground water can be found throughout most of Florida, with the exception of a few areas near the coast (Conover et al. 1984). In 1980, 51% of the total fresh water used in Florida was ground water. There are three basic units of the hydrogeologic framework underlying Florida and the Indian River Lagoon system: the Floridan Aquifer, the intermediate aquifer (regional confining unit) and the surficial aquifer (Figures 16 - 18; Appendix C).

The Floridian Aquifer is a system of limestone and dolomite beds, and is the main source of potable water in Volusia County (Phelps 1990). The raw water supply for the Utilities Commission of New Smyrna Beach (UCNSB) is derived from 19 deep wells obtaining groundwater from the Floridan Aquifer. These wells can produce a total firm capacity in excess of 7.7 million gallons per day. In 1999, the UCNSB distributed 1.7 billion gallons of water to an estimated 17,505 New Smyrna Beach customers within a 41.3 square mile service area. Seven wells are located at the Glencoe Road Water Treatment Plant site and six additional wells are located west of this site along S.R. 44. The remaining six wells are located on S.R. 44, 12.5 miles inland. Well depths range from 183 feet to 364 feet, with an average depth of 240 feet (New Smyrna Beach Utilities Commission 1999).

The Floridan Aquifer underlies the entire state of Florida including the Coastal Plain areas of Alabama, Georgia, and South Carolina. In total, the Floridan Aquifer covers an area of about 82,000 square miles (Parker et al. 1955; Parker 1974). Throughout most of the state, the Floridan Aquifer is one large, mostly artesian, hydrogeologic unit. However, in some areas, where confining beds are absent, thin, or discontinuous, water occurs under water table conditions (Parker et al. 1955; Parker 1974).

The Floridan Aquifer is composed of several formations from the Eocene Era. From youngest to oldest, these include: the Suwannee Limestone, the Ocala Limestone, the Avon Park Limestone, and the Lake City Limestone (Toth 1987). The Suwannee Limestone is not found under the Mosquito Lagoon basin and therefore it is the Ocala Limestone that marks the upper limit of the Floridan Aquifer in this region (Woodward-Clyde 1994b). The depth of the top of the Floridan Aquifer varies considerably throughout the state. For example, the top of the Floridan Aquifer under northern Mosquito Lagoon can be found at –23 meters in reference to mean sea level (National Geodetic Vertical Datum: NGVD). In southern Brevard County, the top of the aquifer lies at –61 meters NGVD, and near St. Lucie Inlet the top is found at –229 meters NGVD (Woodward-Clyde 1994b).

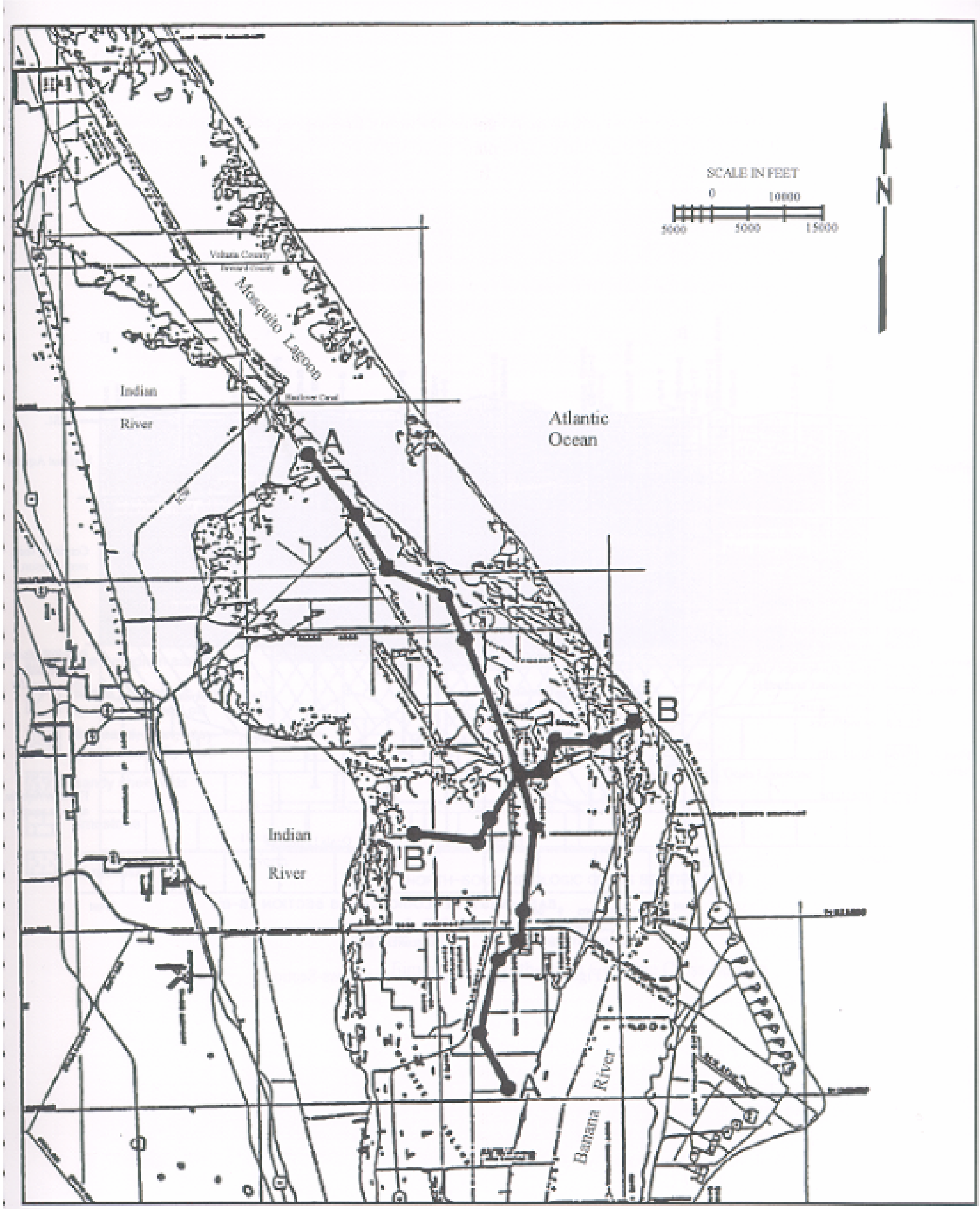


Figure16 - Soil Boring Locations For Geologic Cross-sections

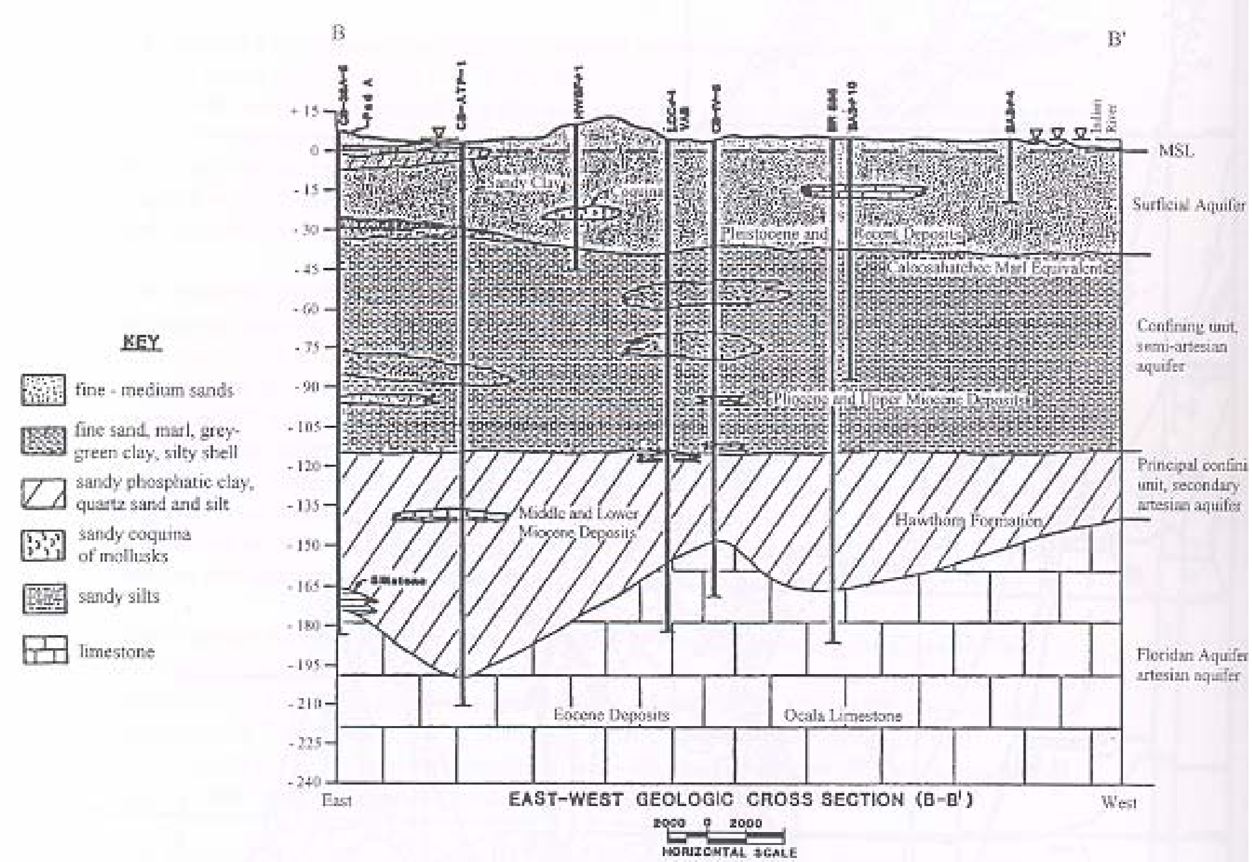


Figure 17 - East-West Geologic Cross-Section

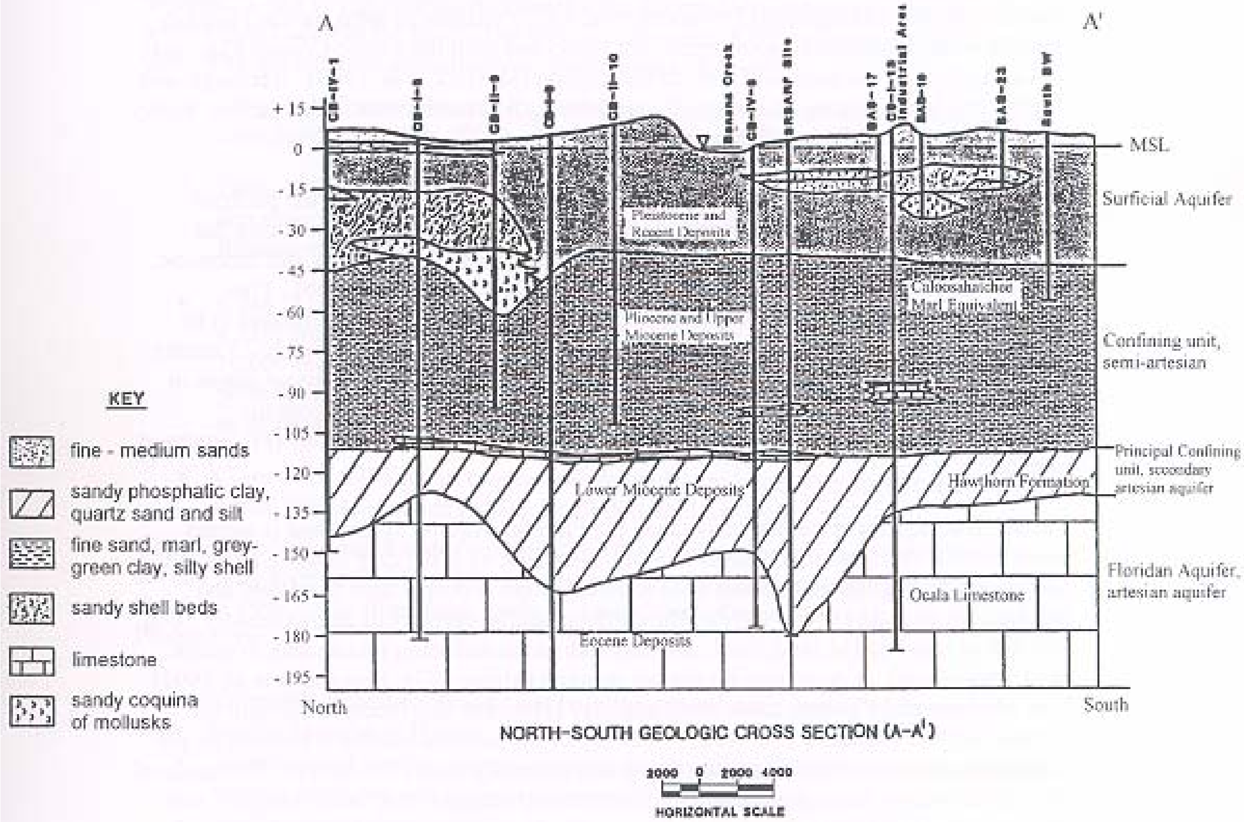


Figure 18 - North-South Geologic Cross-Section

In the northern IRL, the intermediate aquifer-confining unit is not very thick, the Floridan Aquifer probably discharges directly to the surficial aquifer naturally due to the upward flow potential from the deeper aquifer during the dry season (Toth 1987). In Volusia County, the confining unit becomes very thin, or even absent in some areas, which allows greater exchange of ground water between the Floridan and the surficial aquifers (Toth 1987). An example of where the Floridan Aquifer discharges to the surface can be found in Turnbull Hammock (Wyrick 1960). Toth (1987) defines the Mosquito Lagoon sub-basin as an area of active discharge from the Floridan Aquifer. Discharge may occur through springs, artesian wells, or leakage into overlying aquifers through thin or discontinuous confining beds (Provancha et al. 1992). Recharge areas for the Floridan Aquifer in the Mosquito Lagoon region are associated with the karstic Cresent City and DeLand ridges to the north and west of the Lagoon (McGurk et al. 1989). Recharge also occurs, to a lesser degree, as leakage through the surficial sediments in the Eastern Valley and Atlantic Coastal Ridge (Provancha et al. 1992).

The intermediate aquifer is the confining unit between the Floridan and the surficial aquifers. It is composed primarily of the Hawthorn Formation deposited during the Miocene Era (Provancha et al. 1992). This formation is made up of clay and limestone, with some interspersed layers of sand and shell (Woodward-Clyde 1994b). The Hawthorn formation beneath Mosquito Lagoon is relatively thin; it is estimated to be approximately 15 to 30 meters thick (McGurk et al. 1989) and approximately 23 meters below the surface at Ponce de Leon Inlet (Toth 1987). Additionally, at some places in Volusia County, the Hawthorn Formation is absent (Toth 1987). The hydraulic conductivity ranges between only 3.04×10^{-4} and 9.1×10^{-3} meters per day (Provancha et al. 1992).

The surficial aquifer is less extensive than the Floridan Aquifer system and is tapped when the Floridan Aquifer contains non-potable water, as is the case in some areas of the Mosquito Lagoon region, or when the Floridan system is deeper than 61 meters and brackish water occurs (Toth 1987). The surficial aquifer consists of approximately 50 to 100 feet of interbedded sand, shell, and clay sediments including Pleistocene to recent sand, clayey sand, or Anastasia Formation coquina (Miller 1979, Provancha et al. 1992). Late Miocene and Pliocene sand, shell, and clay layers are also incorporated into the surficial aquifer (McGurk et al. 1989). The top of the surficial aquifer is marked by the water table, and the intermediate confining unit generally marks the bottom. Recharge of this aquifer occurs through infiltration of rainfall and seepage from lakes, streams, and marshes. Precipitation is the primary source of recharge. Provancha et al. (1992) documented about 0.5% of the average annual rainfall recharging the groundwater reservoir, whereas Erwin (1988) reported about 14% going into groundwater storage.

Dr. Randall Parkinson (formerly of Florida Tech) is presently investigating the surficial geomorphology of MINWR and KSC. Although important for understanding both present biodiversity and water management strategies, to date, these late Quaternary deposits and associated geomorphology (sinkhole lakes, solution creek channels, etc.) have not been mapped. Results from this study are expected in 2001.

GROUNDWATER QUALITY AND MONITORING

Classification and Regulation

The State of Florida adopted water quality standards for groundwater in 1983. These standards, modeled after the more established surface water criteria, are contained in Chapter 62-3, Florida Administrative Code (FAC). Groundwater criteria have been established as four classes, G-I through G-IV, in order of the degree of protection required. Class G-I groundwater generally has the most stringent water quality criteria, while Class G-IV has the least. The groundwater under KSC has been classified as Class G-II. The groundwater classifications are defined as follows:

- Class G-I: Potable water use, groundwater in single source aquifers that have a total dissolved solids (TDS) content of less than 3000 mg/L.

- Class G-II: Potable water use, groundwater in aquifers that have a TDS content of less than 10,000 mg/L, unless otherwise classified by the Environmental Regulatory Commission (ERC).

- Class G-III: Non-potable water use, groundwater in unconfined aquifers that have a TDS content of 10,000 mg/L or greater; or that have a TDS content of 3,000 - 10,000 mg/L and either has been reclassified by the ERC as having no reasonable potential as a future source of drinking water, or has been designated by the FDEP as an exempted aquifer pursuant to Section 62-28.13(3), FAC.

- Class G-IV: Non-potable water use, groundwater in confined aquifers, which has a total dissolved solids content of 10,000 mg/L or greater.

Establishing background water quality of the State's major potable aquifers is one of several long-term goals of the FDEP's Groundwater Quality Monitoring Program (Maddox 1992). The three basic goals of the statewide Groundwater Quality Monitoring Program are:

- To establish the background and baseline groundwater quality of the major aquifer systems in Florida.
- To detect and predict changes in groundwater quality resulting from the effects of various land uses and potential sources of contamination.
- To disseminate water quality data generated by the network to local governments and to the public.

The FDEP was the lead agency in establishing the Groundwater Quality Monitoring Network (now under the Ambient Monitoring Section). The FDEP works closely with Florida's five water management districts and several counties, which carry out most of the necessary fieldwork and provide local technical expertise. The Florida Geological Survey and the Water Resources Division of the U.S. Geological Survey (USGS) provide additional technical support (Copeland 1996). One third of the State's wells are sampled every year. Therefore, after three years, a complete sampling sweep of the state is completed.

Summary statistics of the background water quality for each of the three major aquifers in the SJRWMD Reporting Unit C can be found at the FDEP website: www/myflorida.com. The Mosquito Lagoon region is located within the SJRWMD Reporting Unit C, but unfortunately it is represented by only a few wells. A higher concentration of wells is located away from coastlines in the central region of the state. Additional information on CANA groundwater quality can be found in NASA Technical Memorandum 2000-208583, published in June 2000 by NASA/Dynamac Corporation (Schmalzer et al. 2000). Of the 24 wells sampled, 6 were located with CANA boundaries. All six sites had shallow wells (4.6 m). Four of the six also had intermediate wells (10.7 m) and three of the six had deep wells (15.2 m). Using standard protocols, groundwater samples were analyzed for organochlorine pesticides, aroclors, chlorinated herbicides, PAH, total metals, dissolved oxygen (DO), turbidity, pH, specific conductivity, temperature, total dissolved solids (TDS), and total organics carbon (TOC). All organochlorine pesticides (25), all aroclors (6) and all chlorinated herbicides (18) were below detection in all samples. Due to these results and much additional data, the report concludes that widespread contamination of the Surficial Aquifer has not occurred (Schmalzer et al. 2000).

Groundwater Resources in Volusia County

Data from the Phelps (1990) study of Volusia County indicate that in some wells in the study area, the lower permeable zone wells of the surficial aquifer and the upper Floridan Aquifer wells have water levels that are about the same, indicating a good hydraulic link between the two. At other sites the water levels are different and the connection between zones is apparently poor. Both the magnitude and direction of the vertical hydraulic gradient between the surficial aquifer system and the upper Floridan Aquifer fluctuate seasonally. At some locations where the gradient is small (such as wells 36 and 37-
located one mile from the east side of the Lagoon: Figure 19), the gradient is sometimes upward and sometimes downward. Comparison of well water levels also indicates whether a particular area is an area of recharge to, or discharge from, the upper Floridan Aquifer. Some wells on the west side of Mosquito Lagoon exhibit a higher hydraulic head in the upper Floridan Aquifer than in the surficial aquifer system, indicating that the area is a discharge area for the upper Floridan Aquifer. Also on the western side of the Lagoon, the lower zone of the surficial aquifer is receiving recharge from the upper zone of the surficial aquifer system and from the upper Floridan Aquifer. It is thus probable that groundwater discharge from the lower zone of the surficial aquifer system to Mosquito Lagoon represents a major input to the system (Phelps 1990).

In the study area (Phelps 1990), sandy beach ridges with altitudes of about 25 feet alternate with low inter-ridge areas with altitudes of about five to ten feet. The potentiometric surface of the Upper Floridan aquifer in some places is above land surface, and generally no more than 15 feet below land surface. Runoff ranges mostly from six to eighteen inches per year, although on the Atlantic Beach Ridge (the barrier island), runoff is only one to six inches, probably reflecting a higher infiltration rate for

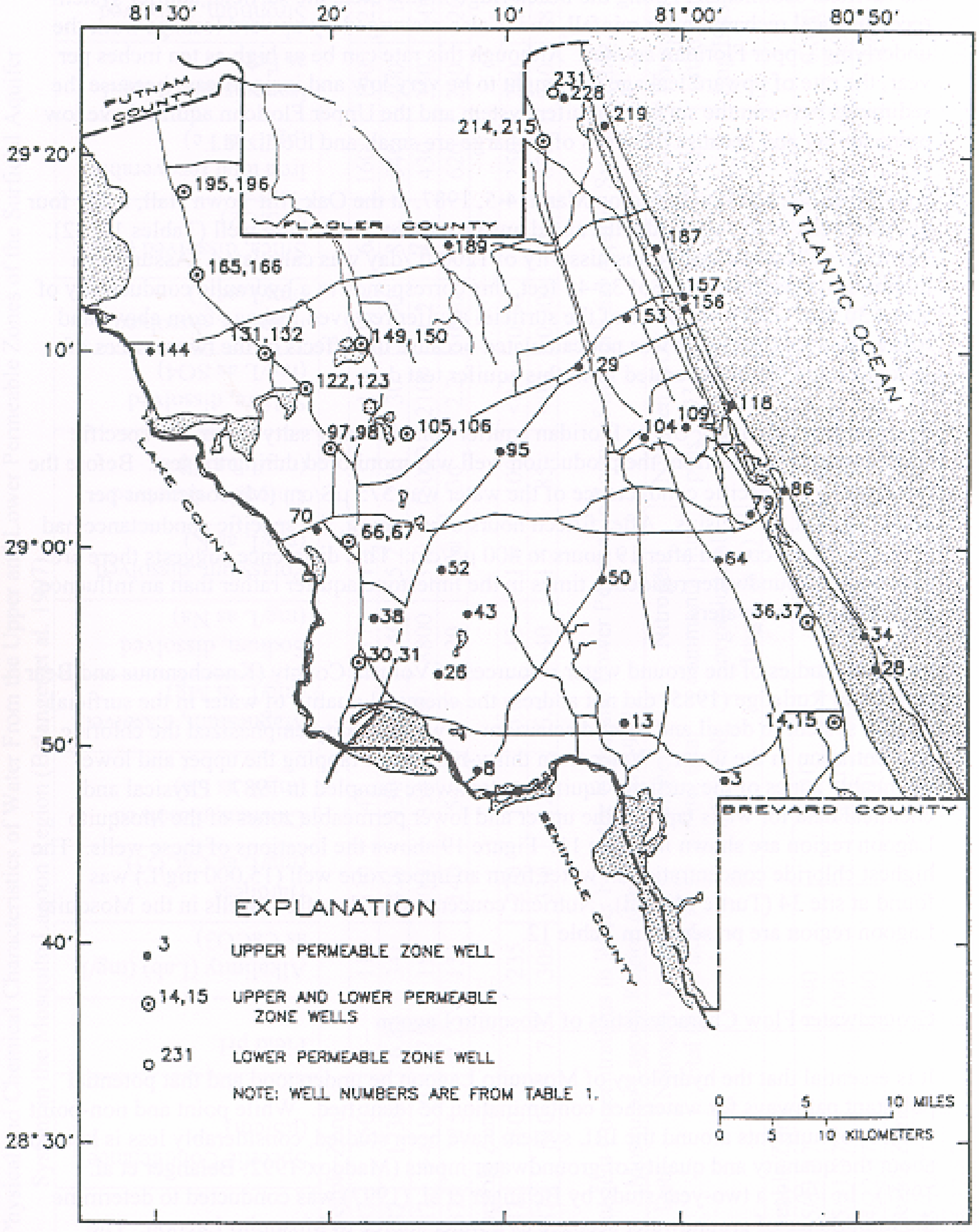


Figure 19: Well Locations (from Belanger et al. 1997)

the surficial sediments. Along the beach ridge in this area, the surficial aquifer system receives local recharge from rainfall, and is also recharged by upward leakage from the underlying Upper Floridan aquifer. Although this rate can be as high as ten inches per year, the rate of upward leakage is thought to be very low and insignificant because the sediments between the surficial aquifer system and the Upper Floridan aquifer have low permeability and because the areas of recharge are small and localized.

An aquifer test was conducted on March 4-5, 1987, at the Oak Hill Town Hall, using four pairs of wells with various depths and diameters, and a production well (Tables 11, 12).
From the collected data, a transmissivity of 1200 ft^2/day was calculated. Assuming a thickness of the lower zone of 35-40 feet, this corresponds to a hydraulic conductivity of about 30 ft/d. The lower zone of the surficial aquifer received leakage from above and below, so a leakage value was not calculated because the effects of the two sources of leakage could not be separated from this aquifer test data.

Because the underlying Upper Floridan aquifer contains very salty water, the specific conductance of water from the production well was monitored during the test. Before the test began, the specific conductance of the water was 575 µS/cm (Microsiemens per centimeter) at 25° Celsius. After fifteen hours of pumping, the specific conductance had risen to 720 µS/cm and after 19 hours to 800 µS/cm. This difference suggests there are changes in groundwater residence times in the limestone aquifer rather than an influence from more saline waters.

Previous studies of the ground water resources of Volusia County (Knochenmus and Bear 1971) and Rutledge (1985) did not address the chemical quality of water in the surficial aquifer system in detail and most discussions of water quality emphasized the chloride concentration in the water. Water from thirty-nine wells tapping the upper and lower permeable zones of the surficial aquifer system were sampled in 1987. Physical and chemical data for wells tapping the upper and lower permeable zones of the Mosquito Lagoon region are shown in Table 11. Figure 19 shows the locations of these wells. The highest chloride concentration in water from an upper zone well (15,000 mg/L) was found at site 34 (Turtle Mound). Nutrient concentration data from wells in the Mosquito Lagoon region are presented in Table 12.

Groundwater Flow Characteristics of Mosquito Lagoon

It is essential that the hydrology of Mosquito Lagoon be understood and that potential pollutant pathways for watershed contamination be identified. While point and non-point sources of nutrients around the IRL system have been studied, considerably less is known about the quantity and quality of groundwater inputs (Maddox 1992; Belanger et al. 1997). In 1995, a two-year study by Belanger et al. (1997) was conducted to determine the importance of groundwater seepage as a water source to Mosquito Lagoon. The objectives of this study were to quantify the concentrations of selected nutrients in groundwater surrounding Mosquito Lagoon, estimate nutrient loading to the Lagoon, and

Table 11. Physical and Chemical Characteristics of Water From the Upper and Lower Permeable Zones of the Surficial Aquifer System in the Mosquito Lagoon Region (Belanger et al. 1997).

Well #	Date	Specific Conductance (µS/cm)	Field pH	Alkalinity (Lab) (mg/L as CaCO3)	Hardness (mg/L as CaCO3)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO4)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO2)	Iron total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Strontium, dissolved (mg/L as Sr)
Upper Permeable Zone																
15	03/10/87	350	--	110	130	47	1.8	17	1.3	23	13	0.10	6.4	1600	190	230
28	05/21/87	1730	6.85	341	420	130	23	140	5.2	240	30	0.50	8.8	540	400	1100
34	05/21/87	>41100	7.3	157	5000	350	1000	8800	310	15000	2100	1.2	4.7	430	350	6000
36	04/22/87	375	7.35	131	140	54	1.3	20	0.20	36	2.2	0.40	4.5	620	230	260
Lower Permeable Zone																
14	03/10/87	750	--	235	270	100	5.0	43	1.6	100	<0.1	0.30	38	250	200	20
37	04/22/87	810	7.0	309	330	120	6.9	40	1.5	85	<0.1	0.30	59	870	540	810

Table 12. Nutrient Concentrations in Water From the Upper and Lower Permeable Zones of the Surficial Aquifer System in the Mosquito Lagoon Region (Belanger et al. 1997).

Well #	Date	Nitrogen, ammonia, total (mg/L as N)	Nitrogen, nitrite, total (mg/L as N)	Nitrogen, ammonia plus organic total (mg/L as N)	Nitrogen, NO2 plus NO3 total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus ortho, total (mg/L as P)
Upper Permeable Zone							
28	05/21/87	0.940	0.010	1.6	0.870	0.560	0.500
34	05/21/87	0.060	<0.010	<0.20	0.020	0.160	0.090
36	04/22/87	0.040	<0.010	<0.20	<0.020	0.450	0.230
Lower Permeable Zone							
14	03/10/87	0.560	<0.010	0.68	<0.020	0.280	0.270
37	04/22/87	0.820	<0.010	1.0	<0.020	0.200	0.070

determine whether specific on-site sewage disposal systems (OSDS) are sources of nutrients to the Lagoon.

Groundwater seepage rates were measured with numerous seepage meters placed throughout the Lagoon region and the quality of groundwater from 12 piezometer wells on the east and west sides of the Lagoon were analyzed for five parameters: 1) conductivity, 2) chloride, 3) soluble reactive phosphorus, 4) combined nitrate-nitrite, and 5) ammonia-nitrogen (Table 13). Mean concentrations of these parameters were combined with flow data from the seepage meters to estimate approximate groundwater loading rates to Mosquito Lagoon. Groundwater data representing different land uses were also compared to show the effects of these particular land uses on groundwater quality (Belanger et al. 1997).

Table 13. Location of Piezometer Wells and Associated Land Use

Well Locations and ID Numbers	Land Use Classification
Turtle Mound (TM1, TM2)	Undeveloped
CANA Ranger Station (NPS1, NPS2, NPS3)	Developed with OSDS
Riverwoods Trailer Park (TP)	Developed without OSDS
Transect B (north of Riverwoods T.P.) (T-B1, T-B2)	Undeveloped
LeFils Fish Camp (LF1, LF2, LF3)	Developed with OSDS
Haulover Canal (HC)	Undeveloped

Forty-six seepage meters were placed in the Lagoon along nine transects extending perpendicular from the shore. Six transects were placed adjacent to the six general locations of the piezometer wells (Table 13). After samples and measurements were taken, nutrient loadings were calculated by multiplying the mean seepage rates for each transect times the adjacent well concentration data. The assumption was made that the seepage meters were measuring a representative sample of seepage from the surficial aquifer (Belanger et al. 1997).

The average groundwater seepage rates for the three transects on the east side of Mosquito Lagoon (offshore from Turtle Mound and the CANA Ranger Station) were 1254, 1022, and 2064 ml/m^2/hr. The four transects on the western side of the Lagoon (offshore from Riverwoods Trailer Park and LeFils Fish Camp) had average seepage rates of 1353, 1181, 400, and 2005 ml/m^2/hr. The central Lagoon and Haulover Canal site had seepage rates of 459 and 1521 ml/m^2/hr, respectively. The overall groundwater seepage rate average for Mosquito Lagoon, over the entire study period, was high (1251 ml/m^2/hr) and indicates significant groundwater input to the Lagoon. No significant correlation was found between groundwater seepage and sediment type or percent organic matter; other factors such as hydraulic gradient, water table configuration, and aquifer characteristics predominated (Belanger et al. 1997).

Figures 20 through 22 show the mean concentrations of soluble reactive phosphorus (SRP), ammonia, and nitrate-nitrite for the east side (barrier island) and west side (mainland) wells over the 8-month sampling period. SWTM (offshore of Turtle Mound) and SWTP (offshore of Riverwoods Trailer Park) are surface water sample sites measured during the study for comparison.

The surface water at Turtle Mound exhibited the lowest mean concentration of SRP of all the sites on the east side of the lagoon, while the NPS3 well had the highest (Figures 20-25). The NPS2 and NPS3 wells were down-gradient from the former OSDS drain-field, while the NPS1 well was up-gradient from the drainfield. As seen in Figure 20, the NPS2 and NPS3 sites had significantly higher levels of SRP than NPS1. This suggests that OSDS leachate was flowing towards the Lagoon. The NPS2 and NPS3 wells also had significantly higher concentrations of ammonia than the Turtle Mound sites (Figure 21). However, nitrate-nitrite concentrations at the Turtle Mound sites were significantly higher than all three NPS sites (Figure 22). The high levels of nitrate-nitrite may also have been due to the presence of large amounts of oyster shells in the area (Sloane 1988), or nitrogen-fixing plants (Johannes 1980).

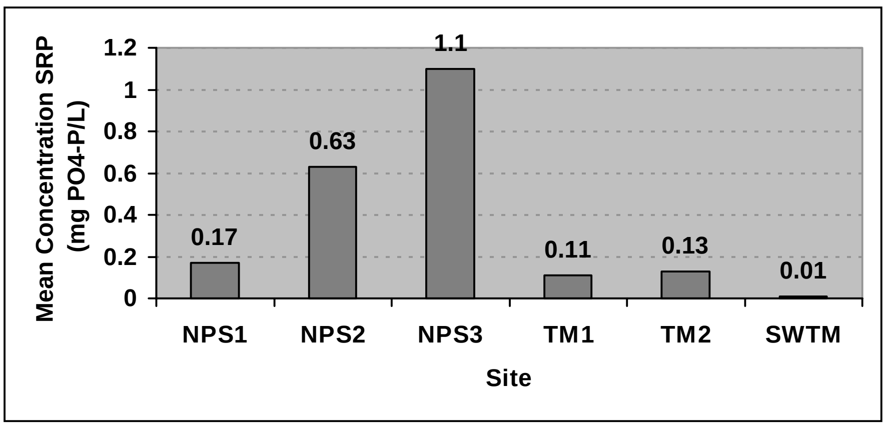


Figure 20. Mean Soluble Reactive Phosphorus Concentrations at East Mosquito Lagoon Sites

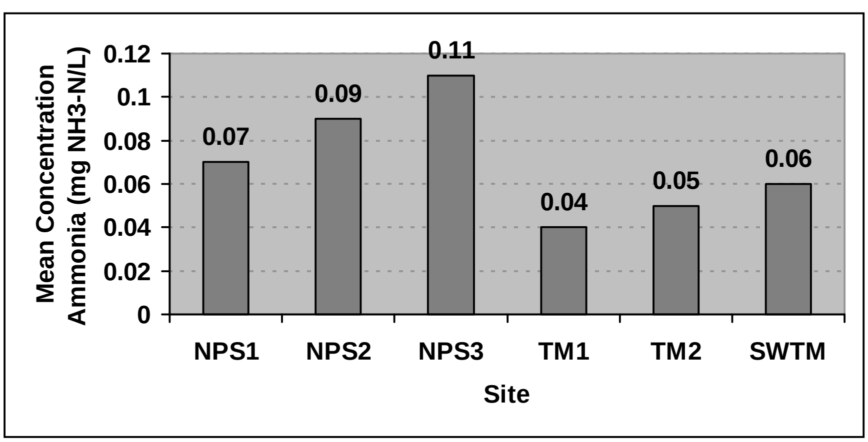


Figure 21. Mean Ammonia Concentrations at East Mosquito Lagoon Sites

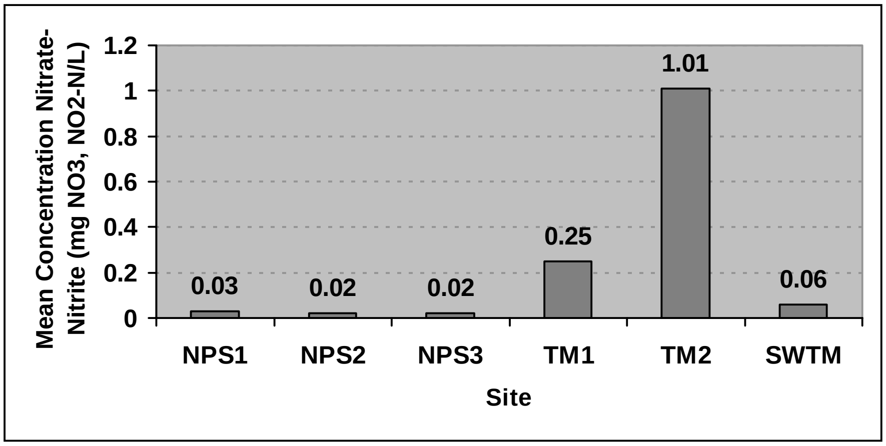


Figure 22. Mean Nitrate-Nitrite Concentrations at East Mosquito Lagoon Sites

On the western side of the Lagoon, the results were not as clear. Transect B wells in undeveloped areas exhibited higher mean concentrations of SRP than all the Lefils Fish Camp wells (developed with OSDS) (Figure 23). The wells at Lefils Fish Camp were installed with the expectations that LF1 would be up-gradient from any OSDS impact. However, there was no significant difference between the down-gradient wells (LF2 and LF3) and the up-gradient well (LF1) for any of the measured parameters (Figures 23-25). This may have been due to the fact that the area is much flatter and the flow of groundwater may not have been in the expected direction, or another source of nutrients could have been present near the LF1 well. The surface water at Riverwoods Trailer Park (developed without OSDS) exhibited the lowest mean concentration for all parameters except nitrate-nitrite, which was lowest at the undeveloped Haulover Canal well (Figure 25). The nitrate-nitrite level at Riverwoods Trailer Park was the highest of all the sites on the western side, indicating that there is an outside source of nitrogen that may be attributed to the pattern of land use (e.g. fertilizer use on trailer park grounds) (Belanger et al. 1997).

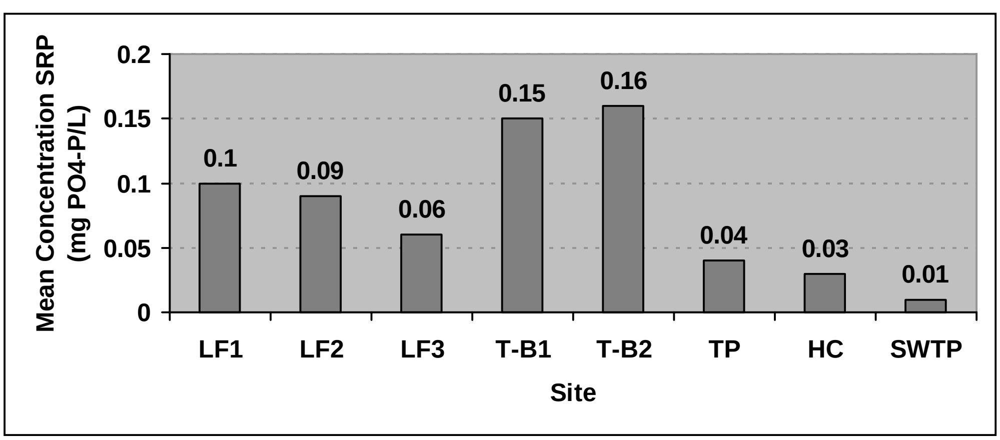


Figure 23. Mean Soluble Reactive Phosphorus Concentrations at West Mosquito Lagoon Sites

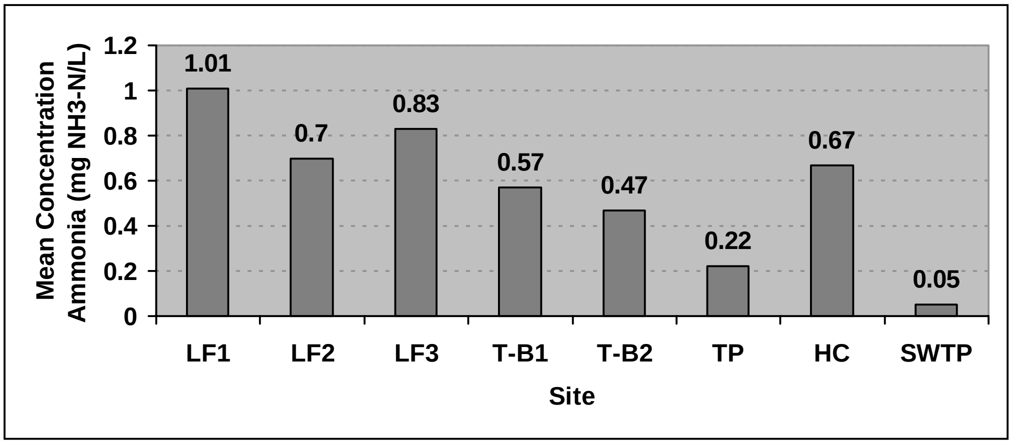


Figure 24. Mean Ammonia Concentrations at West Mosquito Lagoon Sites

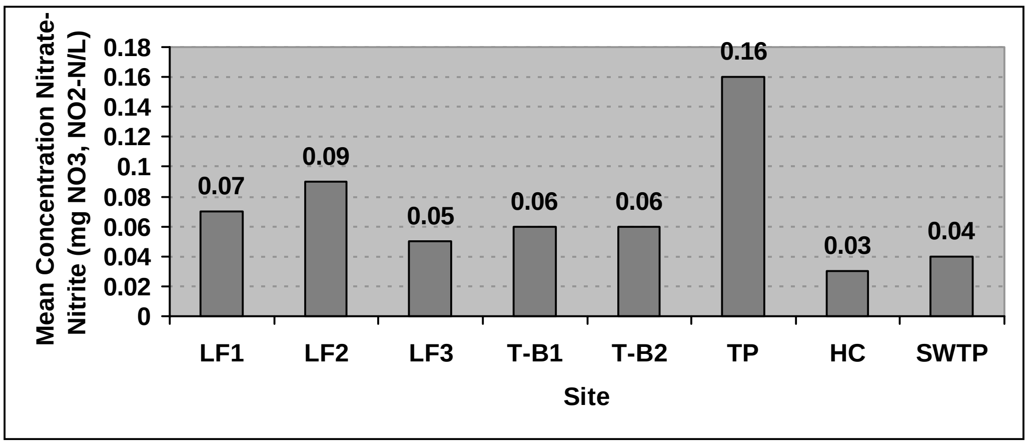


Figure 25. Mean Nitrate-Nitrite Concentrations at West Mosquito Lagoon Sites

Results of this study show that efforts to reduce or eliminate groundwater pollution in this area should be included in Mosquito Lagoon management plans. In 2000, the areas from Bethune Beach south to CANA's information center, were connected to sewer lines. A follow-up study would be useful to determine the impact of switching to sewer lines.

ANTHROPOGENIC INFLUENCES

MOSQUITO CONTROL

Although the salt marsh mosquito has not been a significant carrier of diseases, it can be such a nuisance from May to November that outdoor activities in areas surrounding the IRL system are almost impossible without mosquito control. Salt marsh mosquitoes can travel up to 20 miles (32 km) from their hatching sites (Provost 1960). Thus, almost all of the breeding grounds along Mosquito Lagoon can contribute to pest problems in the urbanized portions of the watershed

(Woodward-Clyde 1994f). The breeding season of the mosquitoes in the tidal wetlands of central Florida is from approximately mid-April to mid-September each year.

In the designation of lands for NPS management, both NASA and the State of Florida stipulated that CANA must cooperate with the local mosquito control districts to control salt marsh mosquitoes. CANA's GMP states that the Park will work with the mosquito districts to implement the most environmentally safe methods of control. Much impact to Mosquito Lagoon's wetlands occurred for the purposes of mosquito control prior to CANA's creation in 1975.

Chemical Control

In the 1940's, the use of pesticides such as DDT, dieldrin, and BHC became the accepted method for control of adult mosquitoes (Rey and Kain 1991). However, by the late 1940's, salt marsh mosquitoes were already beginning to show resistance to these pesticides. Additionally, in the early 1960's, the pesticide DDT and other persistent chlorinated compounds were discovered to be responsible for the decline of many species of birds and wildlife (Rey and Kain 1991; David 1992). Diesel fuel was also used by the Brevard County Mosquito Control District from the 1930's until 1988, when a refined diesel oil (Golden Bear) replaced it (Provancha et al. 1992). Up until 1989, East Volusia Mosquito Control District occasionally used Malathion to control adult mosquitoes in the North District of the Park, but use was stopped that year to comply with NPS restrictions on pesticide use.

Altosid, Altosand (Altosid/sand mix), methoprene, BTI (*Bacillus thuringiensis isaelensis* bacterial pesticide), and Florida larvicides are still being used regularly in most of the counties when the mosquito larval counts are exceptionally high. This generally occurs in spring, if water levels and high temperatures in March and early April promote early mosquito breeding, or in the autumn, after natural water regimes are restored in the impoundments (Rey and Kain 1991; David 1992; Provancha et al.1992). No adult pesticides are allowed except during a Center for Disease Control (CDC) declared emergency. CANA and East Volusia Mosquito Control District (EVMCD) have developed a cooperative agreement that allows for the application of NPS-approved larvicides, only when necessary, and also directs CANA and EVMCD to experiment with other management techniques for mosquito control.

Non-Chemical Control

Prior to the establishment of CANA in 1975, Volusia and Brevard counties oversaw all mosquito control activities. Non-chemical methods of source reduction in Mosquito Lagoon included water management through hand ditching (1920's), grid ditching with draglines (1950's-1960's), and impoundments (1950's-present) (Provancha et al. 1992). Over 1,200 acres of island marsh habitat in Mosquito Lagoon have been dragline ditched. These early methods brought drastic shifts in plant and animal communities in the Park by isolating portions of the Lagoon's wetlands and open water areas (Adams et al. 1996).

Impounding is a non-chemical method for control of mosquito reproduction that continuously floods mosquito-breeding areas during the breeding season, thus preventing mosquitoes from laying their eggs (Haeger 1960; Provost 1977). Impoundments were first tested in 1935 and found to be 99% effective in controlling sand flies and mosquitoes (Hull and Sheilds 1943). However, impounding did not become common practice until after the effects of DDT were discovered. Most impoundments along Mosquito Lagoon were constructed between 1962 and 1970 (Rey and Kain 1993). Although most of these impoundments have been reconnected or restored, over 6,750 acres (34%) of marsh habitat in the Mosquito Lagoon area are still impounded (SWIM Plan Update 2001, in prep.). Figure 26 shows the location and status of all impoundments and dragline-ditched areas in Mosquito Lagoon. A majority of the impoundments are located in the joint area and are managed by MINWR.

In general, impoundments can be operated as closed, seasonally closed, or open. Closed impoundments are completely surrounded by solid dikes. Water is pumped into the impoundment to maintain a depth of several inches so that mosquitoes cannot lay their eggs (Provost 1967; Rey and Kain 1991; David 1992). This practice completely isolates the wetland from the Lagoon, preventing fish and other species from moving between the Lagoon and what was once a tidal wetland (Gilmore et al. 1981; Harrington and Harrington 1982). This also prevents the export of organic matter and nutrients from the wetland to the Lagoon (Woodward-Clyde 1994f). Closed impoundments destroy and alter wetland vegetation, which is adapted to fluctuating water levels rather than continuous inundation. Permanent closure can reduce the salinity in an impoundment where rainfall replaces tidal exchange, or it can lead to hypersaline soil and water conditions when there is an excess of evaporation. These extremes in salinity can greatly alter native vegetation, replacing salt marsh species with non-halophytes or exotic species, such as Brazilian Pepper (Woodward-Clyde 1994f). In some impoundments, mangrove forests and salt marsh were killed and replaced by open water ponds (Montague and Wiegert 1990; Rey and Kain 1991).

The management of closed impoundments has been improved by MINWR through the implementation of the second type of impoundment: seasonally closed. Installation of culverts allows impoundments to be reconnected to the Lagoon during certain months, approaching a more natural hydrologic regime (Woodward-Clyde 1994f). In the past, the opening of culverts was based on administrative requirements and annual schedules (Rey and Kain 1991, 1993; David 1992). If the culverts were opened during low tide or low water conditions, large masses of impoundment water would drain into the Lagoon in a short period of time. The release of impoundment water in this way can have adverse effects, including fish kills near release points (Woodward-Clyde 1994f). This is because impoundment water is typically low in dissolved oxygen (DO), high in hydrogen sulfide (H_2S), high in chemical oxygen demand (COD) and biological oxygen demand (BOD), high in total suspended solids (TSS), and low in pH (Rey et al. 1990, 1991). Impacts to lagoon waters can be reduced through phased release of impoundment water over a longer period of time and through increasing the number of culverts (i.e. release points) to spread discharges over a wider area (Gilmore et al. 1987). Currently, most of the managing authorities utilize a form of seasonal management (Woodward-Clyde 1994f).

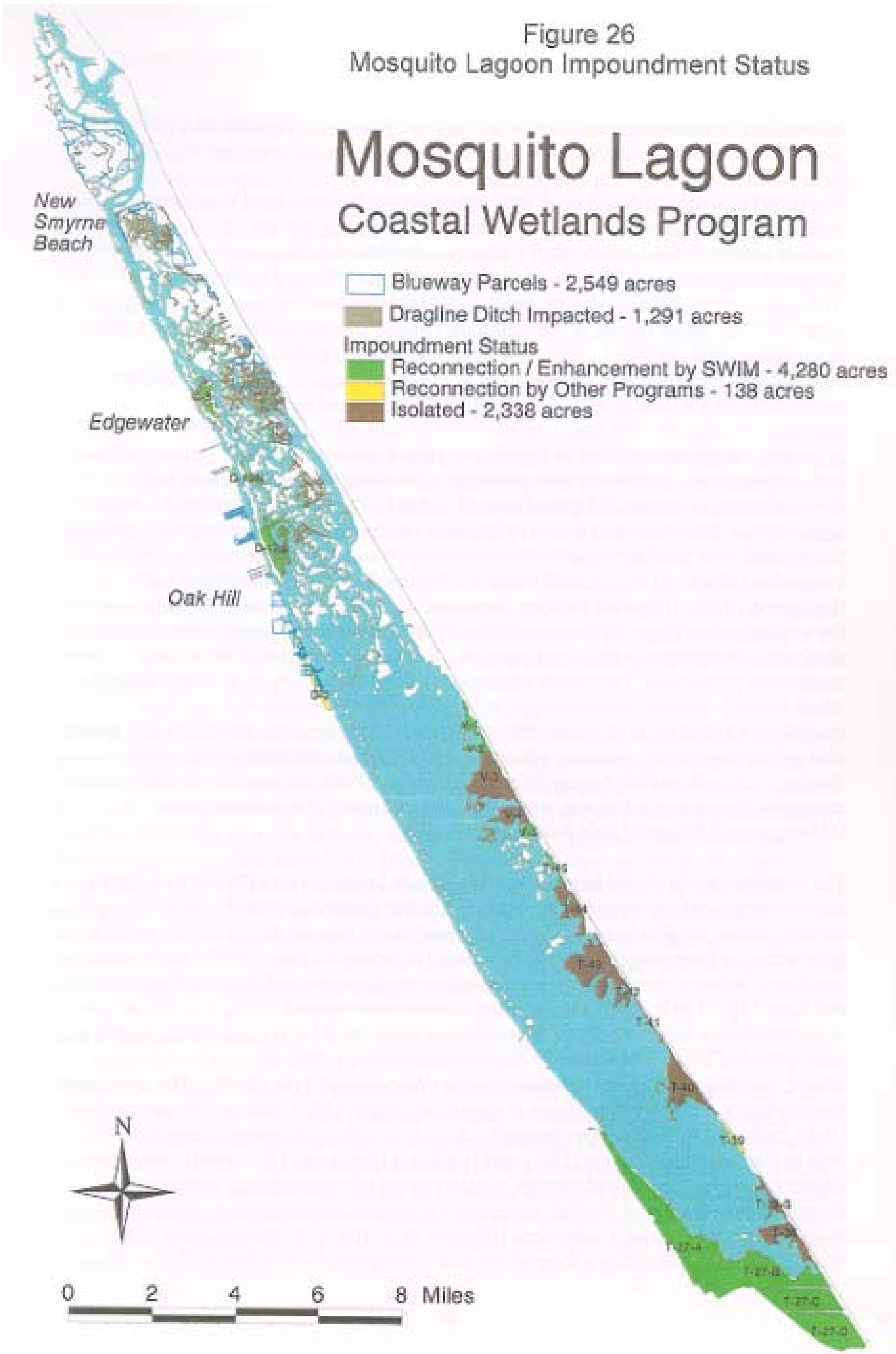


Figure 26
Mosquito Lagoon Impoundment Status

Other management techniques include the use of control gates, flapgate risers, modified tidegate weirs (MTGW), or flow-through systems to maintain better water quality and hydrologic conditions (Woodward-Clyde 1994f).

The management practice used primarily by MINWR is a form of the seasonal management program called Wildlife Aquatic Management (WAM). WAM management is a process by which the opening of culverts is based on the needs of waterfowl and wading birds. These impoundments are closed 8 – 10 months of the year (April/May through February/March). With WAM management, the water levels are allowed to rise throughout the spring and summer months to a maximum depth in November. Then, water levels are slowly lowered through approximately February. The impoundments are then opened from February/March through April/May.

Another type of impoundment, open impoundments, has culverts or breaches in the dikes that are permanently open. In these types of impoundments, additional means of water level control are usually needed for effective mosquito control. The East Volusia Mosquito Control District (EVMCD) has been a leader in the use of open impoundments combined with rotary ditching and open marsh water management (OMWM) to maintain mosquito control and allow transient fish utilization (Woodward-Clyde 1994f). Rotary ditching creates a more natural pattern of small canals that connect isolated ponds to the lagoon. They are dug by a machine that meanders the canals, gives them slanted sides, and scatters the spoil in a thin layer over a large area and prevents the formation of spoil berms, which can interrupt natural sheet flow.

Impoundment Status

CANA, SJRWMD, MINWR, and EVMCD are working together to reconnect and restore mosquito impoundments in Mosquito Lagoon (e.g. Brockmeyer et al. 1997). Since 1993, over 4,450 acres of mosquito impoundments have been reconnected or restored in the Mosquito Lagoon region (Figure 26). MINWR evaluated impoundments on the refuge and jointly-managed portion of CANA for their potential for wetland wildlife management, fisheries management or full restoration (USFWS 2001). This evaluation was reviewed by NASA, Brevard Mosquito Control District and State of FL environmental agencies. In Mosquito Lagoon, four impoundments were designated as Primary Management Impoundments, seven as Restoration and five as Management Flexible. Water levels are manipulated in Primary Management Impoundments to provide habitat and forage for waterfowl, shorebirds, wading birds and other wetland species. In restoration areas, the earthen dike is completely removed and natural tidal flow is restored to enhance fisheries and the natural ecosystem. Management Flexible areas may be managed in several ways, including Primary Management, Restoration or WAM, where impoundments are flooded to improve conditions for waterfowl and wading birds.

Table 14 summarizes a list of mosquito impoundments in the Mosquito Lagoon area that have been restored or are targeted for restoration. *Restored* indicates that the surrounding dike was scraped down to marsh elevation and the perimeter ditch was filled.

Reconnected indicates that culverts were used to provide Lagoon/impoundment connection, while *breached* indicates that sections of the dike were removed. The SWIM program was responsible for the planning, funding, and implementation of most of these projects.

Table 14. Restored or Impoundments Targeted for Restoration in Mosquito Lagoon Region
(* = date established in contract)

SJRWMD Impound. #	**MCD Impound. #**	**Approx. Acres**	**Reconnection Date**	**Restoration Type**	**Managed by FWS or NPS**
10700.0	D-2	28	n/a	reconnected	NPS
5500.0	T-39-S	84	1999	restored	FWS
10600.0	C-8	91	1993	breached	NPS
10800.0	D-12N	45	1995	breached	NPS
10900.0	D-12S	278	1998	breached	NPS
300.0	V-3	490	*	contract to reconnect	FWS
400.0	V-4	163	*	contract to reconnect	FWS
200.0	V-2	51	2001	contract to restore	FWS
500.0	V-5	51	2001	contract to restore	FWS
3700.0	T-27-A	1677	1995	reconnected	FWS
3800.0	T-27-B	713	1995	reconnected	FWS
3900.0	T-27-C	575	1995	reconnected	FWS
4000.0	T-27-D	675	1995	reconnected	FWS
100.0	V-1	92	1999	restored	NPS
6100.0	T-45	35	2000	restored	FWS
5300.0	T-38	260	?	targeted	FWS
5400.0	T-39	30	?	targeted	FWS
5600.0	T-40	401	?	targeted	FWS
5700.0	T-41	38	?	targeted	FWS
5800.0	T-42	116	?	targeted	FWS
5900.0	T-43	555	?	targeted	FWS
6000.0	T-44	231	?	targeted	FWS
10700.1	D-2	25	?	targeted	NPS
10700.2	D-2	55	?	targeted	?

At the present time, the primary use of impoundments in Mosquito Lagoon is wildlife management, especially waterfowl and wading bird nesting and foraging habitat (R. Brockmeyer, pers. comm., SJRWMD, 2001) and enhanced trophic export support to the Lagoon (Woodward-Clyde 1994f). Managers in the southern reaches of the IRL have also proposed that impoundments be used for controlled rearing of fish and shellfish for stocking or commercial purposes.

ATLANTIC INTRACOASTAL WATERWAY (ICW)

Information on maintenance dredging of the ICW in CANA and its spoil placement adjacent to CANA boundaries is found in the FIND Management Plan and Engineering Narrative for site V-22A (Taylor et al. 1991). When shoaling causes the ICW to decrease to only 7 feet, a schedule for maintenance dredging begins. A survey by the Florida Inland Navigation District (FIND) in December 1996 showed that significant shoaling has occurred in the ICW of the New Smyrna Beach area. Also, Reach VI (Figure 7) will be scheduled for maintaince dredging. This part of the ICW runs from northern Oak Hill (ICW mile 116.24), southward 10.09 miles to a point 1.45 miles north of Haulover Canal (ICW mile 126.33). All of Reach VI is adjacent to or within CANA boundaries. Permitting for dredging and the dredged material management site, and construction of the site still need to be completed. Therefore, dredging of Reach VI will not occur for at least 5 years (D. Roach, pers. comm., Inland Water Navigation District, 2000).

Before dredging begins, environmental permits must be obtained from the Florida Department of Environmental Protection (FDEP). During this procedure, CANA will help provide the FDEP with a list of concerns and issues pertaining to dredging in the Park. ACOE and FIND will monitor the dredging procedure. The material from this dredged area will be pumped to the V-22A dredged material management area (Figure 7). Site V-22A will be a permanent facility designed to receive, de-water, and temporarily store dredged material that is removed from Reach VI of the ICW during maintenance dredging operations. FIND estimates that approximately 529,000 cubic yards of material will be dredged from the ICW in this area over the next 50 years. The spoil material from site V-22A will most likely be trucked away and used as high-grade fill material. The hauling of this material may cause temporary dust problems.

The V-22A dredged material management area is a 91.8-acre site, located approximately 0.3 miles west of Mosquito Lagoon’s western shoreline, in the southeast quadrant of Oak Hill. Directly east of this site lies the northernmost mainland parcel of CANA. The only wetland community found on this site is a small (0.5 acre) mixed hardwood wetland located immediately west of a drainage ditch that cuts across the site’s southwest corner and ultimately connects to Mosquito Lagoon. This wetland community falls under the regulatory jurisdiction of SJRWMD, FDEP, and the ACOE. As part of an Environmental Site Assessment, data was obtained to determine the extent of possible groundwater contamination associated with a nearby landfill (Schropp and Taylor 1996). A total of 16 wells, in and around the spoil site, were installed to obtain groundwater samples that were analyzed for the presence of a wide range of possible contaminants. Although no significant on-site contamination was documented, the on-site wells will continue to be monitored.

Dredged material from the ICW will be pumped as a slurry to the containment area via a pipeline. The pipeline route, for both dredge slurry and return, lies within a dedicated pipeline easement, extending approximately 1450 feet from the site’s northeast corner to the mean high water shoreline of Mosquito Lagoon. Before returning the discharge back into the Lagoon, an outlet weir will decant the clarified water, from which the sediment has been removed by settling. The monitoring of effluent released from the V-22A dredged material management area will be an integral part of facility operation. The monitoring program should be in place at all times during active dredging operations. The containment basin has been designed to produce effluent, which meets the water quality standards for Class II waters (Florida Administrative Code, Chapter 62-302).

The water quality of the effluent will be based primarily on turbidity. Turbidity is reliably measured in the field and is a strong indicator of general effluent quality since many contaminants, such as metals, exhibit a strong affinity for fine particles. Thus, reducing turbidity should result in an overall improvement in effluent quality. However, other pollutants, such as nutrients and hydrocarbons, cannot be directly related to turbidity and will also be monitored in different ways (FIND 1997a, b). Limited sediment sampling conducted by FIND in the dredged area in 1993 did not reveal elevated quantities of metals, pesticides, PAH's or PCBs. A more rigorous sampling of the dredged material will be conducted prior to each dredging event.

AQUACULTURE AND SHELLFISH HARVESTING

Oyster Leases within CANA

When CANA was created in 1975, there were approximately 30 oyster lease plots within its boundaries. These plots were granted by the State of Florida prior to the Park's inception. The State retains control of these leases because it owns the bottomlands of the NPS dedicated areas. The leases cannot be sold or transferred, and if not renewed yearly, they permanently expire. Over time, the number of leases has dwindled to 14. Because such leases restrict public access, the State is phasing out the leasing program. As the final leases in CANA expire, no new leases will be granted. Commercial and recreational oyster harvesting will continue into the future in non-leased oyster beds.

Impact of the 1995 Gill Net Ban

Environmentalists, along with Florida's $2.5 billion/year recreational-fishing industry, became concerned when the numbers of mullet, trout, and redfish throughout the state began to dwindle. In the mid-1980's, to protect and restore these fish populations, the State began to regulate the fishery, including restricting the size of gill nets, placing catch limits on trout, and prohibiting commercial harvesting of redfish. This was not sufficient, so in 1994 a law was passed that banned the use of gill nets in the IRL system. On July 1, 1995 the net ban went into effect, prohibiting the use of gill nets to capture fish in all Florida waters (Section 16-Florida Constitution).

Based on the number of permits issued, there has been a large increase in aquaculture and commercial shellfish harvesting activities in Mosquito Lagoon since the gill-net ban went into effect. After the 1995 net ban, many fishermen began to commercially catch shrimp, crabs, oysters or wild clams. The number of commercial harvesting permits issued by CANA for their waters more than doubled from 45 in 1987 to 99 in 1997. In 2000, CANA joined with Merritt

Island National Wildlife Refuge to issue a joint commercial harvesting permit for the Park and Refuge that includes shrimp, crabs, finfish, clams and oysters. Approximately 200 permits were issued in FY 2001. The majority of these were for shellfish.

Other displaced fishermen entered state-sponsored programs to start up aqua-farms for growing, harvesting, and selling clams. In 1997, thirty-five fishermen were trained by clam-farming experts and given clam seed and a lease on 1 acre of Lagoon bottom near Oak Hill, immediately north of the Park boundary. These types of leases are bottom leases and may have land-based nurseries with simple flow-through systems to provide ambient algae to the clams; there is no extra nutrient input to the system. Approximately 12 of these operations were operational in late 2000.

A study by Mojica and Nelson (1993) found no significant detrimental effects from clam aquaculture in the IRL. The presence of clam farms was associated only with a decrease in mean sediment sizes within 1 meter of grow-out bags. Furthermore, there were no changes in the surrounding benthic, soft-bottom communities underlying grow-out bags, suggesting few adverse environmental conditions resulting from simple, flow-through clam farms. Today, there are approximately one dozen leases remaining. Strong storms and heavy sedimentation wiped out many of the clam farms.

Another study by Hamel-LeBlac and Oviatt (2000) looked at the ecological implications of aquaculture of the hard clam *Mercenaria* within Cape Cod National Seashore. To determine if there was an impact on the benthic community in Nauset Marsh, benthic macrofauna (primarily polychaetes) and sediment properties (grain size, porosity, organic matter) were examined. Overall, the biological and physical impacts on the benthos were minor. However, physical forces (storms, high winds, strong tidal flushing) are the dominant forces in this shallow estuary and these forces diminish the effects of increased organic material deposition (Hamel-LeBlac and Oviatt 2000).

Other studies have found aquaculture impacts to range from beneficial to extremely detrimental (e.g. Weston 1990; Grant et al. 1995). This reinforces the idea that aquaculture impacts are very site-specific and each area must conduct its own experiments to study impact on the local community.

Since the net ban, other fishermen have switched to harvesting blue crabs. This, combined with an increased number of out-of-state crabbers, may have detrimental effects on the population of blue crabs and other organisms that feed on them. Figures 27 and 28 show the blue crab landings and number of commercial licenses for Brevard and Volusia counties from 1986 to 1997.

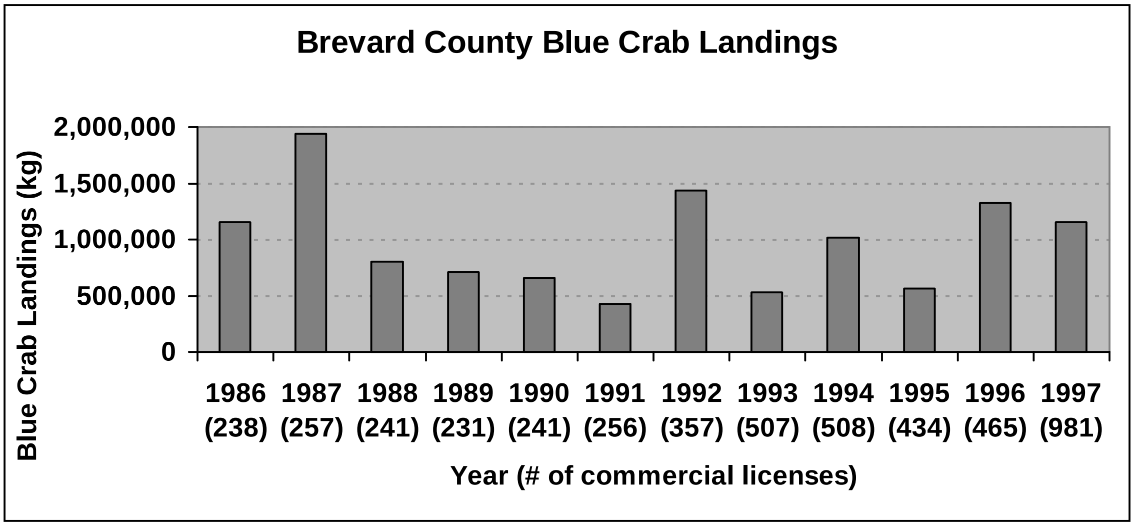


Figure 27. Blue Crab Landings in Brevard County (1986-1997)

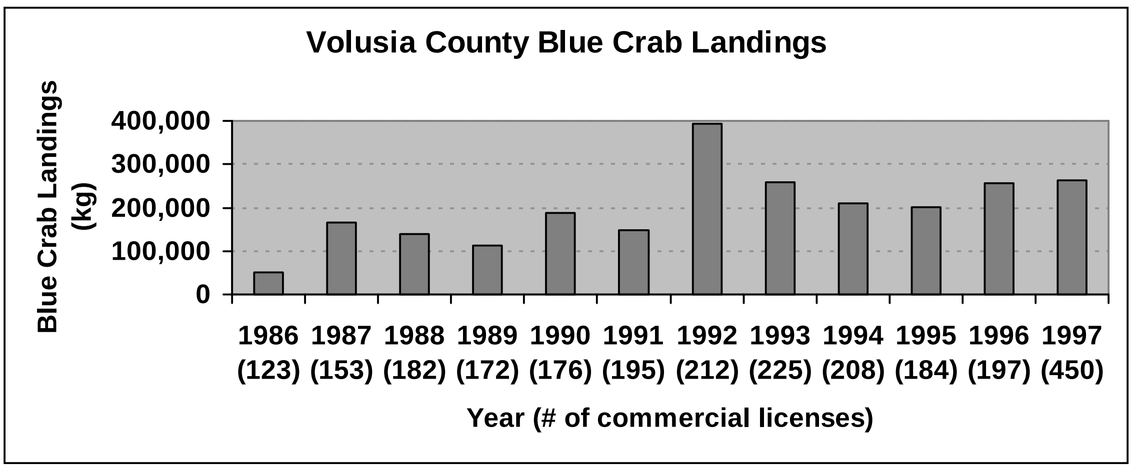


Figure 28. Blue Crab Landings in Volusia County (1986 –1997)

Recreational harvesting of clams, oysters and crabs also occurs within Park boundaries and the number of individuals harvested in each group is completely unknown. Recreational clammers and oysterers are limited to two 5-gallon buckets per day (Florida Fish and Wildlife Commission 2001). Oysters must exceed 3 inches in length; clam thickness across the hinge must be greater than 1 inch. Recreational crabbers are limited to 5 or fewer traps and 10 gallons of blue crabs/day (Florida Fish and Wildlife Commission 2001).

Shrimp harvesting, both commercial and recreational, is also very popular in Mosquito Lagoon. On nights when the shrimp are running, hundreds of shrimping boats can be found in the Lagoon (M. Chambers, pers. comm., CANA, 2001). Commercial trawlers harvest shrimp in the ocean waters adjacent to CANA's beach, occasionally approaching the Park's boundary 0.5 mile offshore. As with other species, State and CANA permits are required for commercial harvesting. Shrimp harvests for the east coast of Florida were 243 metric tons (536,128 pounds) for the year 2000 (NMFS website: www.st.nmfs.gov/st1/recreational/index.html). However, there is no information on amount of shrimp harvesting within CANA waters.

WASTEWATER TREATMENT PLANTS

The Indian River No Discharge Bill (1990) prohibits new discharges or increased loadings from existing sewage treatment facilities into the IRL system (Chapter 90-262, 1990). Also, elimination of existing discharges of treated effluent into the IRL system was required before July 1, 1995. The State of Florida temporarily exempted the New Smyrna Beach and Edgewater Waste Water Treatment Plants (WWTPs), allowing these facilities to continue discharging into Mosquito Lagoon until they could implement the necessary treatment system upgrades and re-use projects. During the later half of the 1990's, these two WWTPs discharged a combined annual loading of 87,700 lbs of TN, 9,480 lbs of TP, and 29,540 lbs of TSS. These point source loads of TN, TP, and TSS comprised 27%, 25%, and <1%, respectively, of the estimated total surface water loads to Mosquito Lagoon (SWIM Plan Update; November 2001, in prep.).

The New Smyrna WWTP has recently moved inland and completed its upgrades, which include a large capacity re-use system, and will now cease discharging into Mosquito Lagoon. Wet weather or emergency discharge will still be allowed. The Edgewater treatment plant will also stop discharging into the Lagoon. The City of Edgewater's wastewater will now be transferred to the new regional plant facility outside of Oak Hill. Edgewater is constructing a 2.25 million gallon storage tank to contain treated (reclaimed) water during wet weather. From here, the treated water will then be re-used in a project for lawn and grove irrigation during dry conditions.

ON-SITE SEWAGE DISPOSAL SYSTEMS (OSDS)

Volusia County is one of the fastest growing counties in the state of Florida and a large portion of all new residences is being served by On-Site Sewage Disposal Systems (OSDS), also known as septic tanks (Woodward-Clyde 1994d). While the communities along the north end of Mosquito Lagoon (New Smyrna Beach, Edgewater, Bethune Beach) are all on central sewer systems, the areas below Edgewater are not. The Volusia County Health Department, Environmental Health Division, is responsible for the permitting and inspection of all OSDS in the county. In the past, Volusia County ranked in the top ten of the sixty-seven counties for number of OSDS permits issued annually. On average, Volusia County permits close to 3000 septic systems per year. About 1000 of those permits are for repairs of failing septic systems. By the year 2005, Volusia County will have an estimated 70,889 septic systems permitted and in use (Volusia County Health Department, Environmental Health Division, pers. comm., 2000). Many of those systems will be at or near the end of their useful life and ready for repair.

Research has shown that up to 77% of Volusia County's soils are rated as severely limited to very severely limited for septic system use (Volusia County Health Department 1999). In addition, most areas of the county are characterized with a very shallow water table, which makes the ground water supply vulnerable to all sources of contamination from the surface. Since Volusia County annually permits so many septic tank systems, and virtually all their drinking water comes from groundwater wells, the proper permitting, installation, inspection and maintenance of septic tank systems is critical to the protection of the public's health and the drinking water supply (Volusia County Health Department 1999).

On the east coast of Volusia County (e.g. the Mosquito Lagoon region), there are a growing number of Aerobic Treatment Units (ATUs). These septic units provide for a higher level of treatment and are required due to a Volusia County Ordinance mandating their use in an "overlay protection zone" near Mosquito Lagoon. Also, since most of the Lagoon is classified as Class II waters and Outstanding Florida Waters, it is further protected from inadequately treated OSDS wastewater entering into the system.

OSDS Problems and Recommendations

There are an estimated 70,000 to 80,000 OSDS systems underground in Volusia County. For the past several years, a portion of every permit sold in Florida has gone towards research on OSDS systems. Fortunately, the research is showing a very effective removal of bacteria before reaching groundwater. Conversely, nitrates are not being effectively removed and will continue to migrate to the water table unless treatment options are found and used to reduce them (Volusia County Health Department 1999).

In 1999, the Volusia County Environmental Health Department evaluated areas in the county and made recommendations on what areas should be placed on a central sewer system. They are strictly health department recommendations for reference only and have not been reviewed by any planning department, utility, or the general public. It is simply a report that can be referenced over the next decade to make informed decisions about providing service to citizens and protecting public health. In trying to provide an objective view of the central sewer vs. OSDS debate, the Volusia County Environmental Health Department developed a sewage recommendation index in which consideration is given to soil permeability, effect on surface water bodies, the age of in-ground OSDS systems, protection of ground water, connection to regulated water supplies, and density of land use. Each of these factors was given an index of weighted values as is shown in Table 15:

Table 15. Sewage Recommendation Indices

Permeability Index

Average Soil Permeability	Index	Examples
>20 inches per hour (in/hr)	5	Astatula, Canaveral
6 to 20 in/hr	4	Apopka, Myakka
2 to 6 in/hr	3	Chobee, Daytona
0.6 to 2 in/hr	4	Myakka Variant, Gator
0.2 to 0.6 in/hr	5	Bluff

- Note that the index is high for excessively drained and poorly drained soils. The actual permeability for a particular site depends as much upon the site as it does the soil type.

Water Body Index

Proximity to water body	Index
Adjacent to food production (shellfish harvesting)	5
Adjacent to protected waterways or public beaches	4
Adjacent area drains to surface water body	3
Not adjacent to (nor flows to) waters of concern	1

Average Age of System Index

Average age of system	Index
1 to 10 years	1
11 to 16 years	2
17 to 26 years	3
>26 years	5

Water Table Index

Depth to water table	Index
>48 in.	1
36 to 48 in.	2
24 to 35 in.	3
0 to 23 in.	4
Above ground surface	5

Regulated Water Index

Regulated water status	Index
Private wells used	5
Mixture of wells and municipal water	3
Regulated water provided	0

Density Index

Density (useable area)	Index
0 to 1 unit per acre	5
1.01 to 2 units per acre	4
2.01 to 3 units per acre	3
3.01 to 4 units per acre	2
4.01 to 5 units per acre	1
> 5 units per acre	0.5

Formula to determine suitability of an area for OSDS**:**

Since density is the most important issue of OSDS, it is given a reverse index and is the denominator in the formula:

(Permeability Index + Water Body Index + Average Age of System Index + Water Table Index + Regulated Water Index) / Density Index

Using this formula, the worst-case scenario would be: (5 + 5 + 5 + 5 + 5) / (0.5) = 50 and the best-case scenario would be: (3 + 1 + 1 + 1 + 0) / (5) = 1.2. Thus, the suitability range for any area will fall between 1.2 and 50. Lower scores could result in recommending that an area stay on septic, whereas mid-range scores will require more investigation. High values not already on OSDS should be placed on central sewer lines as quickly as possible.

Listed below are areas adjacent to Mosquito Lagoon that have high index scores and are strongly recommended for connection to central sewer lines (Volusia County Health Department 1999). See report for maps of areas described below.

- **Bayview Drive Vicinity**: This area is characterized by medium density, very old development, poor soils, and a high water table. The area is adjacent to Turnbull Bay, a water body currently under scrutiny for mitigation of its degraded ecosystem. Score: 4.00 - Recommended for central sewer due to commercial and light industrial establishments.

- **North Beach**: Characterized by very high density, old development, and excessively well-drained soils. The area is adjacent to Mosquito Lagoon, part of the system of Outstanding Florida Waters (OFW). Score: 28.00 - Strongly recommended for central sewer.

- **Mission Oaks**: Characterized by very high density, poor soils, and a high water table. This area is served by an investor-owned sewer collection system, which pumps to a municipal treatment system. The collection system is poorly designed and constructed, and leaks severely. The municipal sewer district placed a limitation on new service in the area during periods of high rainfall, due to infiltration into the collection system from groundwater and the increased load on the treatment system. Score: 22.00 - Strongly recommended for central sewer (or more accurately, replacement of existing sewer system).

- **Waterway Park**: Characterized by medium density, medium-age development, and individual potable wells. A majority of the lots are located on canals that lead to Mosquito Lagoon, part of the system of OFW's that are currently under scrutiny for mitigation of their degraded ecosystems. Achieving proper setbacks from septic systems to surface water and potable wells is a problem for many lot owners; some lots are unbuildable without variance. Score: 9.50 - Strongly recommended for central sewer.

- **Jones Fish Camp Road**: Characterized by medium density, medium-age development, and individual potable wells. Some lots within the area front on Mosquito Lagoon. Score: 5.00 - Recommend for central sewer.

- **South Waterfront Park**: Characterized by very high density, old development. A majority of the lots within this area front on canals that lead to Mosquito Lagoon. Score: 31.00 - Strongly recommended for central sewer.

- **River Road vicinity**: Characterized by medium density, old development, and a system of individual, limited use, and small community potable wells located primarily off-site. The water supply systems pass beneath a canal west of River Road (or down Canal Ave.) under the road to the lots. The density is misleading, as a significant portion of the development is mobile home and RV parks. Density within the parks is more than 8 times greater than the surrounding area. This area is adjacent to Mosquito Lagoon. This portion of Mosquito Lagoon is especially sensitive to surface water contamination, as it is actively harvested for both wild and cultured shellfish. The lots lying on River Road front directly on the Lagoon, and were almost fully developed before 1972. Due to the proximity of a canal west of River Road, most lots do not meet current surface-water setback requirements. Score: 11.50 - Strongly recommended for central sewer.

- **Mobile Village**: Characterized by high density development, individual potable wells, and a high water table. The subdivision was originally approved for an investor-owned water supply. The water supply failed in the early eighties, and property owners were faced with no choice but to construct individual wells. Individual wells and consistently found within the current setback requirement to septic systems, and in some cases the proximity of potable wells to a development project creates problems for the developer and for the Health Department. Score: 18.00 - Strongly recommended for central sewer.

RECREATIONAL ACTIVITES IN CANA

Boating

There is no question that the east coast of central Florida is a hot spot for recreational fishing, cruising, and water sports. In Volusia County alone there are over 100 boat ramps, 75 marinas (including 5,335 slips), and 4,100 shoreline docks (Volusia County Environment Management Services 1996). In 2000, there were 32,465 registered recreational vessels in Brevard County and in Volusia County, there were 25,229 registered recreational vessels (Florida Fish and Wildlife Conservation Commission 2001). Additionally, there were 66 fish guide and 13 eco-tourism license requests to CANA for the 2000-2001 fiscal year. Mosquito Lagoon waters are known nationwide for their beautiful scenery and excellent fishing waters. If this region's population continues to grow at its current rate, the ongoing increase in boat traffic and associated effects on visitor experience, safety and natural resources may become a major concern.

Volusia County Environmental Management (VCEM), under contract to the Bureau of Protected Species Management of FDEP, conducted a boating activity study in Volusia County between July 1994 and March 1995 (Volusia County Environment Management Services 1996). The purpose of this study was to collect data that described and quantified the boating activities, patterns, and composition of boat types taking place on Volusia County's main waterways. The data were collected via interviews at boat ramps, aerial surveys, mail-in questionnaires, and trailer censuses at boat ramps. Of the boat ramps that are within or adjacent to CANA boundaries, interviews were conducted at Haulover Canal and Turtle Mound boat ramps; trailer censuses were taken at Edgewater Landing, Hacienda del Rio, Haulover Canal, Lopez Fish Camp, and Turtle Mound boat ramps. Overall, there are currently 10 boat ramp locations within and adjacent to CANA boundaries (Figure 6).

The results of this boating activity study revealed that the main use for Volusia's waters was for recreational purposes (Volusia County Environment Management Services 1996). Traveling and fishing were the two major boating activities, accounting for 86% of all activity types. The highest concentration of boating activity took place in Silver Glen Springs on the St. Johns River and Mosquito Lagoon, including Ponce de Leon Inlet. There were 50% more boats on the water during the summer than the winter in this area.

The primary boat types in Mosquito Lagoon were Class 1 power boats (16-25 feet) and Class A power boats (<16 feet). These two class sizes made up 88% of all boats observed. Most Class A boats have shallow drafts so that fishermen can access the shallow backwaters on the east side of Mosquito Lagoon. These backwaters are a very active and popular recreational fishing area for sport fish, such as redfish and sea trout. The same types of boats were seen at the Haulover Canal ramp, but unlike the other ramps, this one receives heavy boat traffic during the winter as well as the summer.

Due to overcrowded boat ramps in the Edgewater/Oak Hill area, a four-lane ramp was recently built at River Breeze Park. The boating activity study suggested that unless the current trend of boater activity dramatically increased, there should be sufficient ramps to meet boaters' demands for several years (Volusia County Environment Management Services 1996). Since the Ponce de Leon Inlet area is zoned for marine activity and is the major destination for many boaters, it is a suitable spot for additional ramp development. A future issue, as is currently seen on the St. Johns River, is providing sufficient parking at the ramps to handle an increase in boaters.

Personal Watercraft

Personal watercraft (Jet Skis, Sea Doos, etc.) is the fastest growing segment of the boating industry in the United States and accounts for one third of all boat sales. In Brevard County in the year 2000, there were 3388 PWC registered to individuals plus 758 rental vehicles (Florida Fish and Wildlife Conservation Commission 2001). In Volusia County, there was 2423 personal and 204 rental PWC (Florida Fish and Wildlife Conservation Commission 2001). Due to noise, wildlife and pollution concerns, the USFWS banned the use of personal watercraft in the southern portion of Mosquito Lagoon prior to 1996 (50 CFR, Part 32.28). On December 1, 1998, the use of PWC was banned in all areas of CANA. However, PWC users are still allowed to launch from the north boat ramp inside CANA boundaries since it was built by Volusia County with Port Authority funds. They can launch from this ramp as long as they proceed along a prescribed route through Government Cut along the northern boundary of the Park to reach the Intracoastal Waterway.

BIOLOGICAL RESOURCES

THREATENED AND ENDANGERED SPECIES IN CANA

One of the primary responsibilities of NPS units is to protect federally-listed threatened and endangered fauna and flora within park boundaries. CANA provides habitat for 14 federally listed threatened or endangered animals (Table 16). Of these, 8 species (1 mammal, 2 birds and 6 reptiles) spend some portion of their time in the waters or associated wetlands of Mosquito Lagoon. Additionally, three of the sea turtle species regularly nest on CANA's beach, depositing between 3,00 and 4,000 nests each year, while the right whale *Balaena glacialis* uses near-shore Atlantic waters within CANA boundaries. Several listed species are discussed individually under Important Fauna in the Biological Resources section. At the present time, there are no federally listed threatened or endangered species of plants in CANA, although no extensive search has been conducted to date.

In addition to the species above, a number of birds found in CANA waters are listed as species of special concern by the State of Florida. These include: roseate spoonbill *Ajaia ajaja*, little blue heron *Egretta caerulea*, snowy egret *E. thula*, reddish egret *E. rufescens*, tricolored heron *E. gretta* , American oystercatcher *Haematopus palliates*, black skimmer *Rynchops niger,* white ibis *Eudocimus albus* and brown pelican *Pelecanus occidentalis*.

EXOTIC SPECIES

Exotic or invasive species are organisms that have moved beyond their natural geographical range. An invasion of a non-indigenous species is classified as one of the five most critical environmental issues presently facing life in aquatic habitats (National Research Council 1995). In the Indian River Lagoon, a number of species have invaded in recent years. For example, the Australian spotted jellyfish *Phyllorhiza punctata* was

TABLE 16: Threatened and Endangered Species in Canaveral National Seashore

	MAMMALS	
Trichechus manatus	West Indian Manatee	Endangered
Peromyscus polionotus niveiventris	Southeastern Beach Mouse	Threatened
Balaena glacialis	Right Whale	Endangered
	BIRDS	
Haliaeetus leucocephalus	Bald Eagle	Threatened
Mycteria americana	Wood Stork	Endangered
Aphelocoma coerulescens coerulescens	Florida Scrub Jay	Threatened
	REPTILES	
Chelonia mydas	Green Sea Turtle	Endangered
Caretta caretta	Loggerhead Sea Turtle	Threatened
Eretmochelys imbricata	Hawksbill Sea Turtle	Endangered
Dermochelys coriacea	Leatherback sea Turtle	Endangered
Lepidochelys kempii	Kemp's Ridley Sea Turtle	Endangered
Drymarchon coraisi couperi	Eastern Indigo Snake	Threatened
Nerodia clarkii taeniata	Atlantic Salt Marsh Snake	Threatened

Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12) first documented in the summer of 2001 (L. Hall, pers. comm., SJRWMD, 2001). This species is known for its voracious ability to consume zooplankton, including fish larvae (Smithsonian Institution 2001). Other IRL invaders have included the crabs *Scylla serrata* and *Charybdis hellerii* (Poss 2000). In it not known if reproductive populations of either of these crabs are still present in the Lagoon.

IMPORTANT FLORA

Wetland Vegetation

The Indian River Lagoon has wetland areas that are alternately dry and inundated by salt water. The two basic types of salt water wetlands or intertidal wetlands in the IRL system are mangrove forests and salt marshes. Mangrove forests dominate in the southern reaches while salt marshes dominate in the north. The transition zone between the two types is reported to lie between Sebastian Inlet (near the Indian River/Brevard County line) and Oak Hill in Volusia County (Haddad and Harris 1985). However, small to medium-sized mangroves of all species are present north of this line within the northernmost portion of CANA.

Three types of mangrove trees and one associated species comprise mangrove communities in CANA. The red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), and buttonwood (*Conocarpus erectus*) have specialized morphological and physiological adaptations that enable them to tolerate salt. They are actually facultative halophytes, which means that they can withstand saline conditions but do not require the presence of salt water for normal growth (Egler 1948). However, mangroves are incapable of withstanding competitive pressure from freshwater species and require the salinity to be at least 5 – 15 ppt (Tomlinson 1986). As tropical species, mangroves are sensitive to freezes and low temperatures and losses are profound during cold weather events that have occurred in CANA. Freezes lasting at least 24 hours in 1957, 1962, 1977, 1983, 1985 and 1989 killed all above-ground portions of mangroves north of Haulover Canal (Woodward-Clyde 1994b). Within a few years though, dense growths of seedlings appear beneath the dead mangrove snags to begin a new growth cycle.

Mangrove communities provide valuable habitat for a myriad of animal life, including fish, birds, amphibians, reptiles, invertebrates and mammals (Odum et al. 1982). Many of these species are listed as endangered, threatened or species of special concern (Woodward-Clyde 1994g). Due to their importance, mangroves are protected by Florida law (Florida Administrative code: Chapter 17-321) and mangrove communities cannot be altered. Red mangroves are also being planted in the park to reduce erosion along the shoreline of the Lagoon, such as at the base of Turtle Mound.

Myers and Ewel (1990) state that approximately 10% of the salt marshes in Florida are associated with the IRL system. This community type exhibits both terrestrial and marine ecosystem characteristics and has one of the highest net primary productivites of any ecosystem worldwide (Woodward-Clyde 1994g). The low marsh area is often dominated by smooth cordgrass (*Spartina alterniflora*), extending landward up to the high marsh. Low and high marsh can be separated by 1 – 10 meters in the IRL. High marsh zones are characterized by any of the following plants: black needlerush (*Juncus roemerianus*), glasswort (*Salicornia* spp.), saltwort (*Batis maritima*), salt grass (*Distichlis spicata*), sea oxeye daisy (*Borrichia frutescens*), and salt marsh jointgrass (*Paspalum vaginatum*).

An important feature of the salt marsh is the intimate relationship that exists between the marsh and the adjacent waters of the estuary. Energy fixed in the marsh is flushed out by the tide in the form of organic matter or detritus (Durako et al. 1988). Detritus forms the primary food for many animals in the estuary. The importance of salt marshes to fisheries production primarily results from the high rates of primary production and interaction with the estuary.

Many vertebrate and invertebrate organisms are associated with this habitat; some consume live materials, others consume dead biomass, while others take refuge in the salt marsh. Salt marsh communities surrounding Mosquito Lagoon have been reduced in acreage due to building projects and mosquito impoundments. Efforts are presently underway to return four Volusia County impoundments located within the boundaries of CANA to their original state (Edson 2000). Upon completion of the project, approximately 5.25 miles of shoreline and over 40 acres of spoil dike and ditches will be leveled to marsh elevation. Additionally, as with mangroves, CANA is trying to establish *Spartina alterniflora* in high use areas to reduce erosion.

Submerged Aquatic Vegetation (SAV)

<u>Seagrasses</u>

Both seagrasses and algae are found throughout Mosquito Lagoon and together are referred to as submerged aquatic vegetation (SAV). Seagrasses are totally submerged, rooted angiosperms with vascular systems to transport nutrients and water throughout the plant. Seagrasses reproduce sexually by seeds and asexually by vegetative propagation. Macroalgae have more primitive modes of obtaining nutrients and reproduce through a variety of strategies that do not involve seed production.

Seagrass beds are critical to the health of estuaries (e.g. Zieman 1982; Virnstein et al. 1983). They have been described as nursery habitats for many different juvenile fish as well as recruitment and refuge sites for benthic invertebrates. Seagrass beds provide protection from larger predators and are used as feeding grounds until the juveniles are grown. Seagrass beds are also responsible for keeping the waters clear of suspended sediments. They can act as sediment traps by slowing down currents and taking smaller particles out of suspension. Due to all these critical ecosystem functions, seagrass and other SAV are used as estuary health indicators. Factors that influence seagrass growth and distribution include water depth, water clarity and light availability, substrate, nutrient levels, salinity, temperature, runoff, and human activities (both commercial and recreational).

The Indian River Lagoon is classified as a seagrass-based ecosystem with seven species of grasses found throughout the IRL system (Provancha et al. 1992). This diversity of seagrasses is greater than that of any other estuary in the United States (Woodward-Clyde 1994g). Various organizations map and monitor seagrasses in Mosquito Lagoon on an on-going basis (SJRWMD, NASA). Seagrasses found in transects in Mosquito Lagoon are primarily *Halodule wrightii*, followed by *Ruppia martima* and *Syringodium filiforme*. These transects were run at an average depth of 0.3 m (range: 0.02 – 0.7 m) (e.g. Provancha et al. 1992; Morris et al. 2000a, b).

Along the Atlantic seaboard, *Halodule wrightii* (shoal grass) is found discontinuously from North Carolina to the Caribbean and is one of two species of seagrass found throughout the entire IRL system. It is generally the first seagrass to invade disturbed areas (Williams 1990) and rapidly forms dense beds. Flowers are borne in leaf sheaths, but are rarely seen in IRL waters. Asexual growth via extensive rhizome systems and vegetative fragmentation likely determine the abundance and dispersal of this species. Huge numbers of detached blades and blades with rhizomes are found periodically washed up on the shores of CANA. This may be a natural event or the result of some type of disturbance. Potential candidates include predators, high epiphyte loads, clam raking, boat propellers, and water motion.

The widgeon grass *Ruppia maritima* is similar in appearance to *Halodule wrightii*, but the alternate leaves are generally narrower and tapered at the ends. *Ruppia maritima* reproduces readily from seeds produced on long-stemmed inflorescences. The rhizome system in this species is not well developed. Widgeon grass is the most temperate species of the seagrasses in the IRL system. Its range extends from New England to the IRL system and the Gulf Coast.

Manatee grass (*Syringodium filiforme*) has long (45 cm), thin blades that are cylindrical in cross-section (Woodward-Clyde 1994g). These blades are borne on short, erect stalks from well-branched rhizomes. Asexual growth via rhizomes, vegetative fragmentation and sexual reproduction via flowers and seeds are all found in this species. Manatee grass is found in the Gulf of Mexico, the Caribbean, and along the east coast of Florida. Mosquito Lagoon is accepted to be its northern limit (Woodward-Clyde 1994g).
In terms of succession, *Syringodium* follows *Halodule* in recolonizing disturbed habitats (Williams 1990). However, it is found in slightly deeper waters. *Syringodium* reaches its greatest abundance in 0.5 – 1.5-meter depths; *Halodule* forms dense beds in waters less than 0.5 m.

Seagrass coverage distributions vary widely throughout Mosquito Lagoon. The southern reach of Mosquito Lagoon (segments ML2, ML3-4) contains some of the more extensive seagrass coverage in the IRL system. It boasts approximately 758 acres of seagrass per linear mile of Lagoon. The southern reach of this Lagoon has lost only 12.5% of its seagrass coverage since

1943 (Figure 29). This low level of loss is primarily due to the fact that this section is located within minimally developed watersheds and comprises the federally protected bottomlands managed by CANA and FWS. The northern reach of Mosquito Lagoon (ML1) has seen some of the greatest loss of seagrass acreage in the IRL system. In 1996, there was only 19 acres of seagrass in ML1, which represents a 97% loss since 1943 (SWIM Plan Update, November 2001, in prep.).

The SJRWMD has developed seagrass coverage targets as indicators of the health of the waters of the Indian River Lagoon system (Virnstein et al. 2000). In developing these targets, it was determined that they must be scientifically defensible and ecologically achievable. A primary goal has been to return the number of acres of seagrass to historic (1943) levels, based on aerial photographs from that period (Figure 29).

Throughout the Lagoon system, three levels of seagrass coverage have been targeted: 1) potential coverage = coverage to a depth of 1.7 m (5.5 feet), based on healthy areas of the IRL (this is also based on the maximum depth where light penetration (25%) is sufficient for growth), 2) historical coverage = maximum extent of seagrass from prior mapping (mostly 1943), and 3) persistent coverage = wherever seagrass has been mapped in at least 50% of non-1943 mappings (Figure 30). Current values for Mosquito Lagoon are shown in Table 17:

Table 17. Seagrass Target Categories

Target	Seagrass Coverage (acres)
Historical (1943)	19,043
Persistent	16,071
Potential (<1.7m)	27,203
Current (1996)	15,876

Thus, present and persistent seagrass acreages are 83% and 84%, respectively, of the historical target (Virnstein et al. 2000). Overall, seagrass beds in Mosquito Lagoon have only seen a 17% decline since 1943 (Morris et al. 2000b; Provancha and Scheidt 2000). Therefore, the goal for Mosquito Lagoon is primarily preservation rather than restoration.

<u>Impact of Boat Propeller Scars on Seagrasses</u>

An increasingly common cause of damage to seagrasses is from boat propellers. Scarring occurs when propellers damage seagrass beds by ripping up a path of shoots and rhizomes and exposing the bottom sediment. The most common type of scarring to seagrasses is caused by propellers from small boats. However, larger craft, which are usually confined to deeper waters, may have much larger individual effects when they run aground, especially near shipping channels and ports. Recovery and re-growth of seagrasses from such damage can take years (Durako et al. 1992). Extensive scarring may expose the beds to further disruption from storms and other natural erosional forces,

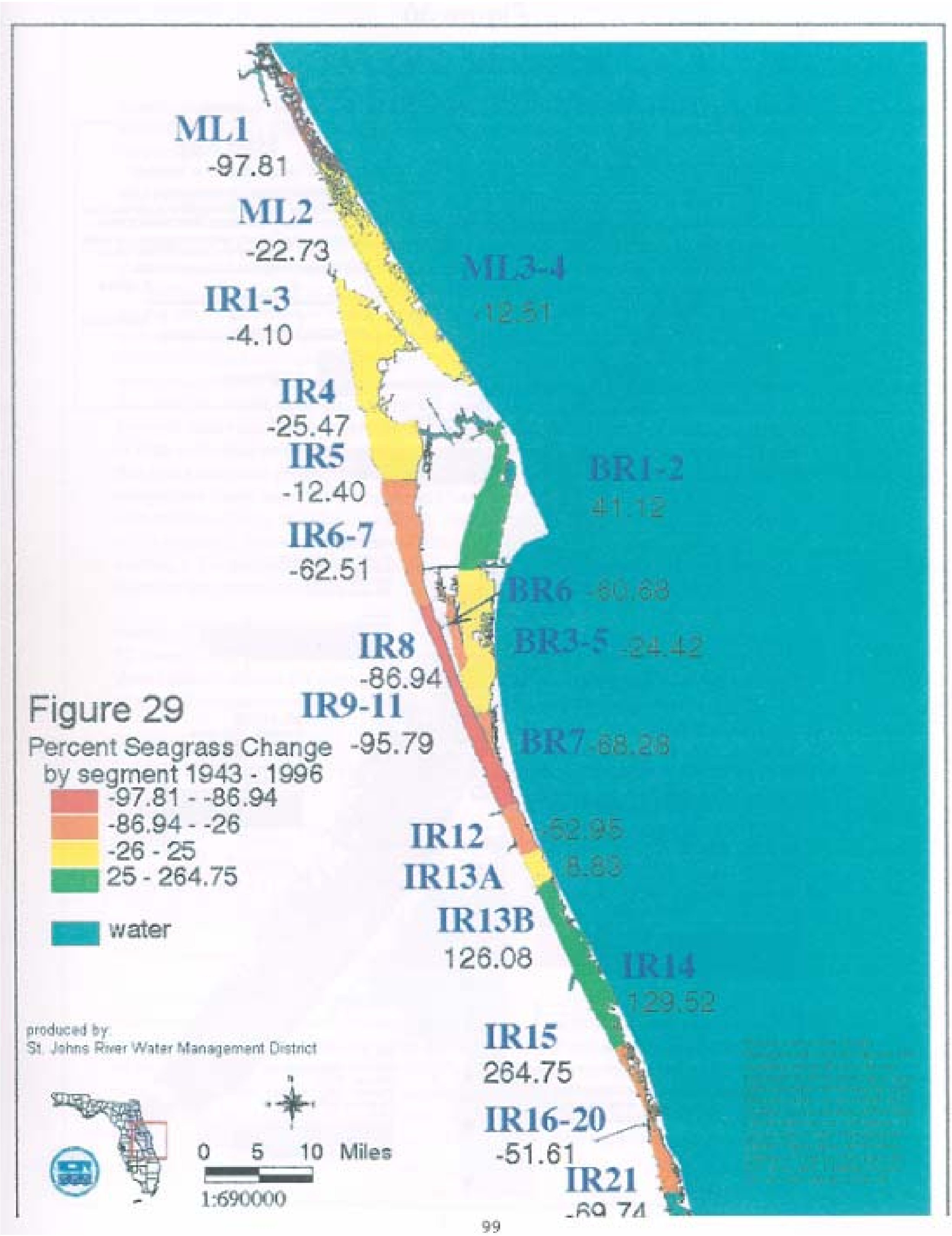


Figure 29
Percent Seagrass Change by segment 1943 - 1996

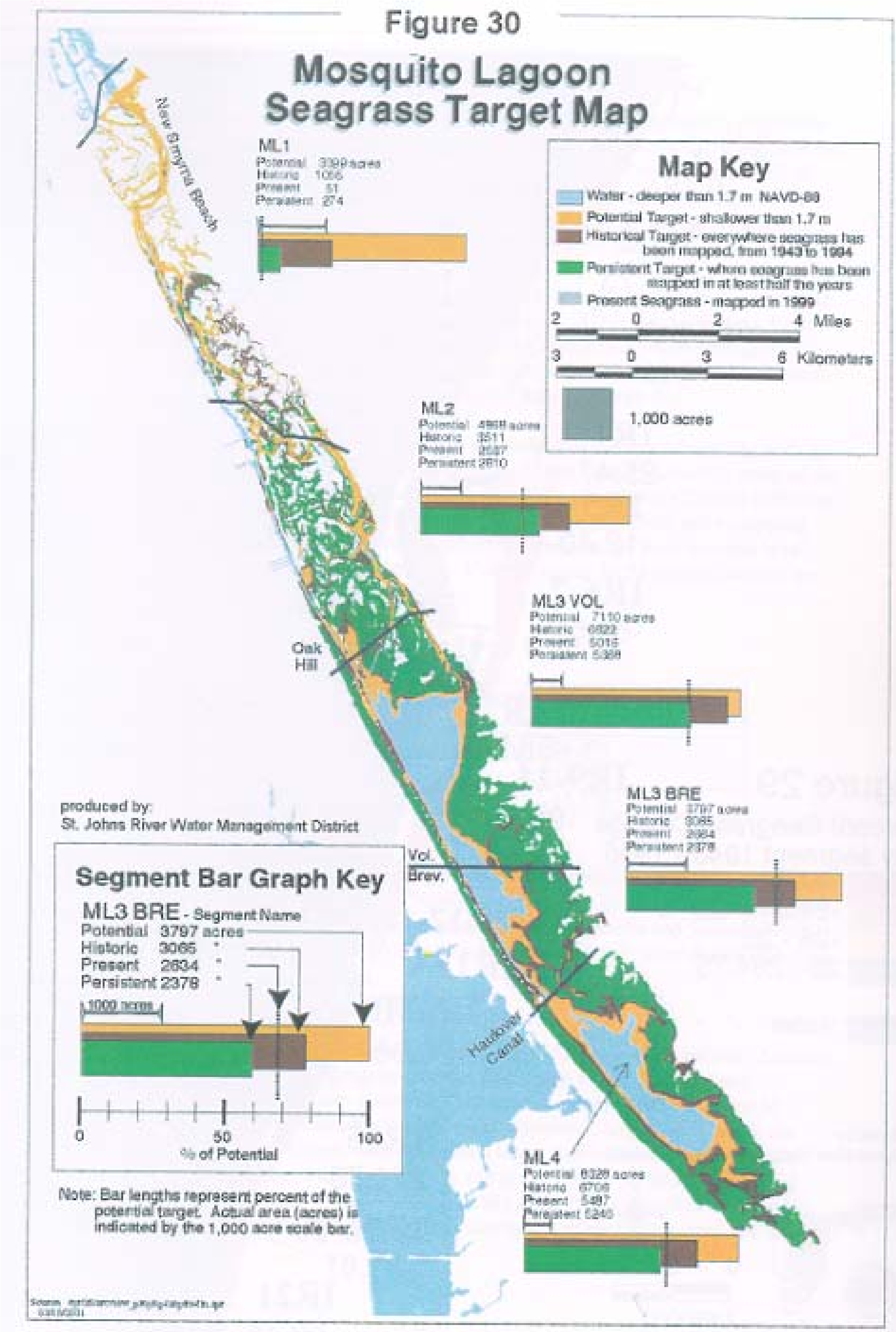


Figure 30
Mosquito Lagoon
Seagrass Target Map
Map Key
Water - deeper than 1.7 m NAVD-88
Potential Target - shallower than 1.7 m
Historical Target - everywhere seagrass has been mapped, from 1943 to 1994
Persistent Target - where seagrass has been mapped in at least half the years
Present Seagrass - mapped in 1999
2 0 2 4 Miles
3 0 3 6 Kilometers
1,000 acres
New Smyrna Beach
Oak Hill
Vol.
Brev.
Haulover Canal
ML1
ML2
ML3 VOL
ML3 BRE
ML4
produced by:
St. Johns River Water Management District
Segment Bar Graph Key
ML3 BRE - Segment Name
Potential 3797 acres
Historic 3065 "
Present 2634 "
Persistent 2378 "
0
50
100
% of Potential
Note: Bar lengths represent percent of the potential target. Actual area (acres) is indicated by the 1,000 acre scale bar.

thereby increasing the rate of cumulative loss. Also, resuspension of sediments into the water column may further contribute to habitat loss by inhibiting the growth of seagrasses.

The FDEP recognized the need to reduce scarring of seagrasses by boats and committed resources to address this issue. As one component of this effort, Florida Marine Research Institute (FMRI) investigated the distribution of scarred seagrass beds in the shallow marine and estuarine waters of Florida's coastal counties (including Brevard and Volusia Counties). Aerial surveys were conducted from May 1992 to May 1993 to confirm and amend the demarcation of scarred seagrass beds. The information acquired in this survey was incorporated into FMRI's Marine Resources Geographic Information System (MRGIS), which was used to produce maps and tabular products for use by resource managers, regional and county governments, and other interested parties. This was the first time the extent of seagrasses and the magnitude of seagrass bed scarring were assessed statewide. This project did not distinguish among the various scarring sources or map individual prop-scars. A bounding polygon was drawn around groups of scars that had a map area greater than one acre. The intensity of scarring in each polygon was categorized based upon the Comparison Chart for Visual Estimation of Percentage Composition (Terry and Chilinga 1955). Polygons were categorized as light scarring (<5% scarring), moderate scarring (5-20% scarring), and severe scarring (>20% scarring). Diagrammatic representations of the three categories of estimated scarring intensity are presented in Figure 31.

Nearly all shallow seagrass beds in Florida have some level of prop-scar damage. Figure 32 shows a scar distribution map for Brevard and Volusia Counties in 1992. Table 18 shows exact numbers for acreage of scarred seagrass per county and relative percentage of scarred seagrass compared to the entire state, respectively (Sargent et al. 1995).

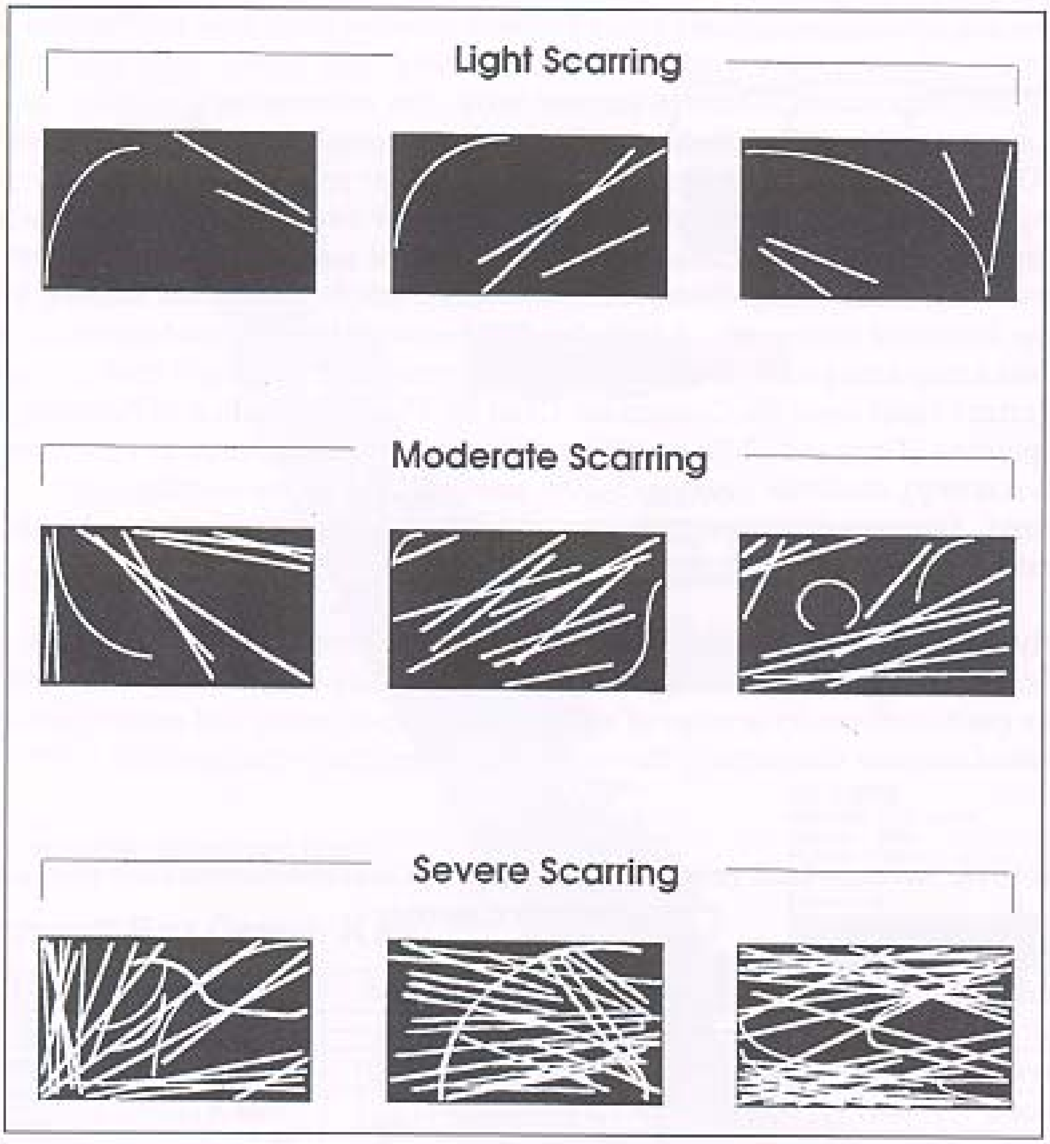
Table 18. Acreage (and relative percentage*) of scarred seagrass for Brevard and Volusia Counties

County	Total Seagrass	Light Scarring	Moderate Scarring	Severe Scarring	Total Scarring
Brevard	46,187 (1.7)	4163.4 (3.8)	1937.5 (4.0)	111.2 (0.7)	6212.1 (3.6)
Volusia	8,489 (0.3)	1432.6 (1.3)	1011.9 (2.1)	354.4 (2.3)	2798.8 (1.6)

*Relative percentage for each category = scarring in the county divided by scarring for the State times100.

Despite the limitations and assumptions of the methodology used, GIS and related technologies provided the necessary capabilities for a study of this nature and geographic extent. This prop-scar report provides a basis for further and more refined management of areas subject to an increase in boat traffic. Management programs to control seagrass scarring have been implemented by various local governments. Additional actions may be needed in areas that show severe scarring. Some programs being implemented and tested use multifaceted approaches such as better educating the boating public, better

Figure 31: Seagrass Scar Categories



National Park Service Canaveral National Seashore

St. Johns River Water Management District

UCF University of Central Florida

Florida Center for Environmental Studies

Figure 32. Scars in Seagrass 1992

SJRWMD
St. Johns River
Water Management District

UTM Zone 17
5,000 meters grid

marking of channels, limiting powerboat access in certain sensitive areas, and more effectively enforcing existing laws. Further investigations and surveys using developing technologies will refine our knowledge of seagrass distributions and the effects of human activities on seagrass productivity (Sargent et al. 1995).

Macroalgae

Macroalgae are abundant throughout Mosquito Lagoon. In fact, algal biomass exceeds seagrass biomass in many places (Woodward-Clyde 1994g). Epiphytic, freestanding attached and drift forms of macroalgae can be found. Epiphytic algae often overgrow seagrass blades. The biomass of these epiphytes can be as great as the blades themselves (Tomasko and LaPointe 1991), thereby significantly reducing seagrass productivity and increasing drag and the chances of dislodgement (Tomasko 1993).

Attached algae are generally not recognized as an important resource in the IRL, although in some areas, it dominates the SAV. Attached algae may compete with seagrasses in shallow waters or thrive at depths greater than those required by seagrasses (Gilbert 1976). Two genera of attached algae are noteworthy. Each summer/fall, the green alga *Codium decorticatum* attaches to live oyster shells in Mosquito Lagoon. By the following spring, individuals are so large (average length: > 1.5 m) that they are dislodged and enter the drift, taking the attached oysters with them (L. Walters, unpublished data). Two other potentially important algae are members of the genus *Caulerpa*. Following its accidental introduction into the Mediterranean Sea from the Monaco Aquarium in 1984, *Caulerpa taxifolia* has spread at a rate of 50 km/yr and dominates estuarine habitats that were once seagrass beds (Meinesz and Hesse 1991; De Villele and Verlaque 1995). This species that has been found primarily on reefs in the Keys, is now moving north along the east coast of Florida and appears to be able to overwinter in these colder waters (B. LaPointe, pers. comm., Harbor Branch Oceanographic Institution, 2001). Although it is presently not found in the IRL, it is found near IRL inlets in waters up to 70 feet. The dispersal potential of this species is enormous (Smith and Walters 1999), making invasion of this species into IRL waters a strong possibility. Blooms of the other species of *Caulerpa*, *C. prolifera*, have occurred in the IRL, especially in 1986 when it covered 40% and 100% of the bottoms of the Banana River and Newfound Harbor, respectively (White 1986). Since then, it has been found occasionally dominating lagoon habitats. Each summer, attached and drift individuals have been recorded near Eldora House, near the northern boundaries of CANA (L. Walters, unpublished data).

Many species of macroalgae incorporate drifting into their life-histories as mechanisms for dispersal and survival in areas where predators or storm events are common. Significant differences in the abundance and diversity of drift algae were found when sampled on a monthly basis at Fellers House Field Station between February 1998 and April 2000 (Abgrall and Walters 2000). Common drift species throughout the sampling period included *Gracilaria armata*, *G. tikvahiae*, *Enteromorpha compressa*, *E. prolifera*, *Cladophora* sp., *Acanthophora spicifera*, *Hypnea cervicornis* and *Spyridia filamentosa*

(Abgrall and Walters 2000). The seagrass *Halodule wrightii* was also frequently collected in nets as were hitchhiking sessile and mobile invertebrates (Abgrall and Walters 2000).

Many species of macroalgae, including epiphytic, free-standing and drift forms, contain novel secondary chemicals (Paul 1992). Many of these compounds are known to be toxic to or reduce the fitness of other marine organisms. Other species are not chemically defended, but may remove sessile organisms they contact via abrasion. Walters and Abgrall (2001) studied the impact of the drift form of the red alga *Gracilaria* on the recruitment and long-term survival of two very common sessile invertebrates, the barnacle *Balanus eburneus* and the bryozoan *Bugula neritina*, in Mosquito Lagoon waters. Neither invertebrate settled on surfaces contacted by *Gracilaria* or *Gracilaria* mimics. Thus, drift *Gracilaria* may be chemically or mechanically deterring attachment of sessile invertebrates. Both *Gracilaria* and mimics reduced survival of *Bugula*; *Balanus* survival was only negatively impacted by live algae (Walters and Abgrall 2001).

IMPORTANT FAUNA

The West Indian Manatee *Trichechus manatus latirostris*

The West Indian manatee *Trichechus manatus latirostris* is a federally endangered species and is protected by the United States Endangered Species Act of 1973 and the U.S. Marine Mammal Protection Act of 1972. Manatees are herbivorous, weigh up to 3500 pounds and average 13 feet in length (Van Meter 1989). Florida manatees may live well over 25 years, and become reproductive between ages 7 and 9 (Van Meter 1989). Usually one calf is born after a gestation period of 13 months. Calves remain with the mother for up to two years and the interval between births is predicted to be 2-5 years (Van Meter 1989). On average, individuals consume 10 – 20 percent of their body weight in seagrass or other submerged aquatic vegetation each day. With a low metabolic rate, manatees lose heat rapidly and need to remain in waters above 64 degrees F (18 degrees C). The West Indian manatee can be found in a wide range of water types, from fresh to hypersaline and from clear to muddy. Water depths from 3 – 16 feet (1-5 meters) are preferred (Van Meter 1989).

Individuals or small groups can regularly be found in Mosquito Lagoon, throughout summer and fall months. The manatees are thought to use this body of water as a travel corridor to move between areas further south in the IRL system and the freshwater springs inland in central Florida and even up to Cumberland Island. From aerial surveys of the western side of Mosquito Lagoon, Shane (1983) found that relative to the Indian and Banana Rivers, the number of manatees in Mosquito Lagoon was very low. This was predicted to be due to lack of freshwater and dredged areas in Mosquito Lagoon (Provancha et al. 1992). However, groups of manatees do frequent the eastern side of Mosquito Lagoon near Eldora and the North District Visitor Center, and the North District boat ramp (L. Walters, pers. obs.).

The Bottlenose Dolphin *Tursiops truncatus*

The bottlenose dolphin is the most commonly sighted marine mammal in CANA (Provancha et al. 1992). Although not listed as threatened or endangered, they are protected by the National Marine Fisheries Service (NMFS) and the Marine Mammal Protection Act of 1972, making it illegal to interact with any marine mammal. Specifically, the act makes it illegal for humans to harass, hunt, capture, kill or feed dolphins. Research is currently underway by both Hubbs/Sea World and Harbor Branch Oceanographic Institution to compile a dorsal fin catalog of the Indian River Lagoon stock and better understand their biology and ecology.

Tursiops truncatus is a cosmopolitan species found in both tropical and temperate waters of the world's oceans. In the western Atlantic Ocean, bottlenose dolphins range from Nova Scotia to Patagonia. In the IRL system, a resident population of 200 – 800 individuals is believed to exist (Smithsonian Institution 2001). Coastal and offshore individuals may also occasionally utilize Mosquito Lagoon. The average lifespan for this species is 20 years. However, through growth layers on their teeth, some individuals have lived as long as 48 years (Smithsonian Institution 2001). Reproductive maturity is variable in this species. On average, females become sexually mature when they reach 2.3 meters (5-12 years old) and males mature at 2.4 meters (10-12 years old). Most births in the IRL occur in April and August.

Tursiops truncatus is carnivorous and consumes over 45 species of fish, squid and shrimp (Barros and Odell 1993). A single dolphin may eat 4-5% of its body weight daily, with nursing mothers consuming 8%. Species that are important to both the bottlenose dolphin and commercial fisheries are the spotted seat trout, striped mullet, Atlantic crocker, spot, weakfish and kingfish (Barros and Odell 1993). If the dolphin population is estimated at 400 individuals in the IRL system, then the total annual fish consumption for this area is predicted to be 598 metric tons per year. This was almost 50% of the commercial catch in 1990 and was valued at over 1.1 million dollars (Barros and Odell 1993). Dolphins are often cooperative hunters. Pods surround schools of fish and stun them with their tail flukes. When the school is dense enough, the dolphins take turns swimming through the school to feed.

Bottlenose dolphins in the IRL system have also been documented to feed in association with commercial fishing operations (Noke 1999). Individuals have been documented to become habituated to feeding on crab pot bait discards and even tipping crab pots over to remove baitfish. Dolphins damaged over one-third of the deployed traps on some summer days (Noke 1999). This significantly reduced crab harvest and has led to the death of dolphins that became entrapped in the crab pot lines and drowned (Noke 1999).

A list of marine mammal strandings, including *T. truncatus* in CANA, is presented in Table 19. There have been occasional strandings of *T. truncatus* along the coastal beaches of CANA, while strandings in the inner lagoon are more rare. In addition to drowning in fishing gear, dolphin mortality may be associated with extreme low temperatures and the fungal skin disease "Lobo

Mycosis" (Woodward-Clyde 1994h). This disease creates lesions, which often lead to bacterial infections. Approximately 10% of dolphins in the IRL system are infected and there are indications that this could be connected to water quality (Woodward-Clyde 1994h).

Table 19. Marine Mammal Strandings in Mosquito Lagoon (1977-1990) (Provancha et al. 1992)

Marine Mammal Species / Common Name	All Strandings	Strandings in CANA
Kogia breviceps / Pygmy Sperm Whale	7	1
Tursiops truncatus / Atlantic Bottlenose Dolphin	50	12
Stenella frontalis / Spotted Dolphin	1	0
Phocoena phocoena / Harbor Porpoise	1	1
Physeter catodon / Sperm Whale	1	0
*Mesoplodon mirus** / True's Beaked Whale	1	0
Kogia simus / Dwarf Sperm Whale	1	0
Tursiops sp. / Dolphin sp.	2	0
Feresa attenuata / Pygmy Killer Whale	1	0
Total	**65**	**14**

* Identification incomplete

Sea Turtles

All species of these large marine reptiles are classified as threatened or endangered under the Endangered Species Act. Five species are found in the IRL system, especially as juveniles. Adult sea turtles nest on beaches on the east coast of central Florida, including CANA. These turtles are long-lived, often not reaching sexual maturity until after they are 20 years old (Ehrhart and Witherington 1992). During their lives, they travel long distances between coastal and open ocean waters.

Ehrhart (1983) found four species of sea turtles in Mosquito Lagoon. The two most common were green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles. Additionally, a small number of Kemp's ridleys (*Lepidochelys kempi*) and one hawksbill (*Eretmochelys imbricata*) were caught. The leatherback turtle (*Dermochelys coriacea*) has been reported from the system as well (Witherington and Ehrhart 1989). Turtle netting surveys in Mosquito Lagoon yielded capture rates of 0.67 turtles per day, mostly of juvenile and sub-adult individuals (Ehrhart 1983). Recaptures indicated some degree of residency.

The green turtle *Chelonia mydas* primarily nests between Cape Canaveral and Palm Beach, although significant numbers of nests are periodically laid on CANA beaches (e.g. 427 in 1998, 5 in 1999, 662 in 2000, 7 in 2001; see Table 20). Adult green turtles weigh between 110-205 kg (250-450 lbs) and are 91-122 cm (36 – 48 inches) in length. Females typically mature from 8 –

35 years (Smithsonian Institution 2001). Nest deposition occurs at night on ocean beaches at the base of well-drained sand dunes. It is estimated that female green turtles nest three times per season and have remigration intervals of 2.86 years (Smithsonian Institution 2001). Nest clutches average 123 eggs per nest and require approximately 60 days to hatch. Sand temperature significantly affects the sex of hatchlings; higher temperatures produce more females (Smithsonian Institution 2001).

Table 20. Sea Turtle Nesting Numbers in Canaveral National Seashore (Stiner et al. 2001)

Year	Loggerhead	Green	Leatherback	Unknown	Total
2001	3257	7	10		3274
2000	3892	662	9		4563
1999	4501	5	9		4515
1998	3976	427	5		4408
1997	2702	21	4		2727
1996	3260	222	3		3485
1995	4121	47	1		4169
1994	3886	364	2		4252
1993	3140	28	0		3168
1992	3279	298	0		3577
1991	4074	25	1		4100
1990	3922	185	1		4108
1989	3091	41	1		3133
1988	2203	43	0	4	2250
1987	1670	90	1	15	1776
1986	3349	22	3		3374
1985	2389	94	0	25	2508

Egg survival varies from site to site and can be significantly reduced in CANA by raccoons and ghost crabs. Predator control in CANA involves placing flat wire screens over newly laid nests. This practice significantly increases survivorship. Nest depredation was reduced from over 95% prior to the screening program to less than 25% (Dennis and Stiner 2000). In 2000, 8% of 662 green turtle nests were partially or fully preyed on (Dennis and Stiner 2000). Although the screens are effective at reducing predation, some raccoons have learned to tunnel underneath them. Six of these individuals were removed from the beach during the 2000 nesting season (Dennis and Stiner 2000).

Hatchlings emerge from beach clutches, enter the ocean, and raft with the seaweed *Sargassum* in ocean currents. Since visitors must leave beaches prior to dark and there is virtually no artificial lighting along CANA's 24 miles of beach, disorientation of newly emerged turtles is less of a factor at CANA than at beaches further north or south. At some point, juveniles return from the ocean and enter the IRL system, remaining in these waters until they are about 5 years old (Ehrhart 1988; Provancha 1997). The seagrasses *Syringodium filiforme* and *Halodule wrightii* are the primary food sources for green turtles in Mosquito Lagoon; *Syringodium* was found to be twice as abundant as *Halodule* in the turtles examined (Mendonca 1983). Other studies suggest small invertebrates are their primary food source (Ashton and Ashton 1991). Mosquito Lagoon probably represents the northern limit of the winter range for juvenile green turtles and can be a difficult developmental habitat, as cold stunning events occur every few years (Schroder et al. 1990). When temperatures fall below 8 degrees C, green turtles become lethargic and float on the water's surface (Witherington and Ehrhart 1989).

An additional threat to green turtles is a disease known as fibropapillomatosis. This herpes-type virus manifests itself as tumors on the fleshy parts of the turtle's body (Holloway-Adkins and Ehrhart 2000). Huge tumors often result that can significantly impact fitness or kill individuals if swimming is impaired or lesions around eyes occlude vision. The disease appears most frequently in juveniles and many individuals residing in Mosquito Lagoon are affected (Provancha 2000). There are indications that fibropapilloma is connected to water quality (Woodward-Clyde 1994f).

The loggerhead turtle *Caretta caretta* nests along beaches throughout Florida, with the region between Cape Canaveral and Palm Beach, having the highest nest densities (Woodward-Clyde 1994h). Table 20 lists the nest numbers within CANA from 1985 to 2001. *Caretta caretta* lives approximately 50 years (Smithsonian Institution 2001) and sexual maturity occurs between 12-35 years (80 cm carapace length, Ehrhart 1983). Nest deposition occurs at night on well-drained sandy beaches. Generally, clutches of 100-120 eggs are laid, which require up to 60 days to hatch. Females nest 2-4 times per season, in 2-3 year nest cycles (Smithsonian Institution 2001). Nest temperature is a primary factor in determining loggerhead sex. If the nest temperature is above 29°C then females develop; below this temperature, individuals are primarily male (Ehrhart 1983). Mrosovsky and Provancha (1989) found that hatchlings at Cape Canaveral were 80-95% female during a 5-year study.

The loggerhead population in Mosquito Lagoon is primarily composed of juveniles and sub-adults that migrate throughout the IRL (Mendonca and Ehrhart 1982). Juveniles feed on molluscs and crabs in the Lagoon throughout the year, usually in shallow, hard bottom areas where these mollusks are most abundant. In particular, the dominant food item found in the stomachs of individuals from Mosquito Lagoon was the horseshoe crab *Limulus polyphemus*. Unfortunately and unexplainably, this prey species has severely declined in recent years (Provancha 1997). Over the last 10-15 years, there has been a noticeable decrease in juvenile loggerheads found in CANA and MINWR waters. At the same time, there has been an increase in juvenile green turtles (Provancha 1999).

Atlantic Salt Marsh Snake *Nerodia clarkii taeniata*

The threatened Atlantic salt-marsh snake *Nerodia clarkii taeniata* is unique to the Mosquito Lagoon region (Woodward-Clyde 1994h). This small water snake is generally less than two feet long and has been observed primarily on marsh islands in Mosquito Lagoon. Very few use intact impoundments (R. Brockmeyer, pers. comm., SJRWMD, 2001). *Nerodia clarkii taeniata* prefers coastal high marsh habitat, consisting of glasswort *Salicornia* spp., saltwort *Batis maritima*, and salt grass *Distichlis spicata* with scattered black mangrove *Avicennia germinans*. It is viviparous and bears several young once per year. It is a piscivorous snake, feeding on small fishes. The future of this species depends largely upon preservation of the habitat. Active management of impoundments that alters vegetation and inundation frequency may impact the survival of this threatened species (R. Brockmeyer, pers. comm., SJRWMD, 2001). Along with habitat loss, the Atlantic salt-marsh snake is also threatened by hybridization with other species, such as the Florida banded water snake.

A three-year mark-recapture study of the Atlantic salt-marsh snake was conducted from January 1997 to October 1999 on four salt marsh islands in Canaveral National Seashore (Cassler and Morris 2000). Two of the islands had been ditched for mosquito control. The overall number of snakes found was low (< 200 individuals) and there was no significant effect of ditching or year on snake numbers (Cassler and Morris 2000). More studies are needed to better understand the ecology and distribution of this threatened species.

Birds

Many water and wetland-dependent birds utilize Mosquito Lagoon. These species play an important role in this aquatic system, affecting fish, invertebrates, reptiles and submerged aquatic vegetation with their various foraging strategies. Their waste matter adds nutrients to the water and affects water quality. Additionally, some species nest on or adjacent to the water. Canaveral National Seashore is home to several federally protected bird species (Table 16). The endangered wood stork *Mycteria americana* is highly dependent on CANA’s water resources. The threatened bald eagle *Haliaeetus leucocephalus* occupies both terrestrial and aquatic niches. A recently delisted species, the arctic peregrine falcon *Falco peregrinus tundrius*, relies on water-dependent birds for much of its food.

The Florida population of the wood stork is believed to have declined by 93% between 1930 and 1988 to a population of 4000 – 5000 birds, making them the most endangered of the wading birds in Florida (Kale 1988). Adults range from 35 – 45 inches (88 – 114 cm) and have a wingspan of 60 – 65 inches (152-165 cm) (Woodward-Clyde 1994h). Wood storks utilize freshwater systems adjacent to the IRL as well as mangrove forests and open water mosquito impoundments. Small fish are the most common food for this species.

The endangered status of this species is probably due to loss of both foraging and nesting habitat by both natural (freezes) and anthropogenic events (Woodward-Clyde 1994f). Nesting occurs from February to April each year and 2 – 4 eggs are generally laid. Nesting occurs in rookeries, several of which are located in mangrove forests in the IRL system. However, hard freezes that killed mangroves, have significantly reduced use of these rookeries (Kale 1988). For example, Bird Island, in the northern section of Mosquito Lagoon, was the site of significant nesting activity until 1982. At this time, a hard freeze damaged vegetation and birds nested elsewhere (Provancha et al. 1992). No wood stork nesting has been documented in the CANA/MINWR area since 1990 (USFWS 1990-1999, 2000a). In 1996, MINWR erected nesting platforms at a former nesting site (Moore Creek) south of CANA; however, these platforms have not yet been used by wood stocks for nesting (USFWS 2000a).

The range of the threatened southern bald eagle *Haliaeetus leucocephalus leucocephalus* extends along the coasts of California, Texas, Louisiana, and the south Atlantic states, including Florida. In fact, Florida has the highest population of bald eagles within the Continental United States (Woodward-Clyde 1994h). The decline of the bald eagle is attributed to habitat loss, reduction in food supply due to water pollution, disturbance of roosting and feeding areas, and the accumulation of pesticides and heavy metals which can reduce reproductive success (Woodward-Clyde 1994h). Bald eagles prey on small mammals, water birds and fish. Eagles can live in the wild for at least 15 years and may not start breeding until they are 4 to 6 years old. Southern bald eagles mate for life, but will re-mate if one of the pair dies. Nesting generally occurs in tall pine or cypress trees, but mangroves have been used in coastal locations (Woodward-Clyde 1994h). Nesting occurs from October through late spring and the young require up to 10 weeks before they are able to leave the nest (Kale 1978).

Fourteen active bald eagle nests were found in the CANA/MINWR area in 1999-2000 nesting season (USFWS 2000a). The bald eagle breeding population on Merritt Island was once among the densest in Florida (Bent 1937). Then, due to the causes listed above, the population experienced a seious decline, with numbers reaching historical lows in the early 1970's (Hardesty and Collopy 1991). A gradual increase in reproductive success occurred at KSC after 1973, with the implementation of various nationwide and local conservation efforts. However, for unknown reasons, the increase of nesting pairs and the reproductive success of eagles at KSC has not matched increases in adjacent populations and remains lower than previous levels (Hardesty and Collopy 1991). This is despite acquisition of large undeveloped areas and a ban on many pesticides. A key factor limiting the recovery of the eagle population in CANA and MINWR may be the small number of tall trees suitable for nesting. An analysis of nesting success between 1983 and 1999 revealed that 74% of nesting productivity came from five established sites (USFWS 2000a).

The arctic peregrine falcon is a migratory visitor to the IRL region, residing in the state between September/October and March-May each year (Kale 1978, 1988). It resides and breeds in the northern United States and Canada. Populations are concentrated on various inlets and wildlife refuges where it feeds on small waterfowl and shorebirds.

CANA and MINWR are major wintering sites and stopovers for migrating waterfowl, wading birds and shorebirds. MINWR adjusts water levels in select impoundments, including the jointly managed portion of CANA, to provide foraging habitat for these birds. Surveys conducted over the last 30 years show that several hundred thousand ducks and coots utilize the essential habitats of the Park and Refuge every winter (USFWS 2001). Primary species are shown in Table 21. Stolen et al. (2001) noted that lesser scaup, while very common in the upper Banana and Indian Rivers, were infrequently seen in Mosquito Lagoon. Since forage biomass was similar for the three bodies of water, the greater amount of boating activity in Mosquito Lagoon may be a factor.

Limited duck hunting is allowed in Mosquito Lagoon during the winter season. The majority of hunting occurs within the joint area of the Lagoon and falls under the responsibility of MINWR. Data on hunting success is collected at check stations each year. The average number of hunters per year between 1996-2000 was 3979, with an average take of 1.9 birds per hunter per day (USFWS 2001). Results of the 1999-2000 season are shown in Table 22.

Many migrating and wintering shorebirds forage on mudflats in the impoundments and along the edges of Mosquito Lagoon. The refuge recently implemented a monitoring program, utilizing volunteers, to track shorebird population trends in select impoundments (USFWS 2001). Survey results from 1998-2001 are shown in Table 21. Beach areas are also surveyed by CANA and MINWR in January for wintering piping plovers *Chadrius melodus* and between April and August for nesting Wilson plovers *Chadrius wilsonii*. While a small number of Wilson's plovers nest along the Refuge's six miles of beach, no nests have been recorded along CANA's 24 miles of beach, immediately to the north. Public use (human disturbance) and higher tidal amplitudes may be the cause.

Colonial wading birds and other water bird species are monitored by MINWR at select spoil and natural marsh islands in Mosquito Lagoon and upper Indian and Banana Rivers (USFWS 2001). Primary wading bird species are listed in Table 21 and the 1999 survey results at Mullethead Island, a major roost site, are shown in Table 23. Note that the majority of heron and egret species are listed as Species of Special Concern (SSC) by the State of Florida. A recent directive by the USFWS has placed additional emphasis on protection of these species. Particularly notable is the roseate spoonbill *Ajaia ajaja*, which has been sighted, in increasing numbers at CANA in recent years and the reddish egret *Dichromanassa rufescens*, the rarest heron species. MINWR is one of the two primary breeding sites for the reddish egret in Florida and possibly the greatest chance for its recovery in the state (USFWS 2001). Reddish egrets breed in the jointly managed area and forage in NPS-managed portions of Mosquito Lagoon.

Table 21. Ten Most Abundant Species of Waterfowl, Wading Bird and Shorebirds in Select Impoundments at MINWR/CANA

Wading Birds		Percent of Total Observations
White Ibis	*Eudocimus albus*	26.6
Snowy Egret	*Egretta thula*	25.8
Tri-colored Heron	*Hydranassa tricolor*	17.2
Great Egret	*Casmerodius albus*	13.5
Roseate Spoonbill	*Ajaia ajaja*	3.4
Wood Stork	*Mycteria americana*	3.1
Little Blue Heron	*Florida caerulea*	3.0
Green Heron	*Butorides striatus*	2.9
Reddish Egret	*Dichromanassa rufescens*	2.4
Glossy Ibis	*Plegadis falcinellus*	1.9
Water Fowl		
Blue-winged Teal	*Anas discors*	40.5
American Wigeon	*Anas americana*	21.7
Lesser Scaup	*Aythya affinis*	11.0
Hooded Merganser	*Lophodytes cucullatus*	10.1
Northern Pintail	*Anas acuta*	9.1
Northern Shoveler	*Anas clypeata*	2.8
Mottled Duck	*Anas strepera*	2.3
Gadwall	*Anas strepera*	1.4
Green-winged Teal	*Anas crecca*	<0.1
Ringed-necked Duck	*Aythya collaris*	<0.1
Shorebirds		
Dunlin	*Calidris ferruginea*	50.5
Least Sandpiper	*Calidris minutilla*	8.7
Lesser Yellowlegs	*Tringa flavipes*	8.0
Greater Yellowlegs	*Tringa melanoleuca*	6.8
Semipalmated Plover	*Chadrius semipalmatus*	5.9
American Avocet	*Recurvirostra americana*	5.7
Short-billed Dowitcher	*Limnodromus griseus*	4.7
Black-bellied Plover	*Pluvialis squatarola*	4.6
Western Sandpiper	*Calidris mauri*	2.9
Black-necked Stilt	*Himantopus mexicanus*	2.3

From: Epstein, M. and G. Poptnik 2001. Summary of Tri-Monthly Impoundment Surveys, 1998 - 2001. Unpublished. Merritt Island National Wildlife Refuge, Titusville, FL.

Table 22. Waterfowl Harvest, 1999 - 2000 Season, MINWR

Species	Check Station Harvest	Total Harvest
Blue-winged Teal	732	2196
Green-winged Teal	481	1443
Pintail	179	537
American Wigeon	684	2052
Mottled Duck	52	156
Northern Shoveler	163	485
Ring-necked duck	10	30
Scaup	106	318
Redhead	7	21
Mergansers	34	102
Coot	44	132
Other	107	321
Total	**2599**	**7793**

Source: MINWR 2000 Annual Narrative (USFWS 2001)

Table 23. 1999 Wading Bird Roost Surveys at Mullethead Island, MINWR

Species	April	May	June	July	August
White Pelican	0	0	0	0	0
Brown Pelican	185	319	356	293	102
Double-Crested Cormorant	448	459	448	255	506
Anhinga	1	2	0	0	0
Great Blue Heron	26	23	28	19	13
Green-Back heron	0	0	0	0	0
Little Blue Heron	50	221	182	198	78
Cattle Egret	5	6	7	2	1
Reddish Egret	35	89	61	21	40
Great Egret	53	104	221	295	100
Snowy Egret	80	186	636	439	247
Tri-Colored Heron	198	263	265	363	435
Black-crowned Night Heron	5	1	3	0	0
Yellow-crowned Night Heron	0	0	0	0	0
Wood Stork	0	0	0	0	0
Glossy Ibis	56	6	2	0	0
White Ibis	137	478	433	219	142
Roseate Spoonbill	37	51	15	14	1
Total	**1316**	**2208**	**2657**	**2118**	**1665**

Source: MINWR 2000 Annual Narrative (USFWS 2001)

Fishes

The entire Indian River Lagoon system is a major contributor to the commercial and recreational fishing industry in Florida. Over 788 fish species have been recorded in the IRL system (Appendix D; Snelson 1983; Gilmore 1994). Diversity and landings data differ between the southern and northern sections of the IRL system. More than twice as many fish species have been recorded in the southern reaches of the IRL system. This is likely due to latitude, scarcity of hard-bottom and reef-like habitats in the northern sections, and the relative abundance of inlets in the southern sections (Snelson 1983). However, landings data found that productivity was highest in the northern reaches of the IRL system, especially Mosquito Lagoon (Durako et al. 1988). This is in part due to higher salinity, lower levels of human disturbance and abundant submerged aquatic vegetation, which provides both refuge and food for many species for at least a portion of their lives.

Mosquito Lagoon is the only known estuary where red drum and weakfish (*Cynoscion regalis*) spend their entire life cycles. It is also one of only two known locations where red drum, weakfish, spotted sea trout, black drum (*Pogonias cromis*) and silver perch (*Bairdiella chrysoura*) all spawn (G. Gilmore, pers. comm., NASA, 2001).

In the 1970's and 1980's, inventories of fish were made in Mosquito Lagoon (Appendix D; Snelson 1983). A variety of sampling methods were employed and collections were made throughout the year. Tropical species, such as grunts, wrasses and sea bass, were rarely found north of Melbourne (Gilmore et al. 1978; Snelson and Bradley 1978). The reciprocal latitudinal gradient was not as apparent. Only one Carolinian fish species, the mummichog (*Fundulus heteroclitus*) ends in the IRL. This species was only found near Ponce de Leon Inlet (Snelson 1983). Additionally, many species that reside in Mosquito Lagoon or transiently use Mosquito Lagoon for nursery or foraging areas are susceptible to winter cold events that occur every few years.

Mosquito Lagoon species that eat plankton at least during some portion of their life and are commercially important include the bay anchovy, striped mullet and silver mullet. Higher-level predators that are also important commercially and recreationally include the common snook (*Centropomus undecimalis*), spotted sea trout (*Cynoscion nebulosus*), and red drum (*Sciaenops ocellatus*). Mosquito Lagoon is nationally known by fishermen for its red drum fishing and this species does particularly well in these waters, potentially due to the higher salinities in this portion of the IRL system. Pressure from recreational fishing and commercial netting was depleting the red drum population. However, since the establishment of the net ban in 1995, red drum populations are recovering but individuals are smaller than in the protected waters of the Banana River (R. Virnstein, pers. comm., SJRWMD, 2001). Details of the life-histories of all these important species can be found in Woodward-Clyde (1994h).

Current and recently completed research will help determine if fish populations are sustainable in Mosquito Lagoon. Dr. Grant Gilmore (NASA) is presently studying the critical fish spawning and nursery habitats in Mosquito Lagoon (Gilmore et al. 2000). In addition to seine, cast net and throw net surveys, he and his colleagues are running acoustic transects to temporally and spatially isolate principal spawning and feeding sites for important fish species. This information will be valuable in helping CANA to protect fish stocks. The Florida Fish and Wildlife Conservation Commission monitored species composition and relative abundance of fishes in the estuarine waters near Ponce de Leon Inlet, Florida, from January 1993 through December 1996 (Paperno et al. 2001). Methodology included trawling and seining once a month at 27 fixed stations. Eleven of the stations were located in Mosquito Lagoon. CANA, SJRWMD, EVMCD and MINWR assisted with data collection.

The South Carolina Department of Natural Resources, in conjunction with the National Marine Fisheries Southeast Area Monitoring and Assessment Program, has been collecting data on coastal fish populations along CANA's beach since 1989 (SEAMAP 2000). Trawls are conducted each spring, summer and fall at four stations with water depths ranging from 15 to 30 feet. This is part of a larger study to assess fish populations along the coast of the southeastern United States.

Commercially and Ecologically Important Invertebrate Species

The Eastern Oyster *Crassostrea virginica*

Intertidal oyster reefs are unique and important habitats, particularly with respect to biodiversity (e.g. Arve 1960; Wells 1961; Breitburg 1992). Reefs provide refuges for many organisms and contain greatly increased fish, invertebrate and algae species numbers and total densities when compared to adjacent non-reef areas (Bahr and Lanier 1981; Burell 1986). The northern section of the Indian River Lagoon system is the southern geographic limit on the Atlantic coast for undisturbed, intertidal reefs of the American, or Eastern, oyster *Crassostrea virginica* (Figure 33; Grizzle and Castagna 1995). Oyster larvae (spat) preferentially settle on adult oysters forming beds or reefs composed of shells from many generations of oysters. Several hundred oyster reefs are
found within the boundaries of CANA (Grizzle and Castagna 1995; Grizzle and Walters 2000).

The eastern oyster is ecologically important as a filter-feeding primary consumer, as prey for numerous higher consumers, and for creating habitat for numerous flora and fauna (e.g. Breitburg 1992). Oysters feed primarily on living phytoplankton throughout all stages of their life cycle (Kennedy 1991). The filter-feeding of oysters is regarded to be of extreme ecological significance (Newell 1988). It is estimated that an oyster filters water at a rate of about 1500 times its body volume per hour (Loosanoff and Nomejko 1946). Declines of the major filter-feeding assemblage provided by extensive oyster beds is cited by Newell (1988) and others as a major factor in an apparent shift to microbial food webs and increases in zooplankton densities in Chesapeake Bay. The free-swimming larvae of oysters are heavily preyed upon by many planktivores (e.g. ctenophores, anemones, and some larval fishes). More than 99% of gametes, embryos, and larvae are believed to be lost, primarily to predation, before settlement (Kennedy

Figure 33. Oyster Reefs in CANA 1996

1991). Newly-formed spat are eaten by carnivorous worms and various small crabs (e.g. mud crabs and juvenile blue crabs). The larger spat and small adult oysters are heavily consumed by a variety of predators, including blue crabs, stone crabs, whelks, oyster drills, skates, rays, and several sciaenid fishes (e.g. black and red drum). Directly or indirectly, oyster reefs provide food for many species, including many of CANA's threatened or endangered aquatic animals and wading birds.

Spat can develop into mature oysters in 4 to 12 weeks (Killam et al. 1992). Spawning by young of the year and production of two generations in a year is likely, although the contribution of first-year spawners to year-class strength is probably insignificant (Woodward-Clyde 1994g). Growth of *C. virginica* is most rapid during the first year of
life (Bahr and Lanier 1981). Lengths of 40 to 50 mm are likely achieved by the end of the first year in the IRL (Berrigan 1990). Growth is much slower once maturity is achieved and metabolic reserves are increasingly devoted to maintenance of reproductive activities and soft tissues (Killam et al. 1992). Under ideal conditions, eastern oysters may survive for 10 years or more (Cake 1983).

Like most sessile estuarine animals, *C. virginica* is anatomically and physiologically well adapted to a wide range of temperatures, salinities and dissolved oxygen levels. Oysters are particularly capable of surviving environmental extremes, as long as the conditions do not persist for extended periods. Although capable of surviving at salinities from about 5 to 40 ppt, the optimum range for oyster reef growth and reproduction is in the range of 10 to 30 ppt (Galtsoff 1964). Low dissolved oxygen concentrations appear to be much less of a problem for oysters than most other estuarine organisms (Berrigan et al. 1991; Kennedy 1991). Although the oyster itself may withstand a wide range of water quality variation, its filter-feeding lifestyle can concentrate contaminants such as heavy metals and fecal coliform bacteria (Kennedy 1991). Thus, while it may survive some water quality degradation, it may no longer be suitable for harvest and ingestion by humans.
Numerous other species that feed on oysters may also be subjected to the effects of accumulated contaminants.

The Hard Clam *Mercenaria mercenaria*

The hard clam (or quahog) *Mercenaria mercenaria* is both ecologically and economically important in estuaries in the eastern United States. The range of this bivalve mollusc extends from Nova Scotia to Florida in estuaries where salinities are > 20 ppt (e.g. Mulholland 1984). It grows best at temperatures between 25 – 30 degrees C, with a minimum temperature requirement for survival of 12.5 degrees C (Ansell 1967). Individuals become reproductively active at approximately 1 year and continue to produce broods throughout their lives, with no reproductive senescence observed (Walker and Hefferman 1996). *Mercenaria mercenaria* is protrandric hermaphrodite, starting its life as a male and then becoming a female. Cues that control this change include age, size and number of individuals of each sex in the population. Approximately 50% of most natural populations are female. In northern climates, gametes are spawned during the summer months. In the Indian River Lagoon, spawning occurs in the autumn after water temperatures drop below 23 degrees C (Busby 1986). Additional spawning events can occur in the spring in the IRL. The natural lifespan of *Mercenaria* is unknown; however, counts of growth rings indicate they can live as long as 40 years and growth can occur year-round in Florida (Smithsonian Institution 2001). Commercially, the peak for collection is between 4 – 8 years of age when individuals measure between 2-4 inches. *Mercenaria* has limited locomotory capabilities. It is generally a sedentary filter-feeder. However, if disturbed it can rapidly burrow with its muscular foot.

To understand the distribution and abundance of *M. mercenaria* in Mosquito Lagoon, Grizzle (1990) raked the sediment in water < 1 m with a scratch rake with teeth 2 cm apart. This adequately sampled clams greater than 35 mm length. In deeper waters, a Shinnecock rake was used. In total, 262 quadrats were sampled. The greatest abundances (1.71 clams/m^2), were collected in water depths from 1 – 1.5 and in firm sand/shell sediments. There were no north-south trends and there was no correlation between their abundance and tidal range (Grizzle 1990). Site-specific manipulative experimental investigations are necessary to fully understand the relationships between sediment characteristics, macrophytes, predators and physical and chemical water parameters in Mosquito Lagoon.

Mercenaria mercenaria is also becoming increasingly important as an aquaculture species, with statewide revenues from farm sales of aquacultured clams reaching 12.7 million dollars in 1997 (Smithsonian Institution 2001). This figure represents a harvest of over 99 million clams by the state's commercial growers. These numbers are expected to significantly increase over time. Although aquaculture is not allowed in the Park, it does occur adjacent to the Park boundary in Oak Hill. A 1993 study by Mojica and Nelson found no significant detrimental affects from clam aquaculture in the IRL. Clam farms decreased mean sediment sizes within one meter of growout bags (Mojica and Nelson 1993). Beyond this no significant effects were observed. However, little study has been done on the genetic impact of cultivated strains of clams on native stocks. Cape Cod National Seashore is currently investigating this issue.

The Blue Crab *Callinectes sapidus*

Blue crabs (*Callinectes sapidus*) play a major role in the ecology of the Indian River Lagoon, because of their widespread occurrence and abundance, broad diet, and importance as prey to numerous other species. In addition to their commercial importance, blue crabs are heavily preyed upon by virtually all carnivorous animals large enough to catch and ingest them, including a number of CANA's threatened and endangered species. Loggerhead and Kemp's Ridley sea turtles are known to consume large quantities of blue crabs, as are many wading birds. Among fishes, some of the most significant predators on blue crabs are American eels, catfish, sciaenids (especially the large drums), several types of sharks, and cownose rays. Mammalian predators include dolphins and raccoons. Presently, little is known about *C. sapidus* populations in CANA.

In Florida, blue crab mating occurs from early spring through early winter when water temperatures are >72°F (22°C) (Steele 1982). Females approaching their final molt, marking the end of the juvenile phase, move into low salinity waters where males concentrate. When molting occurs, the male grasps on to and inseminates the female while continuing to guard her until her shell hardens. The female then migrates to a higher salinity area in the vicinity of an inlet. Females that have mated late in the year will over-winter before spawning in the spring. When fertilized, the eggs are extruded and attached to the underside of the female. Such females are known as "sponge" or "berried" crabs and can carry from 750,000 to 8 million eggs (Prager et al. 1990). The eggs are carried for two to three weeks, gradually enlarging and changing from yellowish orange to dark brown or black as the yolk is used up and the embryos develop. Despite their impressive fecundity, it has been estimated that only about one in a million viable eggs survive to adulthood (Van Engle 1958).

Hatching usually occurs in and around inlets. The first larval stage, the zoea, is planktonic and mainly develops in near-shore waters over the continental shelf. The larvae then transform into a megalops stage and are carried back into estuaries on flood tides (Van Heukelem 1991). Soon after, they settle (ideally in seagrass beds) and transform into the first juvenile crab stage. Growth occurs by numerous successive molts and is highly variable, depending upon temperature, salinity, and food availability (Killam et al. 1992). Male blue crabs usually achieve sexual maturity at about 89 mm carapace width in about one year, after which they will molt several times and may achieve maximum widths of almost 200 mm. Females usually mature after 18 to 20 molts, regardless of size (Van Engle 1958). Most females are sexually mature at 120-140 mm carapace width. In Florida, few blue crabs appear to live beyond their second year, but some individuals may live as long as four years (Tagatz 1968a, b).

From the time they enter estuaries and become juveniles, blue crabs adopt opportunistic feeding behaviors that persist for the remainder of their lives. Extensive literature regarding the food habits of juvenile and blue crabs, is summarized in Van Heukelem (1991) and Killam et al. (1992). In most estuaries, bivalve mollusks tend to be the most important food of all sizes of blue crabs; to such an extent that several authors have suggested that blue crab predation may well determine the abundance of some clam, mussel, and oyster populations (e.g. Virnstein 1977; Van Heukelem 1991). Juvenile blue crabs < 31 mm carapace width also commonly eat substantial quantities of vegetable matter and detritus, particularly when in areas where plants are readily available such as seagrass beds and marshes. Other prominent components of blue crab diets include polychaetes, gastropods, xanthid (mud) crabs, and fish. Blue crabs become increasingly predacious as they grow larger and are also highly cannibalistic.

Blue crabs are extensively distributed throughout all portions of the Indian River Lagoon system, although the females tend to remain in the higher salinity areas, except when mating. Salinities greater than 20 ppt are required for larval survival (Costlow and Bookout 1959), but once the juvenile phase is reached, salinity alone appears to have little influence on the distribution of males. Provided they are given a chance to acclimate, blue crabs appear capable of surviving most temperature extremes likely to be encountered in Indian River Lagoon (Van Heukelem 1991). They are somewhat less tolerant of low temperatures at very low salinities, and the males, which prefer the less saline waters, tend to move into deeper channels during cold weather. Blue crabs are relatively intolerant of poorly oxygenated water, which they will avoid if possible. Crabs caught in fishermen's traps set in hypoxic waters sometimes exhibit substantial mortality, but this "trap death" has been observed to be highly variable in waters of essentially the same level of oxygen saturation (Killam et al. 1992).

In some estuaries, such as the Chesapeake Bay, seagrass beds and other vegetated areas appear to provide crucial structural habitat for the settling of blue crab megalopae (Van Heukelem 1991). The vegetation provides a refuge from predators and is also a food source for the small juvenile blue crabs. On the other hand, several estuaries in the Gulf of Mexico, with little or no submerged aquatic vegetation, also support large blue crab populations. These juvenile blue crabs tend to be associated with soft mud substrates, into which they are known to burrow for protection. In Mosquito Lagoon, less than 10% of the subtidal benthic habitat is composed of soft muds; the substrate is primarily sandy, quartz and shell fragments (Woodward-Clyde 1994a). This again emphasizes the importance of preserving and protecting SAV in CANA.

The Horseshoe Crab *Limulus polyphemus*

The American horseshoe crab *Limulus polyphemus* is distributed along the east coast of North America from Maine to Yucatan, with a peak abundance in Delaware Bay (Botton et al. 1988). The horseshoe crab is a critical component of the ecosystem by providing a food source for many species and by affecting infaunal community structure. *Limulus* is present in all three water bodies of the IRL. *Limulus* is most often found in the more saline portions of estuaries, but they are euryhaline (Shuster 1982).

Limulus polyphemus is generally dispersed sub-littorally, but they spawn on sandy beaches. Most horseshoe crab populations spawn during the spring and early summer on beaches along the Atlantic and Gulf coasts of the United States, and in Yucatan, Mexico (Penn and Brockmann 1994). The movement of mature *Limulus* to the beach to spawn is most likely triggered by a sensory system sensing changes in seasonal light patterns (Shuster 1982). The *Limulus* population in the IRL, however, spawn randomly and erratically (Ehlinger 2000). The lack of a spawning pattern in relation to tidal height, lunar phase, or season differs from previous studies of *Limulus polyphemus* along the northeast coast of the U.S. and on the Gulf Coast of Florida (Rudloe 1980; Shuster 1982; Brockmann 1990).

When spawning events occur, male *Limulus* patrol along the foot of the beach awaiting the female's arrival. Females bury themselves in the sediments near the water's edge and lay a series of discrete egg clusters, each containing 2,000-20,000 eggs (Brockmann 1990). These eggs are fertilized by sperm released by an attached male and by one or more satellite males that typically congregate around the nesting couple (Rudloe 1980). The eggs develop in sediments 5 to 25 cm below the beach surface. Egg nests are found in a broad band starting from the low water line to the high water line. Despite the possibility for wide dispersion during their free-swimming period, many larvae settle in shallow water near beaches where spawning occurred (Shuster

1982). The juveniles move away from the shoal water "nursery" area into deeper water where they remain until they reach sexual maturity, nine to eleven years later, and head back to the beaches in the spring to spawn.

Horseshoe crabs aerate the bottom substrate with their plow-like feeding action. This in turn changes infaunal community structure by controlling species diversity, richness, and abundance (Botton and Ropes 1987, 1989). Because of the horseshoe crab's role in maintaining species diversity and productivity in Mosquito Lagoon, the alarming decline in numbers over the past twenty years may have a serious impact on biodiversity and serve as an indication of profound environmental disturbance in the Lagoon. Horseshoe crabs and their eggs form an important component of the diet for numerous species, including the threatened loggerhead sea turtle, migrating shorebirds, and many species of fish.

Horseshoe crabs also have a very important use for humans. Horseshoe crabs have blue, copper-based blood that clots when exposed to endotoxins, which are chemical poisons released by certain bacteria. The chemical responsible for the clotting is *Limulus* Amebocyte Lysate (LAL) and this clotting serves as an important alarm system when testing the sterility of fluids intended for use on human patients. For LAL, pharmaceutical companies extract up to one-third of the animal's blood volume. The bled animals are then returned safely to the water and have a 90% survival rate. In other regions, horseshoe crabs are being used at an alarming rate as bait in eel and whelk traps and fishermen are able to take large numbers of horseshoe crabs from the beach in the summer during their spawning season and sell them as bait. This is the main reason for the drastic decline in the *Limulus* population in the Delaware Bay region (Botton et al. 1994). In March 2000, a law was passed in Florida establishing restrictions on horseshoe crab harvests (Art. IV, Section 9, Chapter 68B-46).

While the horseshoe crab is not currently threatened, there is a rising concern over signs that the population has sharply declined over the past 20 years in Mosquito Lagoon. In 1978-79, large numbers of *Limulus* were netted in Mosquito Lagoon as by-catch during a juvenile sea turtle netting survey of Mosquito Lagoon and upper Indian River (Provancha 1997). However, in 1994, the number caught per survey in Mosquito Lagoon only ranged from 0-4 animals, with 0 being most common, while no such decline was observed in the northern Indian River (Provancha 1997). A noticeable decrease was also noted in the number of loggerhead sea turtles captured in the 1994 survey. The decline of the horseshoe crab may be directly attributable to this decrease, since it serves as an important food source for the loggerhead sea turtle.

A mass mortality event of *L. polyphemus* occurred in the Indian River and Mosquito Lagoon on July 9, 1999. Over 129,000 dead horseshoe crabs were documented along 60 km of shoreline (Scheidt and Lowers 2000). The cause of this event remains unknown and requires further investigation.

Fouling Organisms

Sessile marine invertebrates that attach to man-made submerged structures, such as boat hulls, pilings and bouys are called biological fouling organisms. In tropical and sub-tropical waters, the most common fouling organisms are barnacles, polychaete worms, sponges, bryozoans, ascidians and hydrozoans. The United States Navy has calculated that between dry-dockings, biological fouling causes a ship's frictional drag to increase by 10% each year and the cost to operate a vessel to increase by 20% each year as speed and maneuverability are reduced and hull corrosion is increased by the fouling (Alberte et al. 1992). Presently the maximum efficient running time between dry-dockings is only three years (Alberte et al. 1992). In relation to the goals of CANA to preserve and protect biodiversity of Mosquito Lagoon, fouling organisms are of special concern because they are readily transported in ballast water and on the hulls of boats. Exotic species introductions of sessile invertebrates via these mechanisms are on the rise and to date, have been poorly documented. Extreme, post-invasion cases, in which the community composition has been radically altered, such as the zebra mussel introduction in the Great Lakes and the common periwinkle *Littorina littorea* on the rocky coasts of New England, need to be avoided.

At certain times of the year in Mosquito Lagoon, fouling organisms can completely cover unprotected surfaces within very short time periods. In particular, in August and September, 100% cover by the barnacles *Balanus amphitrite* and *Balanus eburneus* and the polychaete tubeworm *Hydroides elegans* are regularly found within one week of submergence. This would mean over 1000 newly recruited barnacles and worms with tenacious, calcareous tubes on a 10 X 10 cm surface (L. Walters, unpublished data). In the winter months, the bryozoan *Bugula neritina* and a number of ascidian species (e.g. *Styela plicata*, *Mogula occidentalis*, *Perophora viridis*) dominate hard surfaces (L. Walters, unpublished data). Additionally, throughout the year, huge colonies of the spaghetti bryozoan *Zoobotryon verticillatum* bloom (L. Walters, unpublished data). At its peak, colonies can weigh over a kilogram and filter virtually all phytoplankton from the immediate area (Winston 1995).

WATER RESOURCES MANAGEMENT PLANNING CONSIDERATIONS

The lands and waters of Canaveral National Seashore are subject to myriad regulatory, planning, and management authorities. Many federal, state and local agencies have an interest, mandated or otherwise, in the water resources within the Park. In addition, CANA is a patchwork of landownership types and water management classifications. Protection of water resources requires an understanding of the various policy, regulatory, and management designations to facilitate coordination of all agency efforts and other landowners within CANA. The following section describes federal, state, and local legislation, regulatory designations and management oversight authorities that apply to Canaveral National Seashore.

FEDERAL LEGISLATION, POLICIES, AND EXECUTIVE ORDERS

National Park Service Organic Act (1916)

In 1916 Congress created the National Park Service to:

> promote and regulate the use of the federal areas known as national parks, monuments, and reservations ... by such means and measures as to conform to the fundamental purpose of said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations (NPS Organic Act, 16 USC 1).

The dual, and sometimes conflicting, mandates to preserve and protect resources while providing for their enjoyment by the public often complicates park management. Achieving a balance is at the heart of most decisions affecting the management of the Park.

In recognition of the growing diversity of units and resources in the National Park System, Congress reinforced the primary mandate in 1970 with legislation stating that all park lands are united by a common preservation purpose, regardless of title or designation. Hence, all water resources in the National Park System, including CANA, are protected equally, and it is the fundamental duty of the National Park Service to protect those resources unless exceptions are specifically provided for by Congress.

Canaveral National Seashore (January 3, 1975)

The enabling legislation of CANA (Public Law 93-626) generally directs the National Park Service to preserve and protect the outstanding natural, scenic, scientific, ecologic, and historic values of certain lands, shoreline, and waters of CANA, and to provide for public outdoor recreation use and enjoyment of the same. This legislation provides the following specific directions for management of CANA:

- The Secretary of the Interior may make minor revisions in the boundaries of the Seashore by publication of a revised map or other boundary description in the Federal Register, provided the total area does not exceed 67,500 acres.
- Within the boundaries of CANA, the Secretary may acquire lands, waters, and interests therein by donation, purchase with donated or appropriated funds, exchange, or transfer. Any property owned by the State of Florida, or any political subdivision thereof, may be acquired only by donation.
- The Secretary of the Interior shall have sole authority to develop and improve those State owned lands donated now and in the future in accordance with the intent and purposes of this Act.
- Any federally owned property within the boundaries of CANA may be transferred without consideration to the administrative jurisdiction of the Secretary of the Interior. In accepting lands transferred by NASA pursuant to this Act, the Secretary of the Interior shall enter into a written cooperative agreement with the Administrator (NASA) to assure the use of such lands in a manner which is deemed consistent with the public safety and with the needs of the space and defense programs of the nation.
- No new construction or development shall be permitted within CANA, except for the construction of such facilities as the Secretary of the Interior deems necessary for the health and safety of the visiting public or for the proper administration of CANA.
- The Secretary of the Interior shall permit hunting, fishing, and trapping on lands and waters under his jurisdiction within the boundaries of CANA in accordance with the appropriate laws of the State of Florida and the U.S. to the extent applicable, except that he may designate zones where, and establish periods when, no hunting, fishing, or trapping shall be permitted for reasons of public safety, administration, fish and wildlife management, public use and enjoyment, protection of the resource, or competing public use. Restrictions will only be implemented after consultation with the appropriate state agency.
- Lands and waters in the Merritt Island National Wildlife Refuge which are part of the Seashore shall be administered for refuge purposes through the U.S. Fish and Wildlife Service pursuant to the National Wildlife Refuge System Administration Act, as amended (80 Stat. 926; 16 U.S.C. 668dd-668ee), except that the Secretary of the Interior may utilize such additional authority for the conservation and management of wildlife and natural resources, the development of outdoor recreation opportunities, and interpretive education as he deems appropriate, consistent with the preservation of natural and wildlife values.
- The Secretary of the Interior will issue a well-defined division of management authority between the NPS and the USFWS.
- The Secretary of the Interior shall retain such lands in their natural and primitive condition, shall prohibit vehicular traffic on the beach, except for administrative purposes, and shall develop only those facilities which he deems essential for public health and safety.

Federal Water Pollution Control Act of 1972 (Clean Water Act)

The Federal Water Pollution Control Act, more commonly known as the Clean Water Act, was first promulgated in 1972 and amended several times since (e.g. 1977, 1987 and 1990). This law is designed to restore and maintain the chemical, physical and biological integrity of the nation's waters, including the waters of the national park system. To achieve this, the act called for a major grant program to assist in the construction of municipal sewage treatment facilities, and a program of effluent limitations designed to limit the amount of pollutants that could be discharged. Effluent limitations are the basis for permits issued for all point source discharges, known as the National Pollutant Discharge Elimination System (NPDES).

As part of the act, Congress recognized the primary role of the states in managing and regulating the nation's water quality. Section 313 requires that all federal agencies comply with the requirements of state law for water quality management, regardless of other jurisdictional status or landownership. States implement the protection of water quality under the authority granted by the Clean Water Act through best management practices and through water quality standards. Standards are based on the designated uses of a water body or segment of water, the water quality criteria necessary to protect that use or uses, and an anti-degradation provision to protect the existing water quality.

A state's antidegradation policy is a three-tiered approach to maintaining and protecting various levels of water quality. Minimally, the existing uses of a water segment and the quality level necessary to protect the uses must be maintained. The second level provides protection of existing water quality in segments where quality exceeds the fishable/swimmable goals of the Clean Water Act. The third level provides protection of the state's highest quality waters where ordinary use classifications may not suffice; these are classified as Outstanding National Resources Waters (ONRW). For waters designated as ONRW, water quality must be maintained and protected and only short-term changes may be permitted.

Section 303 of the act requires the promulgation of water quality standards by the states. Additionally, each state is required to review its water quality standards at least once every three years. This section also requires the listing of those waters where effluent limitations are not stringent enough to implement any water quality standard [so called 303(d) list]. Each state must establish, for each of the waters listed, total maximum daily loads for applicable pollutants.

Section 401 requires that any applicant for a federal license or permit to conduct an activity which will result in a discharge into waters of the U.S., shall provide the federal agency, from which a permit is sought, a certificate from the state water pollution control agency stating that any such discharge will comply with applicable water quality standards. Federal permits which require Water Quality Certification from the State of Florida include 404 permits from the U.S. Army Corps of Engineers for the discharge of dredged or fill material.

Section 404 of the Clean Water Act further requires that a permit be issued for discharge of dredged or fill materials in waters of the U.S., including wetlands. The U.S. Army Corps of Engineers administers the Section 404 permit program with oversight and veto powers held by the U.S. Environmental Protection Agency.

It was the 1987 amendment to the Clean Water Act that finally established stringent nonpoint source control mandate. Subsequent amendments further developed this mandate by requiring that states develop regulatory controls over nonpoint sources of pollution and over stormwater runoff from industrial, municipal, and construction activities. Many of the National Park Service's construction activities are regulated by the Clean Water Act under the stormwater permitting requirements.

Coastal Zone Management Act of 1972

The Coastal Zone Management Act enables coastal states to develop a coastal management program that would improve protection of sensitive shoreline resources, identify coastal areas appropriate for development, designate areas hazardous to development and improve public access to the coastline.

National Environmental Policy Act of 1969

Congress passed the National Environmental Policy Act (NEPA) in 1969. Environmental compliance in the National Park Service encompasses the mandates of NEPA and all other federal environmental laws that require evaluation, documentation and disclosure, and public involvement, including the Endangered Species Act, Clean Water Act, Executive Orders on Floodplains and Wetlands, and others.

All natural resource management and scientific activities are subject to environmental analysis under NEPA through the development of environmental assessments and environmental impact statements. Parks are encouraged to participate as cooperating agencies in the environmental compliance process to the fullest extent possible when National Park Service resources may be affected, and as set forth in Council on Environmental Quality (CEQ) regulations. Participation by the National Park Service in the environmental compliance processes of other agencies and jurisdictions is an important management tool. It can provide the National Park Service with information that will allow the Service to respond to possible external threats to a park well before they occur.

Section102 of NEPA sets forth a procedural means for compliance. The CEQ regulations further define the requirements for compliance with NEPA. An environmental assessment is not included as part of this water resources management plan because this plan provides a general direction for the water resources program for the Park.

Clean Air Act of 1970, as amended

The Clean Air Act regulates airborne emissions of a variety of pollutants from area, stationary, and mobile sources. The 1990 amendments to this act were intended primarily to fill the gaps in the earlier regulations, such as acid rain, ground level ozone, stratospheric ozone depletion and air toxics. The amendments identify a list of 189 hazardous air pollutants. The U.S. Environmental Protection Agency must study these chemicals, identify their sources, determine if emissions standards are warranted, and promulgate appropriate regulations. That list includes PCBs; dioxins and furans; chlordane, mercury compounds; lead compounds; cadmium compounds; toxaphene; and trichlorobenzene, to name a few.

Section 10 of the Rivers and Harbors Appropriations Act of 1899, as amended

This was the first general legislation giving the U.S. Army Corps of Engineers jurisdiction and authority over the protection of navigable waters. Navigable waters of the U.S. are those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce. U.S. Army Corps of Engineers permits are required under section 10 for structures and/or work in or affecting navigable waters of the U.S.

The U.S. Army Corps of Engineers began regulation of wetlands under this act, and then received a much broader grant of jurisdictional authority under the Clean Water Act. Because of the broader geographic reach of “waters of the U.S.” jurisdiction under the Clean Water Act, Rivers and Harbors Act jurisdiction will usually not be of significance to wetlands regulation in current cases. There are, however, several situations in which Rivers and Harbors Act jurisdiction alone will be available: when an exemption from section 404 coverage applies, and when activities, as opposed to waters, are covered by the Rivers and Harbors Act and not the Clean Water Act. For instance, the mooring of houseboats in a bay may require a permit under the Rivers and Harbors Act, but would not under the Clean Water Act.

Fish and Wildlife Coordination Act of 1965

This act requires federal agencies to consult with the U.S. Fish and Wildlife Service or the National Marine Fisheries Service and with parallel state agencies whenever water resource development plans result in alteration of a body of water. The Secretary of the Interior is authorized to assist and cooperate with federal agencies to “provide that wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development programs.”

Safe Drinking Water Act and Amendments

This act directs the U.S. Environmental Protection Agency to publish and enforce regulations on maximum allowable contaminant levels in drinking water. The act requires the Environmental Protection Agency to issue regulations establishing national primary drinking water standards.

Primary enforcement responsibilities lie with the states. The act also protects underground sources of drinking water with primary enforcement responsibilities again resting with the states. Federal agencies having jurisdiction over public water systems must comply with all requirements to the same extent as any non-governmental entity.

The 1996 amendments to the Safe Drinking Water Act initiated a new era in cost-effective protection of drinking water quality, state flexibility, and citizen involvement. Source water assessment and protection programs, provided under these amendments, offer tools and opportunities to build a prevention barrier to drinking water contamination. Source water protection means preventing contamination and reducing the need for treatment of drinking water supplies. Source water protection also means taking positive steps to manage potential sources of contaminants and contingency planning for the future by determining alternative sources of drinking water.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

This act commonly referred to as Superfund, was enacted in 1980. It creates a federal Superfund to clean up uncontrolled or abandoned hazardous waste sites as well as accidents, spills and other emergency releases of pollutants. The act contains an extensive list of hazardous substances that are subject to release reporting regulations. The National Response Center must be notified immediately by the person in charge of a vessel or facility when there is a release of any environmental media of a designated hazardous substance exceeding the predefined reportable quantity within any 24-hr period. The reporting quantities are determined on the basis of aquatic toxicity, reactivity, chronic toxicity, carcinogenicity, with possible adjustments based upon biodegradation, hydrolysis, and photolysis.

Resource Conservation and Recovery Act

This act, enacted in 1976, establishes a regulatory structure for handling, storage, treatment, and disposal of solid and hazardous wastes. Many products and materials are regulated under this act, including commercial chemical products; manufactured chemical intermediates; contaminated soil, water, or other debris resulting from the cleanup of a spill into water or on dry land; and containers and inner liners of the containers used to hold waste or residue.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947

Congress originally passed this act of 1947 as a consumer protection statute focused on the registration and labeling of pesticides. It now also regulates the sale, distribution, use, and cancellation of pesticides within the United States. Under this act, the U.S. Environmental Protection Agency has the authority to study the consequences of pesticide use and to require users to register when purchasing pesticides.

Endangered Species Act of 1973

The Endangered Species Act requires the National Park Service to identify and promote the conservation of all federally listed endangered, threatened, or candidate species within any park unit boundary. This act requires all entities using federal funding to consult with the Secretary of Interior on activities that potentially impact endangered flora and fauna. It requires agencies to protect endangered and threatened species as well as designated critical habitats. While not required by legislation, it is the policy of the National Park Service to also identify state and locally listed species of concern and support the preservation and restoration of those species and their habitats.

Executive Order 13112 – Invasive Species

Signed in 1999, this E.O. complements and builds upon existing federal authority to aid in the prevention and control of invasive species.

Executive Order for Floodplain Management (E.O. 11988)

The objective of E. O. 11988 (Floodplain Management) is "… to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative." For non-repetitive actions, the E.O. states that all proposed facilities must be located outside the limits of the 100-year floodplain. If there were no practicable alternative to construction within the floodplain, adverse impacts would be minimized during the design of the project. National Park Service guidance pertaining to this E.O. can be found in Director's Order #77-2, Floodplain Management, (currently under draft review). It is National Park Service policy to recognize and manage for the preservation of floodplain values, minimize potentially hazardous conditions associated with flooding, and adhere to all federally mandated laws and regulations related to the management of activities in flood-prone areas. Particularly, it is the policy of the National Park Service to:

- restore and preserve natural floodplain values;
- avoid to the extent possible, the long- and short-term environmental impacts associated with the occupancy and modification of floodplains, and avoid direct and indirect support of floodplain development wherever there is a practicable alternative;
- minimize risk to life and property by design or modification of actions in floodplains, utilizing non-structural methods when possible, where its is not otherwise practical to place structures and human activities outside of the floodplain; and,
- require structures and facilities located in a floodplain to have a design consistent with the intent of the Standards and Criteria of the National Flood Insurance Program (44 CFR 60).

Executive Order for Wetlands Protection (E.O. 11990)

Executive Order 11990, entitled "Protection of Wetlands", requires all federal agencies to "minimize the destruction, loss or degradation of wetlands, and preserve and enhance the natural and beneficial values of wetlands." Unless no practical alternatives exist, federal agencies must avoid activities in wetlands that have the potential for adversely affecting the integrity of the ecosystem. National Park Service guidance for compliance with E.O. 11990 can be found in Director's Order #77-1 and Procedural Manual #77-1, "Wetlands Protection." Particularly, it is the policy of the National Park Service to:

- avoid to the extent possible the long- and short-term adverse impacts associated with the destruction or modification of wetlands;
- preserve and enhance the natural and beneficial values of wetlands;
- avoid direct or indirect support of new construction in wetlands wherever there is a practicable alternative;
- adopt a goal of no net loss of wetlands and strive to achieve a longer-term goal of net gain of wetlands servicewide;
- conduct or obtain parkwide wetland inventories to help assure proper planning with respect to management and protection of wetland resources;
- use "Classification of Wetlands and Deepwater Habitats of the United States " (Cowardin et al. 1979) as the standard for defining, classifying and inventorying wetlands;
- employ a sequence of first avoiding adverse wetland impacts to the extent practicable; second, minimizing impacts that could not be avoided; and lastly, compensating for remaining unavoidable adverse wetland impacts at a minimum 1:1 ratio via restoration of degraded wetlands;
- prepare a Statement of Findings to document compliance with Director's Order #77-1 when the preferred alternative addressed in an environmental assessment or environmental impact statement will result in adverse impacts on wetlands; and,
- restore natural wetland characteristics or functions that have been degraded or lost due to previous or ongoing human activities, to the extent appropriate and practicable.

National Park Service Management Policies and Guidelines

The National Park Service Management Policies (2001) provide broad policy guidance for the management of units of the national park system. Topics include park planning, land protection, natural and cultural resource management, wilderness preservation and management, interpretation and education, special uses of the parks, park facilities design, and concessions management.

With respect to water resources, it is the policy of the National Park Service to determine the quality of park surface and ground water resources and avoid, whenever possible, the pollution of park waters by human activities occurring within and outside of parks. In particular the National Park Service will work with appropriate governmental bodies to obtain the highest possible standards available under the Clean Water Act for protection of park waters; take all necessary actions to maintain or restore the quality of surface and ground waters within the parks consistent with the Clean Water Act and all applicable laws and regulations; and, enter into agreements with other agencies and governing bodies, as appropriate, to secure their cooperation in maintaining or restoring the quality of park water resources.

Natural shoreline processes (such as erosion, deposition, dune formation, shoreline migration) will be allowed to continue without interference. Where human activities or structures have altered the nature or rate of natural shoreline processes, the National Park Service will investigate alternatives for mitigating the effects of such activities or structures. The National Park Service will comply with the provisions of Executive Order 11988 and state coastal zone management plans prepared under the Coastal Zone Management Act.

Recommended procedures for implementing service-wide policy are described in the National Park Service guideline series. The guidelines most directly pertaining to actions affecting water resources include:

Director's Order #2: Park Planning;
Director's Order #12: Conservation Planning, Environmental Impact
Analysis, and Decision-making;
Director's Order #77-1: Wetland Protection;
Director's Order #77-2: Floodplain Management (under draft review);
Director's Order #83: Public Health;
NPS-75: Natural Resource Inventory and Monitoring; and
NPS-77: Natural Resources Management.

STATE OF FLORIDA STATUTES AND DESIGNATIONS

The State of Florida follows Riparian Doctrine in allocating its water resources, and has several established programs to help protect resource values within and outside CANA's boundaries.

Florida Air and Water Pollution Control Act (Chapter 403, F.S.)

This 1967 act repealed most of the existing environmental statutes and replaced them with the State of Florida's first real pollution control program. The act contained a declaration from the legislature to prevent the pollution of Florida's air and water. The act was codified in Chapter 403 Florida Statutes, and created the Florida Air and Water Pollution Control Commission, consisting of the Governor and Cabinet. The act was amended in 1971 to require a permit for the construction and operation of every stationary source of water pollution.

Pollutant Discharge Prevention and Control Act (Chapter 376, F.S.)

This 1970 act authorizes the Florida Department of Natural Resources (now FDEP) to impose rules concerning methods of materials transfer from ships, to contain and clean up any offshore spills of pollutants, and to charge polluters for clean up costs. This act also establishes the Florida Coastal Protection Trust Fund, which uses fees and damage judgments for the administration of the act.

Florida Environmental Land and Water Management Act

This act, established in 1972, created the Development of Regional Impact (DRI) and the Area of Critical State Concern. This program is designed to address state or regional interest in any "...development which because of its character, magnitude, or location would have a substantial effect upon the health, safety, or welfare of citizens of more than one county."

The act also enables the Florida legislature the ability to designate Areas of Critical State Concern (ACSC). An area may be designated a ACSC if it:

- contains or has a significant impact on environmental or natural resources of regional or statewide importance.
- contains or has a significant impact on historical or archaeological resources of regional or statewide importance.
- has a significant impact upon, or is significantly impacted by, an existing or proposed major public facility.

Land Conservation Act

This 1972 act was the first major land acquisition program for Florida. The program resulted in the issuance of $240 million dollars in state bonds for acquiring environmentally endangered lands. The objective of the act is to protect environmentally unique and irreplaceable lands that are important state ecological resources.

Florida Water Resources Act (Chapter 373, F.S.)

This 1972 act created six water management districts to address the unique water management problems in the various regions of Florida. Each district is governed by a nine-member board appointed by the Governor and confirmed by the Senate. The act established regional administration and comprehensive planning for use of state waters.

Environmental Reorganization Act

This 1975 act created the Department of Environmental Regulation to oversee and centralize environmental regulation. Virtually all regulatory functions created in the 1972 Water Resources Act were delegated to the water management districts.

Safe Drinking Water Act

This act, created in 1977, gave Florida's Department of Environmental Regulation authority to regulate public water systems.

Coastal Management Act

This 1978 act provides for Florida's participation in federal/state partnerships to ensure the wise use and protection of coastal resources authorized under the U.S. National Coastal Zone Management Act of 1972. The state receives federal funding assistance to implement approved programs and is granted review authority of federal activities for consistency with the state's coastal resources management program. Under this consistency determination, the state may prevent a federal proposed action if it is found to be inconsistent with the state program.

Conservation and Recreation Lands Trust Fund (CARL Program)

This fund, created in 1979, utilizes money acquired from state severance taxes on oil, gas, and solid minerals to purchase lands. Up to $20 million is collected annually to purchase environmentally endangered lands such as natural floodplains, marshes, estuaries, wilderness areas, and wildlife management areas. These funds may also be used for the restoration of altered ecosystems. High priority is given to lands in or near counties with highly concentrated populations and with Areas of Critical State Concern.

Florida Aquatic Preserve Act

Established in 1975, this act brought all existing aquatic preserves under a standardized set of maintenance criteria. Most of these aquatic preserves (18) were established by the Governor and Cabinet through a 1969 resolution, but others were established by subsequent legislative action.

State aquatic preserves are afforded protection against water quality degradation through permit review for dredge and fill, development leases, and dock facilities. Prohibited activities include oil and gas wells, mining, storage of any hazardous materials, habitat modifications for mosquito control, and deep water ports. All proposed uses must be shown to be clearly in the public interest, and cumulative impacts should be considered as well as direct impacts. All of Mosquito Lagoon is an aquatic preserve but, since the creation of CANA, the state now only manages the 3,500 acres north of the Park.

Outstanding Florida Waters (Rule 62-302.700 F.A.C.)

As part of the implementation of the Clean Water Act's antidegradation policy (40 CFR 131.12), this statute grants the Florida Department of Environmental Protection the power to establish rules, which provide a special category of water bodies. These rules are intended to prevent any degradation from existing conditions. The two non-degradation categories established under this authority are Outstanding Florida Waters and the more stringent Outstanding National Resource Waters. The waters of the Indian River Lagoon system, including Mosquito Lagoon, are classified as Outstanding Florida Waters. Designated waters are to be preserved in a non-degraded state and protected in perpetuity for the benefit of the public.

Under the Outstanding Florida Waters designation, industrial, commercial and residential wastewater discharges (treated or untreated), and dredge and fill operations are prohibited except where clearly in the public interest. Stormwater discharge is permitted only if it has been treated according to strict state standards. Permitting under the Outstanding National Resource Waters designation is more restrictive. Area in common with other management groups assumes that the public interest is best served by not permitting any degradation, except in the most extenuating circumstances, and even then, variances, exemptions, and changes in classification can only be granted through legislative action. Because it is so restrictive, an Outstanding National Resource Waters designation can only be granted by the state legislature. In contrast, an Outstanding Florida Waters designation can be granted or modified administratively by the Florida Department of Environmental Protection.

For Outstanding Florida Waters, the usual water quality classification standards or criteria (Appendix A) are replaced by the ambient water quality characteristics as determined during the "baseline" year (1-year time period before the designation date of March 1, 1979). If inadequate data exists during the baseline year, a reasonable, scientifically informed estimate of ambient water quality during that time period is used to establish the new criteria.

Hazardous Waste Management Act

This act, established in 1980, created the Florida State Hazardous Waste Management Program to set standards for hazardous waste generators and disposal facilities. This act adopted federal definitions of hazardous wastes, established manifest systems for tracking shipments of hazardous wastes (includes generation, transport, storage, treatment and disposal), and created a "clean up" trust fund through an excise tax on waste generators.

Water Management Lands Trust Fund (Section 373.59, F.S.)

This 1981 "Save our Rivers" Trust Fund provided revenues from a documentary stamp tax administered through the Florida Department of Environmental Regulation, and established the Water Management Lands Trust Fund with revenues of approximately $85 million per year from the excise tax on real estate deeds, stock certificates, and other official documents. This trust fund is used to acquire lands "necessary for water management, water supply and the conservation and protection of water resources, except... rights-of-way for canals or pipelines." Lands must be identified in five-year acquisition plans produced by the water management districts and revised annually.

Stormwater Discharge Regulations (Chapter 17-25, F.A.C.)

This 1982 Florida regulation authorizes the Florida Department of Environmental Regulation (DER) to permit storm water discharge facilities to prevent pollution of waters and to ensure that designated beneficial uses of waters are protected. As instructed by the legislation, the Florida Department of Environmental Regulation has delegated authority for storm water management to the water management districts. This legislation also mandates the use of best management practices for construction, erosion and sediment control, and permitting of storm water discharges with guidelines for use of wetlands.

Water Quality Assurance Act

This act, established in 1983, moved authority for water well contractor licensing, regulation of storm water runoff, and injection well permitting from the Florida Department of Environmental Regulation to water management districts. However, storm water runoff regulations were moved back to the Florida Department of Environmental Regulation in 1984. The act gave the Florida Department of Environmental Regulation discretion for delegation of all water management authorities, except state water quality certification for federal water pollution permits, to the water management districts. It also instructed the Department to: 1) generate and compile a database, 2) provide a central depository for all scientific information on groundwater, 3) establish a state-wide groundwater monitoring network, 4) create a Pesticide Review Council to comment on restricted-use pesticides, 5) impose a tax on waste handling to accrue to the local government where the waste facility is located, and 6) change hazardous waste identification and sitting procedures.

Warren S. Henderson Wetlands Protection Act

This 1984 act consolidated regulation of dredge and fill operations in the Florida Department of Environmental Regulation, and gave the department jurisdiction over wetlands "up to landward extent of waters" to prevent degradation of water quality below established numerical standards. However, it exempted some activities, such as irrigation and drainage ditches, within an Agricultural Management District.

Florida and Regional Planning Act

This 1984 act requires that the state adopt land use goals and policies, that the state's eleven regions write policy plans that conform to those goals and policies, and that the cities/counties adopt plans whose elements reflect the state and regional goals and policies. The state reviews local plans for conformance and either accepts them or requires modification.

Local Government Comprehensive Planning and Land Development Act

Contained in Chapter 163, Florida Statutes, this 1985 act requires that regional policy plans must be consistent with the state comprehensive plan, and local government plans must be consistent with the regional and state plans.

Surface Water Improvement and Management Act (SWIM) (Chapter 373, F.S.)

This 1987 act authorizes the water management districts to correct and prevent problems concerning the declining quality of surface waters. This act also created the SWIM Trust Fund, with monies from appropriations to help with implementation of restoration plans.

The SWIM program provides resources through the St. Johns River Water Management District for identification of pollution problems, technical assistance and planning to ameliorate pollution problems, funding for research, enforcement and educational programs, and coordination among regulatory and management agencies. The SWIM plan is presently being revised and updated for each of the three major sections of the IRL system (Mosquito Lagoon, Indian River Lagoon, and Banana River).

Reuse of Reclaimed Water and Land Application Rules (Chapter 17-610, F.A.C.)

These regulations, established in 1989, instruct the Florida Department of Environmental Regulation to set requirements for wastewater treatment and discharge, including land application, absorption fields, overland flow, wetlands application, and injection to protect beneficial uses of affected waters.

Preservation 2000 Act (Section 259.001, F.S.)

This 1990 act provides funding to supplement land acquisition programs designed to protect the integrity of ecological systems and provide multiple benefits, including preservation of fish and wildlife habitat, recreation space, and water recharge areas, if one of five criteria is met:

- Land is in danger of imminent development or subdivision.
- Land value is escalating faster than interest rates.
- Land protects groundwater or provides natural resource-based recreation.
- Land can be purchased at 80% of appraised value.
- Land has rare, threatened, or endangered species or areas listed in the Florida Natural Areas Inventory (1993) as critically imperiled, imperiled, rare, or excellent natural communities.

The act also requires water management districts to identify lands needed to protect or recharge groundwater supplies and include them in five-year acquisition plans.

Environmental Reorganization Act (1993)

This 1993 act created the Florida Department of Environmental Protection by fusing the Florida Department of Natural Resources and the Florida Department of Environmental Regulation. This act gave the new Department of Environmental Protection responsibility for: management and protection of marine resources including endangered species and their habitats; protection, restoration and management of environmentally important lands and the ecosystems upon them;

parks and recreation; water management; and, pollution control and environmental protection. Six district offices issue permits, provide information, and enforce rules. The Division of Environmental Resource Permitting administers wetlands protection programs through the Bureau of Submerged Lands and Environmental Resources, which reviews applications to use sovereignty submerged lands and is responsible for wetlands dredge and fill permitting.

The Division of State Lands, Office of Environmental Services selects lands to be acquired under CARL. The Division of Water Facilities monitors surface water quality, develops standards, and administers storm water management through its Bureau of Surface Water Management, and issues rules for wastewater treatment and NPDES permitting through its Bureau of Water Facilities Planning and Regulation. The Florida Department of Environmental Protection has general oversight of the water management districts, and delegates authority for permitting to the districts except for: industrial; hazardous; solid or domestic waste facilities; marinas; public works projects; navigational dredging; docks and sea walls not included under other development; and, activities of the water management districts. The Florida Department of Environmental Protection works with the St. Johns River Water Management District on a number of programs, including SWIM plans.

Florida Water Quality Legislation

The Environmental Control Statute (Chapter 403, F.S.) declares it is the policy of the state to ensure that the existing and potential drinking water resources of the state remain free from harmful quantities of contaminants, and outlines data management and inter-agency regulatory cooperation. Two relevant subsections of the legislation are:

- Water Resources Restoration and Preservation Act (Chapter 403, F.S.) -- This legislation includes Sections 403.0615 (Pollution Control) and 403.063 (Groundwater Quality Monitoring).

- Permitting of Activities in Wetlands (Section 403.91, F.S.) -- This legislation defines requirements regarding dredging, filling, wetland monitoring, and mangrove alteration.

Water Quality Assurance Act (F.S. Section 403.063 (1997))

This act directs the FDEP to establish and maintain a ground water quality monitoring network designed to detect or predict contamination of the State's groundwater resources.

IRL No Discharge Act

In 1990, the Florida Legislature enacted the "Indian River Lagoon No Discharge" Act (Chapter 90-262, *Laws of Florida*). The Act prohibits new discharges or increased loadings from domestic wastewater treatment facilities to the Indian River Lagoon system. Elimination or reduction of treated effluent into the Lagoon system was required before July 1, 1995. The "No Discharge" Act also directed the St. Johns River and South Florida Water Management Districts, through the SWIM Plan, to identify areas where existing septic tank systems or OSDS (On-Site Sewage Treatment and Disposal Systems) are considered a threat to the water quality of the

Lagoon (e.g. from nutrient and pathogen loadings). Information developed from this identification survey (inventories, maps, etc.) has been completed and provided to the counties and municipalities within the Lagoon basin. Based on this and other information, local governments are required to develop and implement programs for the remediation of the identified OSDS problem areas.

OSDS and Central Sewerage System Regulations

F.S. Chapter 381.0065-Onsite sewage treatment and disposal systems; regulation:

> (1) Legislative Intent: It is the intent of the Legislature that where a publicly owned or investor-owned sewerage system is not available, the department [DOH] shall issue permits for the construction, installation, modification, abandonment, or repair of onsite sewage treatment and disposal systems under conditions as described in this section and rules adopted under this section.

F.S. Chapter 381.00655-Connection of existing onsite sewage treatment and disposal systems to central sewerage system; requirements:

> (1a) The owner of a properly functioning onsite sewage treatment and disposal system, excluding an approved onsite gray water system, must connect the system or the building's plumbing to an available publicly owned or investor-owned sewerage system within 365 days after written notification by the owner of the publicly owned or investor-owned sewerage system that the system is available for connection. The publicly owned or investor-owned sewerage system must notify the owner of the onsite sewage treatment and disposal system of the availability of the central sewerage system.

As a result of the language in F.S. Chapter 381, the Florida Department of Health instituted Chapter 64E-6 of the Florida Administrative Code that details density considerations, design and construction standards, permitting, and licensing of contractors and inspectors. Note that the F.S. states that the department *shall* issue permits where sewer is not available. When lot size and other parameters are met, the Department has no choice but to issue permits. Most of the lots were approved so long ago that present day codes would not affect them.

OTHER STIPULATIONS AND AGREEEMENTS

Deed from the Board of Trustees of the Internal Improvement Trust Fund of the State of Florida (Deed No. 26106)

This indenture was made on April 1, 1980 between the Board of Trustees of the Internal Improvement Trust Fund (BTIITF) of the State of Florida and the United States of America. The Board of Trustees granted and conveyed, to the USA, all of the described real property located in Volusia County, Florida and signed on January 13, 1986. This conveyance of property was for the express purpose of inclusion into CANA with the right to police, patrol, preserve, and protect the land and water area. This conveyance was made subject to the following conditions:

1. Outstanding easements, reservations, oyster leases, and other interests appearing of record.
2. Retention of all interests in oil, gas, and other mineral rights held by said Board of Trustees in the area conveyed. However, the Board of Trustees by these presents does remise and release its rights of entry and exploration for said oil, gas, and other mineral interests retained by the Board.
3. The United States of America shall permit hunting, fishing, and trapping on lands and waters conveyed herein in accordance with the appropriate laws of the State of Florida and, the USA may designate zones where and establish periods when no hunting, fishing, or trapping shall be permitted for reasons of public safety, administration, fish and wildlife management, or protection of the resource. Except in emergencies, any regulations prescribing any such restrictions shall be put into effect only with the approval of the BTIITF.
4. Retention of the right to maintain existing mosquito control ditches pursuant to Section 388.411(2), Florida Statutes.
5. No causeway or paved road may be located in or on any lands located below the mean high water mark, or in or on any lands or waters falling within the dredge and fill regulatory jurisdiction of the U.S. ACOE or the Florida Department of Environmental Regulation (now FDEP), without the written approval of the BTIITF.

Interagency Agreement between National Park Service and U.S. Fish and Wildlife Service (Interagency Agreement No. 14-16-0004-90-915, NPS Agreement # IA-5180-9-9001)

In consideration of joint interest and concerns, the NPS and FWS mutually agreed to a list of 19 statements of work. Among them are several elements that may relate to water resources management planning efforts.

- The FWS shall administer those lands and waters as described in Section 5(1) of Public Law 93-626 (jointly managed area).
- FWS will act as the lead agency in any studies in the Seashore/Refuge Joint Area involving wildlife species including species listed by federal law as threatened or endangered. All studies will be conducted under FWS permit.
- Information and/or interpretive signing or exhibitry including costs of purchase and maintenance within the Joint Area will be the responsibility of the NPS upon consultation with FWS. Any signing or exhibitry relating specifically to wildlife or the mission of FWS will be the responsibility of FWS upon consultation with NPS.
  The Beach Road and parking areas, the Eddy Creek boat ramp, dock and parking area, and informational and interpretive signing related to these areas, will be the maintenance responsibility of the NPS.
- An agency liaison will be appointed by the NPS and the FWS to handle coordination of all activities and functions referred to in this agreement. These representatives will maintain

frequent contact with respect to activities within the Seashore/Refuge in an effort to increase the cooperative efforts between the NPS and the FWS.

- Informational or interpretive publications dealing with the Seashore/Refuge will be coordinated and reviewed by both NPS and FWS. Following such review, these publications will be made available to each agency on request on an "as available" basis.
- Visitor control programs will be coordinated among NASA, FWS, and NPS with enforcement being the responsibility of the jointly agreed upon agency requiring the control. Each agency will take the lead in enforcement in their respective areas of administration, and will keep NASA informed of any changes or major issues regarding enforcement policy. NPS and FWS have shared jurisdiction in the Joint Area. FWS will act as the lead agency in enforcement activities in the Joint Area, and any enforcement actions in the Joint Area by NPS will be fully coordinated with and approved by FWS.
- Mosquito control coordination in Brevard County will be conducted by FWS, and that in Volusia County will be coordinated by NPS. All planned over flights by Mosquito Control will be coordinated with NASA and will comply with existing regulations. Any changes from the Mosquito Control Agreement desired by the FWS or NPS within the NASA boundary will be coordinated jointly with NASA and the Brevard Mosquito Control District.

This agreement was made on February 9, 1990. Because sufficient time has passed since the original drafting, the duties and activities of each agency should be reviewed and reassessed.

Agreement between National Aeronautics and Space Administration and Department of the Interior for use of property at John F. Kennedy Space Center, NASA, as a part of the Canaveral National Seashore

This agreement states that NASA made approximately 41,000 acres of lands and submerged lands and waters available to the Department of the Interior for construction of a visitor's center, access to the seashore, and administrative purposes of the Seashore. This agreement supersedes the Agreement of June 2, 1972, between NASA and the Department, for use of property at the JFK Space Center, NASA, by the Bureau of Sport Fisheries and Wildlife. The following are conditions for the Department to comply with:

- The Department is authorized to construct, alter, operate and maintain dikes, impoundments, subimpoundments, and water control structures in Area II (the entire Park, except for a 1088 acre tract south of Oak Hill), which do not interfere with or adversely affect NASA operations. These activities will be coordinated with KSC and the Brevard Mosquito Control District to assure an effective mosquito control program which as nearly as possible is compatible with good recreational, wildlife, and habitat management of the area.
- NASA reserves the right to sight any future space program facility at any location in Area II, but in such sighting, as well as other space program operations, NASA will take under

- consideration the Department's utilization and administration of said property in order to ensure compatibility of NASA activities with those of the department where ever practicable.
- The Department shall cooperate to the fullest extent possible with the Brevard Mosquito Control District for the suppression and control of arthropod production in that portion of the Seashore covered by this agreement, under terms and conditions, including funding arrangements, as may be agreed to with the District.
- In order to ensure the greatest possible compatibility between the Space Program and the National Seashore, the parties hereto shall meet at least once annually and communicate from time to time on matters of mutual concern and interest.
- This Area II agreement may be terminated in whole or in part in the event the administrator determines that use of Area II as a Seashore is inconsistent with public safety and the needs of the space and defense programs of the Nation provided, however, that the administrator shall make no such determination without first obtaining and considering the views of the Department.

This Agreement became effective on April 2, 1975, when executed on behalf of both parties, and shall remain in effect until terminated or amended as provided herein.

RELATIONSHIPS TO OTHER PLANNING EFFORTS

Many management and resource protection issues are a direct result of the complex pattern of multiple landownership and activities on lands adjacent to National Parks. These activities could significantly affect the success of a water resources management plan. The following is a brief description of other known planning efforts or plans that potentially have an effect on this Water Resources Management Plan.

Merritt Island National Wildlife Refuge Comprehensive Conservation Plan (CCP)

This CCP is currently in preparation and is expected to be complete around December 2002. This plan will describe the desired future conditions of the refuge and provide long-range guidance and management direction for the refuge. Comprehensive conservation plans are required by the National Wildlife System Improvement Act of 1997 to ensure: 1) wildlife have first priority in refuge management, 2) wildlife-dependent and all other recreational uses are compatible, and 3) wildlife-dependent and compatible recreational activities (e.g. hunting, fishing, wildlife observation, wildlife photography, environmental education and interpretation) are emphasized. Coordinator: C. M. Ehrhardt.

Surface Water Improvement and Management (SWIM) Program

The IRL system has been designated as a priority body of water for the state of Florida's Surface Water Improvement and Management (SWIM) Program. SWIM's primary objectives are to upgrade water quality, improve and maintain existing natural conditions and protect threatened and endangered species in designated waters in cooperation with government entities and the private sector. Ron Brockmeyer, Joel Steward, and Robert Virnstein (SJRWMD) are currently updating the SWIM Plan. The updated plan will be complete in 2002 and will discuss programs on *Seagrass and Water Quality*, *Coastal Wetlands*, and *Public Involvement and Education*. These programs and many of their projects were initiated in 1988/89 at the inception of the IRL SWIM Program. Progress on the projects prior to 1994 is provided in the *1994 SWIM Plan*. Progress since 1994 will be discussed in the 2002 SWIM Plan. This updated plan will assess the ecological health of seagrasses, present general findings on the status and trends of water quality, cover the campaign for the restoration of impounded wetlands, and cover the progress and future establishments of IRLNEP's education strategies and projects.

This SWIM Plan approaches the findings and future developments on an IRL system-wide basis and also on a sub-lagoon basis. Both this Water Resources Management Plan and the draft 2002 SWIM Plan were shared between CANA and SJRWMD. Therefore, the two plans are compatible and collaboration between the two parties is encouraged.

Indian River Lagoon National Estuary Program

The Indian River Lagoon system was designated as an Estuary of National Significance in 1990 and included in the National Estuary Program. Through the NEP consensus-building process, the Comprehensive Conservation and Management Plan (CCMP) for the IRL was adopted in 1996. While the IRL CCMP and IRL SWIM Plan share common goals and objectives, the IRL CCMP stresses collaboration with the public and local governments in activities to protect and restore the Indian River Lagoon. Furthering the coordination between these two programs, in 1986 the IRLNEP and IRL SWIM Program were combined to create the IRL Program. Through the IRL Program, both the actions found in the IRL CCMP and the diagnostic and restoration activities found in the IRL SWIM Plan are being implemented.

EPA Wetlands Project

This is an intensive study of selected wetland functions, including nutrient cycling, sediment biogeochemistry, organic matter accumulation, fisheries, and the value of the wetlands in the regulation of water quality in the estuary. Specifically, this study enables scientists to better understand the effectiveness of various mosquito impoundment restoration techniques. Results will provide input for a Lagoon-wide model presently under development. Primarily SJRWMD and MINWR run this project.

WATER RESOURCES ISSUES AND RECOMMENDED ACTIONS

SCOPING MEETING

On August 17, 1999 a scoping meeting was held to identify key water management resource issues for CANA. Table 25 lists participants of this meeting.

Table 25: Participant List for August 17, 1999 Scoping Meeting

Name	Affiliation	Email Address
Superintendent Bob Newkirk	CANA/NPS	CANA_resource_management@nps.gov
Mr. John Stiner	CANA/NPS	CANA_resource_management@nps.gov
Mr. Don Mock	CANA/NPS	CANA_resource_management@nps.gov
Mr. Don Weeks	NPS-Water Resources Division	don_weeks@nps.gov
Mr. David Spencer	NPS - Atlanta	David_Spencer@nps.gov
Dr. Ross Wilcox	CES/FAU	jrwilcox@ces.fau.edu
Dr. Carlos de la Rosa	CES	cdelaros@co.pinellas.fl.us
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Mr. Arte Roman	Univ. of Central Florida	Arte_Roman@alumni.fit.edu
Mr. Steven Kent	F.D.E.P	kent_s@orl1.dep.state.fl.us
Dr. C. Ross Hinkle	KSC/Dynamac	ross.hinkle-1@ksc.nasa.gov
Dr. Grant Gilmore	KSC/Dynamac	rggilmorej@aol.com
Ms. Jane Provancha	KSC/Dynamac	jane.provancha@esc.pafo.af.mil
Mr. Doug Scheidt	KSC/Dynamac	douglas.scheidt1@ksc.nasa.gov
Mr. Robert Day	IRLNEP/SJRWMD	robert_day@district.sjwmd.state.fl.us
Mr. Randall Sleister	Volusia County	rsleister@co.volusia.fl.us
Dr. Tom Belanger	Florida Tech	belanger@fit.edu
Mr. Jim Adamski	USGS	jadamski@usgs.gov
Mr. Marc Epstein	USFWS	marc_epstein@yahoo.com
Mr. Gary Popotnik	USFWS	gpop_wild1@yahoo.com
Mr. Ron Brockmeyer	SJRWMD	rbrockmeyer@sjwmd.com
Mr. Ron A. Paradise	Volusia County	

PRIORITY ISSUES FOR CANAVERAL NATIONAL SEASHORE

The following is a list of issues identified at the August 17, 1999 scoping meeting as primary water-related concerns for CANA at the beginning of the 21st century. The ranking of issues was based on participant responses at the end of the meeting, with those noted most frequently determining the priority ranking below.

1. Investigate the present hydrological condition of Mosquito Lagoon to incorporate into a comprehensive groundwater/surface water model for the east coast of central Florida.

2. Create an aquatic species inventory for flora and fauna in CANA waters.

3a. Determine the impact of boat wakes on intertidal reefs of the eastern oyster *Crassostrea virginica* in CANA waters.
3b. Determine the impact of harvesting on intertidal reefs of the eastern oyster *Crassostrea virginica* in CANA waters.

4. Determine the impact of clam harvesting on clam populations and seagrass habitats in CANA.

5. Develop a water quality baseline and monitoring protocol for CANA.

6. Research the potential impact of bivalve aquaculture in areas adjacent to the Park on CANA's resources.

7. Inventory water-related activities of visitors and determine their impact on CANA water quality and biodiversity.

8. Inventory commercial and recreational water use in areas adjacent to CANA (e.g. marinas, eco-tourism industries, recreational and commercial harvesting of finfish, crabs and shellfish, boating traffic, etc.)

9. Determine human population growth and associated waterfront construction adjacent to Park boundaries.

10. Assess the effect of mosquito impoundment reconnection/restoration on aquatic biodiversity in CANA.

11. Understanding horseshoe crab mass mortality events and how to prevent future mortality events in the IRL.

12. Determine the extent of fibropapillomatosis on juvenile turtles in Mosquito Lagoon and the survival of afflicted individuals.

13. Determine primary use areas of the endangered West Indian manatee *Trichechus manatus latirostris* in CANA waters.

14. Determine the effect of the blue crab fishery on CANA biodiversity.

15. Develop a public advocacy group to protect Mosquito Lagoon habitats and biodiversity.

16. Provide the public with written information on CANA's future plans and goals in terms of development, protection of flora and fauna, and scientific research.

17. Develop a better understanding of shorebird/wading bird ecology in Mosquito Lagoon.

18. Continue research on the impact of raccoon and ghost crab foraging on nesting sea turtles.

Through subsequent meetings between CANA Resource Managers, the NPS-Water Resources Division, UCF and St. Johns River Water Management District, three items were added to the list of priority issues (numbers 19 - 21 below).

19. Determine the impact of boat propeller scarring on seagrass beds and associated seagrass bed biodiversity in CANA waters.

20. Determine if critical finfish spawning/juvenile nursery areas require additional protection.

21. Develop a spill contingency plan and protocol for regulating waste management.

Additionally, the working group came to a consensus as to which of these issues CANA should address as project statements, with the goal to request funding for these issues from the NPS in the near future. This list was determined by selecting issues that: 1) were under the direct jurisdiction of CANA, 2) could be addressed within a NPS budget, and 3) could be addressed or completed within a 3-5 year period. A brief description of each selected issue is described below and the project statement associated with each is provided in the project statement section of this WRMP. Also included are brief descriptions of the remaining issues and how CANA will work with other agencies to accomplish these important goals. It is likely that project statements will be developed for many of these issues in the future.

ISSUES DEVELOPED AS PROJECT STATEMENTS

Issue #2: Complete Aquatic Species Inventory for Mosquito Lagoon (CANA) (Project Statement 1)

One of the primary missions of NPS units is to protect native biological diversity. To accomplish this, there must be accurate, up-to-date inventories of all flora and fauna in all terrestrial and aquatic habitats within Park boundaries. At the present time in Canaveral National Seashore (CANA), information about aquatic organisms is limited to a few taxa and much of that information is difficult for users to locate.

Much of the available data is either outdated (i.e. Dr. F. Snelson's fish survey data was collected in the 1970's and 1980's) or not site-specific. There is an Indian River Lagoon (IRL) Species Inventory that was first created by Dr. Hillary Swain in 1994 and then turned over to the Smithsonian Marine Station (SMS) in 1997. The list is definitely useful, but it has three major drawbacks. First, this database is system-wide and includes all species that complete at least a portion of their life-cycle somewhere in the IRL system, without making any distinctions as to what portions of the IRL the organism can be found (e.g. Mosquito Lagoon versus the Banana or Indian Rivers). Additionally, most of the data has been collected approximately 150 miles to the south near SMS and Harbor Branch Oceanographic Institution, where the conditions are significantly more subtropical (Mosquito Lagoon is a temperate/subtropical transition zone). Third, the SMS database is the result of reader response cards rather than field sampling. Thus, many taxa, especially those living in Mosquito Lagoon waters, may have been overlooked. For CANA to truly protect its biological resources from threats such as point and non-point source pollution, exotic species invasions, and over-exploitation, it is critical to establish a site-specific species inventory.

Issue #3a: Impact of Boat Wakes on Intertidal Reefs of the Eastern Oyster *Crassostrea virginica* in CANA Waters (not listed as a project statement, research is currently funded by the NPS)

Several hundred intertidal reefs of the oyster *Crassostrea virginica* are found within the boundaries of CANA and together represent the southern geographic limit for this species. Aerial imagery and field studies have documented dead areas on reef edges ranging in size from <100 m^2 to >2000 m^2 and represent < 5% to greater than 10% of each reef's total area (Walters et al. 2001). Dead zones along the edges are not typical, suggesting that factors other than natural long-term processes are occurring. In the shallow waters of CANA, one possible cause of this problem is boating activity as the dead zones are adjacent to heavily used boating channels and survival of newly settled oysters is significantly reduced in these same locations (Walters et al. 2001). Dr. L. Walters (University of Central Florida) and Dr. R. Grizzle (University of New Hampshire) are being funded by the National Park Service to: 1) compare aerial photographs from 1943 to the present to determine the extent of the dead zones, 2) determine if boat wakes are dislodging shells and piling them up to create these dead zones, and 3) determine if larval recruitment and juvenile (spat) survival is reduced in areas of intense boating activity, potentially due to sediment resuspension associated with boating in shallow waters.

Issue #3b: Impact of Harvesting on Intertidal Reefs of the Eastern Oyster *Crassostrea virginica* in CANA (Project Statement 2)

Oyster harvesting in Mosquito Lagoon predated the establishment of CANA and thus, both commercial and recreational harvesters have always been allowed to harvest within Park boundaries. Based on the number of licenses issued by CANA and MINWR, there has been a dramatic increase in commercial shellfish harvesting in Mosquito Lagoon waters following the statewide gill net ban that went into effect in 1995. Presently, there are 14 active commercial oyster leases in CANA, over 200 commercial harvesting permits, and an uncounted number of recreational harvesters. Recreational harvesters are allowed to collect two 5-gallon buckets of oysters per person per day; commercial harvesters are allowed unlimited access to the resource. Thus, the number of adult *C. virginica* removed from CANA each year is not known.

To protect this very important intertidal reef ecosystem and create sustainable harvesting practices for *C. virginica*, CANA needs to better understand harvesting levels in CANA waters and the reproductive success of oysters on reefs throughout the Park. It is not known if all reefs produce equal numbers of gametes, if all gametes are equally successful, if all reefs receive equal numbers of larvae (spat), or if juveniles on all reefs are equally successful. While the reproductive fitness of oysters on various reefs has not yet been examined, preliminary data suggests that the number of juveniles and survival of these individuals varies by several orders of magnitude between reefs (Walters et al. 2001). If certain reefs are producing the majority of successful gametes and/or spat are most successful on specific reefs in the Lagoon, then protective action via localized harvesting restrictions should be considered for these locations.

Issue #4: Determine Effects of Harvesting the Hard Clam *Mercenaria mercenaria* on Seagrass Beds and Clam Populations in Mosquito Lagoon (Project Statement 3)

The harvesting of the hard clam *Mercenaria mercenaria* is a popular recreational and commercial activity in Mosquito Lagoon. As of December 2000, CANA and FWS have already issued over 200 permits for the 2000/2001 season to individuals involved in the commercial harvesting of finfish or shellfish. Of the 88 individuals who reported which species they planned to harvest, 67 listed clams; most did not identify a target species. Commercial harvesters do not need to report their catch to the Park. Thus, total harvests by this group are not known. Recreational harvesters with a harvest limit of two 5-gallon buckets/day do not need permits, so the number of clams harvested by this group is also completely unknown. The Park needs to ensure that the clam population is sustainable with this level of harvesting.

In addition to concerns about maintaining sustainable populations of *M. mercenaria*, CANA is concerned with the impact of harvesting on associated fauna and flora, especially seagrasses. Clam harvesting is restricted to individuals gathering by hand, feet or hand-held raking devices. However, clam harvesters frequently spend long periods of time concentrated in small areas. Peterson et al. (1987) studied the impact of clam raking and different intensities of mechanical harvesting of clams on an estuarine seagrass bed in North Carolina. In this four-year study, they looked at clam recruitment, seagrass biomass, and density of benthic macroinvertebrates. With raking, seagrass biomass dropped approximately 25% below control plots, with full recovery after 1 year. With mechanical harvesting, seagrass biomass dropped to 65% below controls. Recovery of these beds began only after 2 years and the biomass was still about 35% lower than controls 4 years later. Both quantitative data on clam population densities and clam harvests as well as research on the impact of clam harvesting on the biodiversity of Mosquito Lagoon are required to determine if any sort of permanent, temporary or cyclical regulations for the harvesting of *M. mercenaria* are needed.

Issue #5: Develop a Baseline and Monitoring Scheme for Water Quality for CANA and Mosquito Lagoon (Project Statement 4)

CANA needs to regularly assess water quality within Park boundaries to ensure that it is safe for humans and for aquatic flora and fauna. However, water-related issues extend beyond the Park's boundary and, thus, multi-agency communication and coordination are essential to successfully manage this watershed. One example is maintenance dredging of the ICW adjacent to Park boundaries. Lack of information or assembly of current information on CANA's water quality (both surface and ground water) and aquatic biology compromises the status of the Park's water resources and the direction of water resources planning. In 1988, the Indian River Lagoon Water Quality Monitoring Network (IRL-WQMN) was established as a coordinated multi-agency project spanning the entire length of the Indian River Lagoon system (Ponce de Leon Inlet to Jupiter Inlet). Under this monitoring effort, 22 surface water-sampling sites in Mosquito Lagoon were monitored. NASA sampled an additional 11 sites away from major facilities and operational areas once every two months. In 1996, the number of sampling stations was reduced to become more cost effective.

Without timely and comprehensive water quality information or adequate baseline data, impacts on water resources will remain undetected and changes will be difficult to document. Determining the status of contaminants on water, sediment, and biota of the park would serve as a benchmark for future comparisons and would help to identify problem contaminants and/or sites for possible remedial action. At a minimum, Park waters should be in compliance with state water quality standards (surface waters are designated as Class II and OFW, ground waters are designated as Class G-II). A comprehensive water quality monitoring program for surface and subsurface waters is essential to develop adequate baseline information and to determine compliance with water quality standards.

What is now needed by CANA is collation of these efforts to locate programs collecting critical water quality data, identify data presently being collected, and find gaps in data collection that are vital to the Park's goal of preservation and protection. In particular, special efforts are needed to understand the impacts of ICW dredging on CANA water quality. Currently, many monitoring programs could be better coordinated to facilitate sharing information among all potential users. Efforts may be duplicated in some areas, while other critical areas and parameters are neglected. If information gaps are identified, feasible ways to obtain the data must be established. This will include encouraging other agencies (FDEP, SJRWMD, EPA, etc.) to expand their programs and/or creation of protocols for Park employees to run to determine if bacteria, nutrients, and other chemical levels are within acceptable limits. If necessary, funding should be secured by CANA, including staff assistance, to help support these efforts. It is important that monitoring programs follow regionally accepted QA/QC protocols and that individuals are adequately trained on these procedures. Procedures also need to be developed which identify actions to be taken when water quality is deemed unacceptable.

Issue #10: The Effect of Mosquito Impoundment Reconnection and Restoration on Aquatic Biodiversity in CANA (Project Statement 5)

Impounding is a non-chemical, highly effective method for controlling reproduction of salt marsh mosquitos in shallow water areas. However, these impoundments can dramatically alter estuarine habitats. Vegetation changes are often dramatic, with much loss of high-marsh meadows of *Batis/Salicornia*, *Spartina alterniflora,* and mangrove communities due to flood frequency and alterations of salinity (Montague and Wiegert 1990; Rey and Kain 1991). These communities are adapted to fluctuating water levels rather than continuous inundation (Woodward-Clyde 1994g). Permanent closure of impoundments can greatly decrease salinity if rainfall replaces saltwater tidal exchange as the main source of water or significantly increase salinity if evaporation creates hypersaline conditions (Woodward-Clyde 1994g). Some impoundment effects are however considered positive. For example, some wading birds preferentially frequent these open water ponds. Overall, however, most researchers agree that the negative impacts of mosquito impoundments outweigh their benefits and as a result much effort and money has been recently placed on reconnecting or restoring impoundments.

Most impoundments in Mosquito Lagoon were constructed between 1962 and 1970 (Rey and Kain 1993). 27,770 of the 40,400 originally impounded acres have already been reconnected or restored and the results of these efforts are very encouraging. Waters levels are similar to the open waters of the Lagoon and increased diversity and abundances of plants, fish and wildlife has also been recorded in restored areas, including a number of locations within the boundaries of CANA. As of May 2001, 7000 acres (34%) of Mosquito Lagoon marsh habitat remained impounded (R. Brockmeyer, pers. comm., SJRWMD, 2001). In terms of research opportunities, CANA is in a unique position to collaborate with SJRWMD, MINWR and EVMCD to directly quantify the effects of these restoration activities on water quality and aquatic biodiversity.

Issue #13: Determine Primary Use Areas of the Endangered West Indian Manatee *Trichechus manatus latirostris* in CANA Waters (Project Statement 6)

The endangered West Indian manatee *Trichechus manatus latirostris* was once thought to concentrate primarily along the west side of Mosquito Lagoon, as it utilized the Intracoastal Waterway as a travel corridor to move between areas to the north and south. However, regular sightings by Park staff and visitors in recent years show that manatees spend significant amounts of time on the east side of Mosquito Lagoon near the North District boat launch and Eldora State House (CANA Wildlife Observation Cards). One of the major threats to manatees in Florida is collisions with watercraft, with such collisions being responsible for an average of 25% of the recorded manatee deaths annually since 1976 (30 percent in 1999) (USFWS 2000b). The ICW along Oak Hill is one of the four highest areas for recorded manatee boat-related fatalities along the ICW system (Volusia County Manatee Protection Plan 2000).

Factors that make the manatee vulnerable to boat collisions are its large size (up to 3500 pounds) and habit of foraging in shallow water, where it is unable to dive to escape approaching boats (Van Meter 1989). Mosquito Lagoon is quite shallow, averaging less than 1.5 meters in depth (Provancha et al 1992). Boating activity has increased significantly in Mosquito Lagoon over the past 10 years, partly due to construction of a boat ramp in the North District in 1991 and the opening of other ramps along the west side of the Lagoon. In addition, boaters may be detouring through the shallower waters of CANA to avoid a five-mile long slow speed zone along the Intracoastal Waterway (ICW).

Although no reported manatee deaths from boat collisions have been reported in CANA in recent years, such an event is quite possible. Measures to protect manatees such as slow speed zones are highly controversial. The Park needs good science to make management decisions that ensure protection of the manatee in CANA waters. Primary manatee use areas and locations which may pose a high risk of manatee/boat collisions need to be identified. A boating survey being conducted by MINWR, with support from CANA, will provide valuable information on boating activity.

Issue #14: The Effect of the Blue Crab Fishery on CANA Biodiversity (Project Statement 7)

The blue crab *Callinectes sapidus* is an aquatic keystone species and plays a major role in the ecology of the Indian River Lagoon because of its widespread occurrence and abundance, broad diet, and importance as prey to numerous other species, including a number of CANA's threatened and endangered species. Each year, numerous crab-harvesting licenses are given to commercial fishermen and each fisherman checks these traps every 24-36 hours. However, very little is known about crab harvests within Park boundaries and if the fishery or the pots are significantly impacting Mosquito Lagoon organisms.

Many fishermen switched to crab harvesting after the statewide gill-net ban went into effect in 1995. Additionally, the number of out-of-state crabbers fishing in central Florida waters greatly increased during this same time period. For example, the number of crab harvesting licenses in Brevard County increased from 257 to 981 between 1987 and 1997 (Noke 1999). During this same period, Volusia County licenses increased from 153 to 450 (Noke 1999). If this trend continues, over-harvesting may result, leading to the decline of this important fishery. Increases in the fishery may increase negative secondary effects, including alterations in the estuarine food web if blue crab numbers are greatly reduced, marine mammal entanglement in trap lines, and the death of large numbers of mobile, aquatic species in the associated ghost fishery that results when traps are lost (Noke 1999). CANA needs to determine if present harvesting practices for *C. sapidus* are sustainable. To accomplish this object, data on both harvesting and recruitment should be collected.

Issue #19: Determine Impact of Boat Propeller Scarring on Seagrass Beds in CANA Waters (Project Statement 8)

Recreational boating activity is increasing significantly as Florida's human population grows and as Mosquito Lagoon and CANA gains national acclaim for sport fishing (National Marine Fisheries Service, pers. comm., 2001). The increase in commercial shellfish and blue crab harvesting has also added additional boaters to the area. Increases in boating activity may lead to increases in damage to seagrasses from boat propellers. Scarring occurs when boat propellers cut through seagrass beds, ripping up a path of shoots and rhizomes and exposing bottom sediments. The most common type of scarring to seagrasses is caused by propellers from small boats. However, larger craft, which are usually confined to deeper waters, may have much larger individual effects when they run aground (Sargent et al. 1995).

Recovery and re-growth of seagrasses from such damage can take months to years (Durako et al. 1992). Extensive scarring may expose the beds to further disruption from storms and other natural erosional forces, thereby increasing the rate of cumulative loss. Also, seagrass beds that once acted as sediment traps are now a source of sediments for resuspension into the water column that further contribute to habitat loss by inhibiting the growth of seagrasses and smothering associated organisms, such as juvenile oysters. Thus, water quality and clarity are reduced when boat propeller scarring occurs. Another critical negative impact of loss of seagrass habitat is the loss of nursery habitat for many economically important IRL fish species and the loss of recruitment sites for many invertebrates.

Previous statewide research by FMRI in the early 1990's involved aerial surveys and characterization of scarring intensity (Sargent et al. 1995). Nearly all shallow seagrass beds in Florida have some level of prop-scar damage, with severe scarring visible within CANA boundaries. Because seagrass beds are critical to the health of estuaries, including Mosquito Lagoon (e.g. Zieman 1982, Virnstein et al. 1983), more research is needed on this issue. The prop-scar report published by Sargent et al. (1995) provides a basis for further and more refined research of areas subject to increasing boat traffic. First, the current level of scarring within CANA will be determined from aerial photographs and boat surveys. In areas where persistent damage is evident, recovery and protection plans will be evaluated. In other locations, including Biscayne Bay National Park, they are currently utilizing multifaceted approaches to protect seagrass beds, which include educating the boating public, marking channels more clearly, limiting powerboat access in certain sensitive areas, and more effectively enforcing existing laws.

Issue # 20: Determine if Critical Finfish Spawning/Juvenile Nursery Areas Require Additional Protection (Project Statement 9)

Sustainable fisheries require that harvests be balanced with production and survival of offspring. With funding from the NPS and the USGS, Dr. Grant Gilmore (NASA) and colleagues have been conducting important research on a variety of commercially important fish species in CANA waters to determine if spawning locations are distinct and predictable. Additionally, this group has examined the importance of Lagoon waters and associated wetlands to ascertain the predictability of critical nursery zones for these fish species.

Once present research is complete, CANA, MINWR, Florida Fish and Wildlife Conservation Commission, SJRWMD, U.S. Fish and Wildlife Service, Dr. Grant Gilmore and other renown fisheries biologists should meet to evaluate the sustainability of the Mosquito Lagoon fishery and the vulnerability of identified spawning and nursery areas to anthropogenic disturbances. If it is determined that specific areas are potentially threatened based on existing data, the group will provide recommended management strategies, including additional research, if necessary.

Issue #21: Spill Contingency Planning and Regulated Waste Management (Project Statement 10)

Hazardous waste spills have the potential to adversely affect CANA's water resources. Three major transportation routes are found adjacent to CANA's boundary. Located along the Seashore's western boundary is U.S. Highway 1, which is heavily traveled by motorists and large trucks. The Intercoastal Waterway (ICW) is also located along the western Park boundary and it too is heavily trafficked by recreational and commercial vessels. Several miles off CANA's eastern coastal boundary are shipping lanes that are common transportation routes for large vessels. With these active transportation routes so close to CANA, accidental spills of toxic materials will always threaten the Seashore's water resources.

It is important for CANA to be prepared for spills, while maintaining environmental compliance with their internal operations. The NPS is severely limited in qualified personnel and spill response equipment to effectively respond to hazardous waste spills in CANA. Emergency response to a major spill requires expertise and field equipment that extends beyond the capabilities of the NPS. As a result, a communication process (i.e., Spill Prevention Control and Countermeasure (SPCC) Plan) should be completed by CANA so designated Park staff can request assistance from qualified federal, state, county, and/or private contractor personnel in a time-efficient manner. The SPCC Plan is also required to maintain NPS compliance. Kennedy Space Center presently handles any hazardous waste that washes up on the beach. They will likely assist with major spills as well.

ISSUES THAT ARE NOT DEVELOPED AS PROJECT STATEMENTS AT THIS TIME

Issue #1: Investigate the Present Hydrological Condition of Mosquito Lagoon to Incorporate into a Comprehensive Groundwater/Surface Water Model for the East Coast of Central Florida.

Due to urbanization of the areas surrounding Mosquito Lagoon and potential anthropogenic impacts on CANA, it is critical to fully understand groundwater and surface water movements in this region. A multifaceted model is required to reach this goal. St. Johns River Water Management District has been working on developing such a model in recent years and it is hoped that all necessary data to complete the model will soon be in hand. CANA and the scoping committee acknowledge the importance of obtaining this information and listed it as the #1 priority for preserving and protecting the water resources at this National Park. Although not listed as a project statement, CANA staff will cooperate fully to help develop this model as quickly as possible.

Issue #6: Research the Potential Impact of Bivalve Aquaculture in Areas Adjacent to the Park on CANA's Resources.

There has been an increase in shellfish aquaculture activities in Mosquito Lagoon since the statewide gill-net ban went into effect in 1995. Of the 35 clam-lease aquaculture sites started in 1997 near Oak Hill, approximately 12 are still actively worked. Each lease covers one acre of Mosquito Lagoon bottom and begins immediately adjacent to the Park boundary. The water provides the nutrients and environment needed to feed and raise the clams. In other locations north and south of CANA boundaries, clams are raised in simple flow-through systems that provide ambient plankton concentrations and releases water back into the Lagoon.

CANA is concerned about preserving biodiversity within Mosquito Lagoon and potential negative impacts of aquaculture. Primary concerns are increased nutrient loadings from feeding juveniles or waste products and the introduction of exotic species that can be associated with the grow-out industry. A 1993 study by Mojica and Nelson found no significant detrimental effects from IRL clam aquaculture. On April 17, 1996, Cape Cod National Seashore Resource Specialists, CANA Resource Specialists and University of Rhode Island faculty met to determine how Park units should study potential negative impacts of aquaculture adjacent to or within park boundaries. Following this meeting, Hamel-LeBlac and Oviatt (2000) looked at the ecological implications of *Mercenaria* aquaculture within Cape Cod National Seashore. Like Mojica and Nelson (1993), they found that the biological and physical impacts on the benthos were minimal and physical forces (storms, high winds, strong tidal flushing) diminished the effects of increased organic material deposition (Hamel-LeBlac and Oviatt 2000). Since the results of both of these projects showed little impact of aquaculture on biodiversity, CANA will not directly address this topic at this time. However, by collecting data for the aquatic species inventories (Issue #2) and water quality monitoring (Issue #5), CANA will be able to monitor changes in species abundances and compositions throughout the Park, including areas adjacent to aquaculture operations. If significant negative impacts are found in these locations, CANA managers will be poised to examine the situation in greater detail.

Issue #7. Inventory Water-Related Activities of Visitors and Determine Their Impact on CANA Water Quality and Biodiversity.

There is no information available documenting water-related activities of CANA visitors or their harvests. Information of this type would greatly enhance CANA's ability to protect Mosquito Lagoon. Water activity surveys should include information from both the high and low usage seasons on the numbers, speeds, and destinations of: 1) recreational boats, 2) commercial fishing vessels, 3) eco-tourism boats, and 4) non-motorized vessels. Although not permitted, the numbers of jet skis, knee-boarders and tubers in Park boundaries should also be recorded. Creating GIS maps of high traffic areas would enable CANA to determine if measures are necessary to protect critical habitats. If and where possible, harvests of: 1) game fish, 2) bait fish, 3) crabs, 4) clams, and 5) oysters and the collection location should be recorded to reduce chances of overexploitation. Due to the enormous amount of manpower needed to collect this data, this issue is not listed as an individual project statement. However, information will become available through other project statements, such as Issue #3a on the impact of boat wakes on intertidal oyster reefs, Issue #3b on the impacts of harvesting on oyster populations, Issue #4 on the impact of calm harvesting, Issue #13 on the movements of the West Indian manatee through CANA waters, Issue #14 on the impact of blue crab harvesting on CANA biodiversity, and Issue #19 on the impact of seagrass scarring on grass beds and associated biodiversity.

Issue #8. Inventory Commercial and Recreational Water Use in Areas Adjacent to CANA.

The goal for this issue is to develop a GIS map that will provide information on the location of various water-related activities adjacent to CANA that may impact CANA's biodiversity and water quality. Locations of: 1) the Intercoastal Waterway, 2) other shipping channels, 3) primary recreational boat destinations, 4) marinas, 5) manufacturing plants, 6) aquaculture facilities, and 7) shellfish leases will be included in this map. It is hoped that this project can be included with other Park-related GIS activities.

Issue #9. Determine Human Population Growth and Associated Waterfront Construction Adjacent to Park Boundaries.

Population growth, as well as associated construction, water use, and sewage disposal needs continue to rise in urban and rural areas adjacent to all shorelines in east-central Florida. The Mosquito Lagoon basin is projected to receive a 58% growth increase by the year 2010. The 1990 population density for the basin was 528 people per square mile (psm), and is projected to increase to 839 psm by 2010 (Woodward-Clyde 1994a). Although CANA has no direct control over human population growth or its impact on water resources outside Park boundaries, monitoring water quality (Issue #5) and biodiversity (Issue #2) within Park boundaries will enable Resource Managers to access any impacts that are potentially related to human population growth and provide data to regulatory groups as needed.

Issue #11. Understanding Horseshoe Crab Mass Mortality Events and How to Prevent Future Mortality Events in the IRL.

To date, most research done on the American horseshoe crab *Limulus polyphemus* has focused on the northeast United States, while little is known about populations along the east coast of Florida. With funding from the National Park Service, Ehlinger (2000) has gathered some baseline data on the horseshoe crab population in Mosquito Lagoon and the upper Indian River Lagoon. After two years of mark-recapture and spawning surveys, very little is still known about the life-history of the *Limulus* population in the Lagoon system. In order to protect this species, CANA needs to know: (1) the number and distribution of horseshoe crabs in Mosquito Lagoon; (2) the areas of critical habitat for spawning and juvenile development; (3) what life-cycle stages are most at risk; (4) the impact of sediment change, impoundments, and other environmental effects caused by humans, and (5) the amount and the impact of human take on the *Limulus* population in Mosquito Lagoon.

A mass-mortality event of *Limulus polyphemus* occurred in the Indian River and Mosquito Lagoon on July 9, 1999. An aerial survey was undertaken by NASA to document the number of dead crabs along the IRL shoreline and inside impoundments (Scheidt and Lowers 2000). This survey covered over 69 km of shoreline and documented 129,177 dead horseshoe crabs. In the Mosquito Lagoon portion of the study, 104 dead individuals were recorded inside impoundments while 9391 were recorded along the Lagoon shoreline. The cause of this event remains unknown. No other organisms, such as fishes or marine mammals, were affected. Possible causes for this die-off include a low dissolved oxygen event, high sulfide levels in the lower water column, bacterial or viral infection, or even a natural cyclical event (Scheidt and Lowers 2000). This reduction of *Limulus* numbers in Mosquito Lagoon could have grave consequences for loggerhead and green sea turtle populations and other species that rely on *Limulus* as a food source. Dynamac, Inc. (NASA) has set up a rapid response team to react quickly to any future mass mortality events. CANA managers and researchers will assist in these efforts however possible.

Issue #12. Determine Extent of Fibropapillomatosis on Juvenile Turtles in Mosquito Lagoon and Survival of Afflicted Individuals.

At some point after crawling out to sea from central Florida beaches, juvenile green turtles (*Chelonia mydas*) return from the ocean and enter the Indian River Lagoon system, remaining in these waters until they are approximately 5 years old (Ehrhart 1988; Provancha 1997). If individuals are able to find sufficient food and avoid cold weather events, they may still succumb to a disease known as fibropapillomatosis. This herpes-type virus manifests itself as tumors on the fleshy parts of the turtle's body. Larger numbers of juveniles in IRL waters are affected by this disease and it has been hypothesized that water quality may be involved. CANA will work with (NASA) Dynamac, Inc. and numerous other turtle research groups around the state to understand the causes and development of this disease.

Issue #15. Develop a Public Advocacy Group to Support and Protect Mosquito Lagoon Habitats and Biodiversity.

Environmental advocacy groups provide public awareness, education, research support and legal aid in addition to monetary support to non-profit entities such as National Parks, important bodies of water (e.g. Tampa Bay Estuary Program, Chesapeake Bay Foundation) or specific organisms (e.g. Save the Manatee Club). There are many such groups in Florida and close collaboration with them could greatly increase public support of CANA's mission. The park already has a core of almost 200 volunteers who are actively involved in a variety of maintenance, interpretation and resource management projects. Under the right leadership, it should be possible to found a Mosquito Lagoon or CANA advocacy group that focuses solely on issues that matter most to the Park and its habitats.

Issue #16. Provide the Public With Written Information on CANA's Future Plans and Goals in Terms of Development, Protection of Flora and Fauna, and Scientific Research.

CANA has recently developed two types of materials to communicate with Park visitors before and during their visit. First, they have created a CANA newspaper entitled, "Sea Breeze" that is given to all visitors as they enter the Park. In this paper, viewers can learn much about the Park, especially the biology of many of its organisms. Second, the CANA has developed a web site (www.nbbd.com/godo/cns/) that provides details on a range of topics including press releases and numerous downloadable brochures to help the public better understand the biology, ecology, geology and history of the area. There is a need for additional materials (posters, brochures, web-based, videos, and direct interactions with Park educational employees, the scientific community and advocacy groups) to inform the public about CANA-related research and issues. It is especially critical to rapidly and accurately disseminate information on negative anthropogenic impacts and how problems can be eliminated before it is too late.

Issue #17. Develop a Better Understanding of Shorebird/Wading Bird Ecology in Mosquito Lagoon.

Wading birds play an important role in aquatic systems and CANA is home to many wading birds, including the endangered wood stork *Mycteria americana*. This wood stork can be found in the Park foraging in open water mosquito impoundments and roosting in mangrove trees. CANA does not intend to develop a project statement on aquatic birds at this time because their adjacent federal agency, Merritt Island National Wildlife Refuge, has been charged with preserving and protecting avian species in the jointly managed portion of Mosquito Lagoon. Additionally, NASA has collected data on this topic in southern Mosquito Lagoon. CANA will cooperate fully to ensure all bird species are protected and all necessary data is collected within Park boundaries.

Issue #18. Continue Research on the Impact of Raccoons and Ghost Crab Foraging on Nesting Sea Turtles.

CANA is an important nesting area for several species of threatened and endangered sea turtles. These are primarily the loggerhead (*Caretta caretta*), with fewer numbers of green turtles (*Chelonia mydas*) and leatherback turtles (*Dermochelys coriacea*). Predation on nests, primarily by raccoons, is a serious threat, and predation rates exceeding 90% were recorded in the early 1980's (McMurtray 1986). In 1984, the CANA implemented a nest-screening program that protected nests, allowed the raccoon to remain as an integral part of the barrier island ecosystem, and was compatible with National Park Service guidelines and objectives. 2000 was the 17th year for CANA's sea turtle nest protection program. With help from a large number of volunteers, Park staff managed to screen over 90% of the several thousand nests deposited in 2000, reducing nest predation to less than 30% overall, with only 7% of the screened nests depredated (Dennis and Stiner 2000).

All National Parks are charged with the protection and recovery of threatened and endangered species. One of CANA's goal is to achieve a 60% hatching rate for loggerhead and green sea turtles as stated in their respective recovery plans (NMFS and USFWS 1991a, b). Many man-hours are devoted to this very important project each summer. However, removing sea turtle eggs as a food source may increase predation by raccoons on the nests of other ground-nesting species, including gopher tortoises, wading birds, etc. Conversely, the raccoon may play an important role in limiting the number of ghost crabs that may destroy large numbers of sea turtle eggs and hatchlings. A study is needed to compare population densities of gopher tortoises, ghost crabs and other representative ground-nesting species at CANA with adjacent areas where the raccoon population has been reduced.

PROJECT STATEMENT #1 CANA-

Last Update: 11/01 Priority: High
Initial proposal: 1/01 Number of pages: 4

Title: COMPLETE AQUATIC SPECIES INVENTORY FOR MOSQUITO LAGOON (CANA)

Funding Status: Funded: 0% Unfunded: 100%

Servicewide Issues:
Cultural Resource Type:
N-RMAP Program Codes:

Problem Statement

Canaveral National Seashore (CANA) was established by federal legislation to, "… preserve and protect the outstanding natural, scenic, scientific, ecologic, and historic values of certain lands, shoreline, and waters of the State of Florida, and to provide for public outdoor recreation use and enjoyment of the same…" (Public Law 93-626). This National Park unit represents an excellent example of a relatively stable barrier beach backed by a productive lagoon system (Mosquito Lagoon).

Mosquito Lagoon is the northernmost sub-basin of the Indian River Lagoon Estuary along Florida's East Coast. This estuarine system contains the highest species diversity of any estuary in North America (see references in 1995 special issue of *Bulletin of Marine Science*, Vol. 57). Several endangered species (green sea turtle, loggerhead sea turtle, West Indian manatee) occupy this important habitat. Because of its recognized importance as a habitat for aquatic fauna, the Mosquito Lagoon has been included in the National Estuary Program by the EPA. The ecological importance of CANA has also been recognized by the State of Florida, with waters in the Park being designated as Outstanding Florida Waters (62-302.700 F.A.C.), the highest level of state protection. Under this designation, ambient water quality must be maintained and protected, and any degradation must be short-term or temporary.

In order to protect Mosquito Lagoon's natural, scientific and ecologic values, CANA must maintain the native biological diversity upon which the Lagoon's ecosystem is built. To accomplish this, there must be accurate, up-to-date inventories of flora and fauna in all habitats within Park boundaries. Inventories have been completed for fish, terrestrial vertebrates and terrestrial plants; however, no inventories have been done of aquatic invertebrates or plants. The fish inventory, published in 1983 by Dr. Snelson of the University of Central Florida, was collected in the 1970's and 1980's. It is unclear has much has changed since then with the invasion of exotic fish species into Florida.

Dr. Hillary Swain produced the first IRL-wide list of organisms in 1994, containing over 2,493 species of one-celled organisms, plants, and animals. The Smithsonian Marine Station (SMS) in Ft. Pierce became the depository for these species in 1997. The list is useful, but has three major drawbacks. First, this database is system-wide and includes all species that complete at least a portion of their life-cycle somewhere in the IRL system. No distinction is made as to what portions of the IRL an organism can be found (e.g. Mosquito Lagoon versus the Banana or Indian Rivers) (Smithsonian Marine Station 2001). Second, most of the data was collected approximately 150 miles to the south near SMS and Harbor Branch Oceanographic Institution, in significantly more subtropical conditions (Mosquito Lagoon is a temperate/subtropical transition zone) (Provancha et al. 1992). Third, the SMS database is the result of reader response cards rather than field sampling. Thus, many taxa may have been overlooked due to this method of data collection.

The NPS has implemented an inventory and monitoring program that will generate a list of 90 percent of the species present for vertebrate animals, terrestrial vascular plants and, eventually, federally listed species. This too places emphasis on terrestrial habitats. CANA is primarily a water park, with over 2/3 (40,000 acres) of its area contained within Mosquito Lagoon. Many of the Lagoon's species are vulnerable to point and non-point pollution, exotic species invasion and over-exploitation. For CANA to understand and protect its aquatic resources, it is critical to obtain a comprehensive species inventory.

Description of Recommended Project or Activity

The CANA Mosquito Lagoon biological inventory will be completed in two phases. First will be a literature search, including the SMS inventory for the Indian River Lagoon. It should be relatively easy to collect information on marine mammals, reptiles, birds, commercially important invertebrates and fish, seagrasses, and intertidal wetlands flora (e.g. mangrove trees, salt marsh grasses). Published data however, does not exist for the majority of the invertebrates and macroalgae in these waters. Unpublished data on Mosquito Lagoon biodiversity will also be sought. For example, Dr. Linda Walters at the University of Central Florida (UCF), monitored recruitment of sessile invertebrate species from January 1998-June 2001. Additionally, unpublished data on fish from Dr. Grant Gilmore (Dynamac Corp.) and Dr. Snelson (UCF), small crustaceans from Dr. Walter Nelson (Sea Grant) and Dr. Kerry Clark's (Florida Institute of Technology) records on aquatic molluscs will be obtained. Other sources will be utilized as they are discovered. Once the literature has been thoroughly examined, gaps in the species inventory database will be identified.

In the second phase, field surveys will be conducted to fill in any gaps in the species inventory matrix. Federal bioassessment protocols, established by the Department of the Interior and the Environmental Protection Agency, will be utilized (Barbour et al. 1999; Gibson et al. 2000). Emphasis will be placed on protocols that are both rapid and cost-effective; for example, invertebrate diversity data will be collected from settling plates, seining, and sieving. Data will be collected each season of the year for one (1) year (January, April, July, and October).

Tasks and associated costs are divided into two phases. The student or contractor will spend the first 6 months creating a CANA database, inputting data into the NPS database (NPSpecies), and identifying gaps in the species inventory. The next twelve months will involve seasonal data collection using appropriate bioassessment techniques

Literature Cited

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Budget and FTEs:

The following budget reflects use of a graduate student through a Memorandum of Understanding with a university; however, use of a contractor will also be considered.

UNFUNDED

Phase 1: 6 months

Direct labor:

Graduate student (3 months summer salary): $5,000
Faculty advisor (summer contract): $1500
Fringe for student (0.30%): $15
Fringe for faculty advisor (24.55%): $368

Equipment:

Dedicated computer: $1000

Supplies:

HTML training to place inventory lists on CANA web site: $300
Software, computer disks, etc.: $900

Travel:

0.29/mile: $1200

Overhead costs (Off-campus rate: 26%): $2674

Phase 1 Total: $12,957

Matching will occur as graduate student salary during the academic year while employed as a teaching assistant, tuition waiver for graduate student, release time for faculty member, and use of Fellers House Field Station.

<u>Phase 2: 12 months</u>
Direct Labor:
    Graduate student (3 months summer salary): $5000
    Undergraduate assistant (10 hr/week X 52 weeks at $7.00/hr): $3640
    Faculty advisor (summer contract): $1500
    Fringe for graduate student (0.30%): $15
    Fringe for undergraduate (0.62%): $23
    Fringe for faculty advisor (24.55%): $368
    Contract work with taxonomic specialists (15 days @ $100/day): $1500
Supplies:
    Supplies for field sampling, including seines, nets, buckets, sieves, sediment corers, plant press and paper, film, film processing, waterproof paper, clipboards, transect tapes, etc.: $3000
Travel:
    Around Florida (@ 0.29/mile): $1500

Overhead costs (Off-campus rate: 26%): $4302

Phase 2 Total: $20,848

Matching will occur as graduate student salary during the academic year while employed as a teaching assistant, tuition waiver for graduate student, release time for faculty member, and use of Fellers House Field Station.

TOTAL FUNDING REQUESTED: $33,805

PROJECT STATEMENT #2 CANA-

Last Update:11/01 Priority: High
Initial proposal: 7/01 Number of pages: 5

Title: DETERMINE IMPACT OF HARVESTING ON INTERTIDAL REEFS OF THE EASTERN OYSTER *CRASSOSTREA VIRGINICA* IN CANA

Funding Status: Funded: 0% Unfunded: 100%

Servicewide Issues:
Cultural Resource Type:
N-RMAP Program Codes:

Problem Statement

Canaveral National Seashore (CANA), established in 1975, consists of approximately 58,000 acres within the Mosquito Lagoon watershed. Mosquito Lagoon is the northernmost sub-basin of the Indian River Lagoon Estuary along Florida's East Coast. This estuarine system contains the highest species diversity of any estuary in North America (see references in 1995 special issue of *Bulletin of Marine Science*, Vol. 57). Several endangered species (green sea turtle, loggerhead sea turtle, West Indian manatee) occupy this important habitat. Because of its recognized importance as a habitat for aquatic fauna, Mosquito Lagoon has been included in the National Estuary Program by the EPA. The ecological importance of CANA has also been recognized by the State of Florida, with Mosquito Lagoon being designated as an Outstanding Florida Water (62-302.700 F.A.C.), the highest level of state protection.

CANA was established by federal legislation to, "… preserve and protect the outstanding natural, scenic, scientific, ecologic, and historic values of certain lands, shoreline, and waters of the State of Florida, and to provide for public outdoor recreation use and enjoyment of the same…" (Public Law 93-626). One of the Lagoon's significant resources is the eastern oyster *Crassostrea virginica* (Provancha et al. 1992). No one debates the economic importance of *C. virginica*. Now, there is also a preponderance of data documenting the important ecological services provided by *C. virginica* (e.g. Coen et al. 1996, 1999a, b; Breitburg et al. 2000). As summarized by Coen et al. (1999a), these services include: 1) filtering capacity (estimated at 1500 times body volume per hour: Loosanoff and Nomejko 1946), 2) refugia from predation, 3) feeding habitat for juvenile and adult forms of mobile species, 4) food for many species, including some threatened/endangered bird species, and 5) substrate for sessile fauna and flora. Meyer and colleagues (1996, 1997) have also found that oyster reefs can play a significant role in stabilizing creek banks and preserving emergent salt marsh vegetation. In Florida waters, intertidal oyster reefs also protect mangrove communities (L. Walters, pers. obs.).

Unfortunately, oysters and oyster reef habitat have declined dramatically along the east coast of the United States over the past century due to habitat degradation (Rothschild et al. 1994), overharvesting (Gross and Smyth 1946), reduced water quality (Seliger et al. 1985) and disease (Ford and Tripp 1996). The decimation of stocks of *C. virginica* throughout much of its range has prompted restoration and/or enhancement efforts in many coastal states (e.g. Berrigan 1988, 1990). Within the past decade, this has become a priority issue, as evidenced by: 1) the Oyster Reef Restoration Workshop (VA, April 1995), 2) the 2nd International Conference on Shellfish Restoration (SC, November 1998), and the Chesapeake Bay Oyster Restoration Consensus Meeting (VA, June 1999). Fortunately, research scientists in these groups have been adamant that the ecology of oyster reefs carry weight in restoration efforts (e.g. Coen et al. 1999b; Coen and Luckenbach 2000; Breitburg et al. 2000).

Within CANA boundaries, reefs of *C. virginica* have declined over 50% between 1943 and 1995 (Walters et al. 2001). Researchers are presently studying the impact of habitat degradation on this decline. To compliment this data and to more fully understand this dramatic decline, we need to understand harvesting impacts in Park waters. Oyster harvesting in Mosquito Lagoon predated the establishment of CANA and thus, both commercial and recreational harvesters have always been allowed to harvest within Park boundaries (Grizzle 1990). A dramatic increase in commercial shellfish harvesting in Mosquito Lagoon waters followed the statewide gill net ban, which went into effect in 1995. There are 14 active commercial oyster leases in CANA, approximately 200 commercial harvesting permits issued for FY 2001, and an uncounted number of recreational harvesters. Recreational harvesters are allowed to collect two 5-gallon buckets of oysters per person per day; commercial harvesters are allowed unlimited access to the resource. The Park lacks critical data to determine if the current harvest rates are sustainable or a threat to the long-term survivorship of the oyster population in Mosquito Lagoon.

Description of Recommended Project or Activity

To address the impacts of harvesting of *C. virginica* in CANA waters, three types of data must be collected. First, a better understanding of harvesting intensity within the Park is needed to determine how quickly this resource is being removed. Second, research is needed to understand if harvesting on an oyster reef reduces the long-term success of oysters on the reef. Third, it should be determined if: 1) certain key reefs are producing the majority of spat in Mosquito Lagoon, which are then carried by currents to other reefs where they develop, or 2) certain key reefs are producing the majority of adult oysters.

Although crucial to determining if overharvesting is occurring in CANA, harvesting data is difficult to collect due to the expansive collecting area and because harvesters are wary of providing information on their catches. DEP databases (HACCP: Hazard Analysis of Critical Control Points) that record commercial harvests (amount and collection location) will be examined to get a better understanding of the number of bushels of oysters commercially removed from CANA waters on a daily basis. From this data, it will be possible to estimate annual oyster loss to harvesting. This data can also be compared to recruitment and survival numbers for *C. virginica* (Walters et al. 2001) to determine if harvesting is sustainable in this habitat.

The second hypothesis to be considered is that harvesting negatively impacts an oyster reef. Thirty reefs will be compared for long-term fitness. Recruitment, proportion of live individuals to dead shells, and changes in dimensions of the reef boundaries over 2 years will be compared on 30 reefs within CANA. Of these 30 reefs, 10 reefs will be refuges (no harvesting permitted), 10 will allow harvesting only around the edges, and 10 will allow full harvesting.

If harvesting is found to negatively impact reef sustainability, then some oyster reefs in Mosquito Lagoon may warrant protection to ensure survival of the population. Oyster reefs that produce the most gametes and have the highest recruitment are the best candidates for refuges. However, it is not known if all reefs in CANA: 1) produce equal numbers of gametes, 2) if all gametes are equally successful, 3) if all reefs receive equal numbers of larvae (spat), or 4) if juveniles on all reefs are equally successful. Preliminary data suggests that the number of juveniles and survival of these individuals varies by several orders of magnitude between reefs (Walters et al. 2001).

The reproductive success of sixty reefs within CANA boundaries will be examined. These reefs will be determined by initial boat surveys looking at recruitment and tracking current movements with florescin dye and the movement of passive particles (larval drogues). Thirty, healthy reefs will then be compared to an equal number of reefs that have seriously declined in recent years (Walters et al. 2001). Within each group of thirty, 10 reefs will be refuges (no harvesting permitted), 10 will allow harvesting only around the edges, and 10 will allow full harvesting. At monthly intervals, 10 adults will be collected from each reef for fecundity analysis. First, dry shell weight and dry tissue weight will be recorded as will any evidence of male or female gametes. An enzyme-linked immunosorbant assay developed by Choi et al. (1993) will then be run to give the best estimate of individual oyster fecundity. Statistical comparisons of the shell: tissue weight ratio, evidence of gametes, and the assay results will then be run to compare reefs.

To determine if larvae of *C. virginica* preferentially settle and survive on some reefs more than others, the number of new individuals will be recorded at monthly intervals at each site. To do this, a method developed by Walters et al. (2001) will be modified and used at each site. Twenty-five, cleaned oyster shells will be attached face-down to frames composed of PVC and plastic mesh in the most protected and most exposed areas on each of the 30 study reefs. These shells are similar to actual reef substrate within a few days in terms of fouling and siltation, and oyster larvae readily attach to them. Once a month, the frames will be removed and replaced by similar, clean frames. In the laboratory, the numbers of new recruits (live and dead) on these shells will be counted. Statistical analyses will then be used to compare recruitment and survival among reefs.

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Budget and FTEs

The following budget reflects use of a graduate student through a Memorandum of Understanding with a university; however, use of a contractor will also be considered.

100% UNFUNDED

YEAR 1

Direct labor:

Graduate student (6 months): $7500
Undergraduate assistant (3 months): $3000
Faculty advisor for 1 month of summer: $5000
Fringe for graduate student (0.30%): $23
Fringe for undergraduate (0.30%): $9
Fringe for faculty (24.00%): $1200

Supplies:

Clipboards, waterproof paper, binoculars, stamped postcards, PVC pipe and glue, Vexar plastic mesh, cable ties, cinder blocks, chemicals for enzymatic assays, oyster knives, flourescin dye, etc. $4500

Travel (0.29/mile): $2500
Boat travel in Mosquito Lagoon: $3500

Overhead (Off-campus rate: 26%): $7080

Year 1 Total: $34,312

<u>YEAR 2</u>
Direct labor:

Graduate student (9 months): $10,500
Undergraduate assistant (9 months): $6500
Faculty advisor for 1 month of summer: $5500
Fringe for graduate student (0.30%): $32
Fringe for undergraduate (0.03%): $17
Fringe for faculty (24.00%): $1320

Supplies:

Clipboards, waterproof paper, stamped postcards, PVC pipe and glue, Vexar plastic mesh, cable ties, chemicals for enzymatic assays, oyster knives, etc. $4500

Travel (0.29/mile): $3000
Boat travel in Mosquito Lagoon: $3750

Overhead (Off-campus rate: 26%): $9131

Year 2 Total: $44,250

TOTAL FUNDING REQUESTED: $78,562

PROJECT STATEMENT #3 CANA-

Last Update: 11/01 Priority: High
Initial proposal: 7/01 Number of pages: 4

Title: DETERMINE EFFECTS OF HARVESTING THE HARD CLAM *MERCENARIA MERCENARIA* ON SEAGRASS BEDS AND CLAM POPULATIONS IN MOSQUITO LAGOON

Funding Status: Funded: 0% Unfunded: 100%

Servicewide Issues:
Cultural Resource Type:
N-RMAP Program Codes:

Problem Statement

Background

Canaveral National Seashore (CANA) consists of approximately 58,000 acres within the Mosquito Lagoon watershed. This National Park unit represents an excellent example of a relatively stable barrier beach backed by a productive lagoon system. This estuarine system contains the highest species diversity of any estuary in North America (see references in 1995 special issue of *Bulletin of Marine Science*, Vol. 57) and provides critical habitat for 14 federally listed threatened and endangered species, including the green sea turtle, the loggerhead turtle, and the West Indian manatee. The far-reaching, ecological importance of this area has been demonstrated by the EPA in listing it as an Estuary of National Significance and by the state of Florida in classifying it as a Florida Outstanding Waterway and Aquatic Preserve, the highest level of state protection. Under this designation, ambient water quality must be maintained and protected, and any degradation must be short-term or temporary.

CANA was established in 1975 by federal legislation to, "… preserve and protect the outstanding natural, scenic, scientific, ecologic, and historic values of certain lands, shoreline, and waters of the State of Florida, and to provide for public outdoor recreation use and enjoyment of the same…" (Public Law 93-626). The hard clam (or quahog) *Mercenaria mercenaria* is an economically and ecologically important component of Mosquito Lagoon. Annual statewide revenues for *M. mercenaria* exceed 12 million dollars. Ecologically, it filters large volumes of water and is prey to many species, including a number of threatened and endangered birds.

The harvesting of the hard clam *M. mercenaria* is a popular recreational and commercial activity in Mosquito Lagoon. Harvesting increased significantly in the early-mid 1990's as clammers moved north to Mosquito Lagoon waters after clam populations were depleted south of the Park in central/south Brevard County. As of December 2000, CANA and FWS had already issued over 190 permits for the 2000/2001 season to individuals involved in the commercial harvesting of finfish or shellfish. Of the 88 individuals who reported which species they planned to harvest, 67 listed clams; most did not identify a target species. Commercial harvesters do not need to report their catch to the Park. An unsuccessful effort was made in the early 1990's to have clammers submit daily catch logs. Thus, total harvests by this group are not known. Additionally, recreational harvesters are limited to two 5-gallon buckets/day and do not need permits; the numbers of clams harvested by this group is also completely unknown. CANA is greatly concerned that the clam population cannot sustain this harvest pressure.

In addition to worrying about maintaining sustainable populations of *M. mercenaria*, CANA is concerned with harvesting methods on associated fauna and flora, especially seagrasses. Clam harvesting is restricted to individuals gathering by hand, feet or hand-held raking devices in areas with little or no seagrass. However, clam harvesters frequently spend long periods of time concentrated in small areas, especially areas adjacent to dense seagrass beds. Peterson et al. (1984) found that densities of 0-2 year old hard clams were 5 times greater in seagrass beds than in nearby sand flats in North Carolina. This result is likely due to reduced predation and reduced water movement within the grass bed. Anecdotal reports suggest the sediments are disturbed and large quantities of seagrass are dislodged during these harvesting events. Peterson et al. (1987) studied the impact of clam raking and different intensities of mechanical harvesting on an estuarine seagrass bed in North Carolina. In their 4-year study, they looked at clam recruitment, seagrass biomass, and density of benthic macroinvertebrates. With hand raking, seagrass biomass dropped approximately 25% below control plots, with full recovery after 1 year. With mechanical harvesting, seagrass biomass dropped to 65% below controls. Recovery of these beds began only after 2 years and the biomass was still about 35% lower than controls 4 years later.

Quantitative data on clam densities, harvest levels, and research on the impact of clam harvesting methods are imperative to determine if currents harvesting levels and practices are threatening the clam population, the seagrass beds and associated seagrass fauna in Mosquito Lagoon.

Description of Recommended Project or Activity

To address the impacts of harvesting of *M. mercenaria* in CANA waters, three types of data must be collected. First, updated population density measures are needed. Second, a better understanding of harvesting within the Park is needed to determine how quickly this resource is being removed.

The methods of Grizzle (1990) will be duplicated to determine any changes in the distribution and abundance of *M. mercenaria* in CANA waters since 1987. He systematically divided the study area (water depth: > 1 m) into 86 grid blocks with their boundaries drawn at 0.5-minute intervals of latitude and longitude. Within each block, between two and six 1-m^2 quadrats will be raked using a scratch rake or a Shinnecock rake (deeper waters) and all clams encountered will be sized and recorded. This will provide information on recruitment rate and longevity of this species in CANA waters. Additionally, sediment type, macrophyte cover and water depth will be recorded for each quadrat.

Harvesting information will be collected from DEP databases (HACCP: Hazard Analysis of Critical Control Points) that record commercial harvests (amount and collection location) will be examined to get a better understanding of the number of bushels of clams commercially removed from CANA waters on a daily basis. From this data, an estimate of annual clam loss to harvesting and which CANA areas are most heavily impacted will be produced. Using available fisheries models, clam recruitment, population size and harvest values will be compared to determine if the annual CANA harvest is sustainable.

Methods similar to those employed by Peterson et al. (1987) will be used to determine the impact of harvesting on newly settled and adult clams, seagrass and other benthic invertebrates. The experimental design will combine 3 factors: 1) seagrass density, 2) harvesting, and 3) addition/no-addition of juvenile clams. The juvenile clam addition treatment is included to ensure that vulnerable, new recruits are present in the system during the trials. All quadrats will be 1-m^2. Half of the quadrats will be in areas with dense *Halodule wrightii* cover (greater than 70% cover); the other quadrats will have low *H. wrightii* density (< 20% cover). Harvesting treatments will include: 1) unmanipulated quadrats, 2) quadrats subjected to light raking, and 3) quadrats subjected to intense raking. Finally, 3000 juvenile clams will be added to half of the replicates of each seagrass density/harvesting treatment combination immediately after raking has occurred to ensure that juveniles present in certain treatments.

There will be 18 replicates of each combination of seagrass density/ harvesting method/ addition/no addition of juvenile clams. Six replicates of each treatment will be surrounded by a mesh cage to deter large predators, such as the blue crab *Callinectes sapidus*, six will be surrounded by partial cages to control for any caging impacts, and six replicates will be uncaged. For all replicates, sediment cores will collected, stained, sorted and counted to estimate infaunal invertebrate abundances (including adult and juvenile clams). Seagrass density counts will be used to monitor seagrass persistence. Benthic sampling, including clam abundances, and seagrass density data will be collected immediately prior to the start of the experiment and twice monthly for 12 months. At the end of the experimental period, the data will be analyzed using the appropriate statistical methods.

Literature Cited

Grizzle, R.E. 1990. Distribution and abundance of *Crassostrea virginica* and *Mercenaria* spp. (quahogs) in a coastal lagoon. Journal of Shellfish Research 9:347-358.

Peterson, C.H., Summerson, H. and P.B. Duncan. 1984. The influence of seagrass cover on population structure and individual growth rate of a suspension-feeding bivalve, *Mercenaria mercenaria*. Journal of Marine Research 42: 123-138.

Peterson, C.H., Summerson, H.C. and S.R. Fegley. 1987. Ecological consequences of mechanical harvesting of clams. Fishery Bulletin 85: 281-298.

Budget and FTEs

The following budget reflects use of a graduate student through a Memorandum of Understanding with a university; however, use of a contractor will also be considered.

100% UNFUNDED

YEAR 1

Direct labor:

- Graduate student (6 months): $7500
- Undergraduate assistant (3 months): $3000
- Faculty advisor for 1 month of summer: $5000
- Fringe for graduate student (0.30%): $23
- Fringe for undergraduate (0.30%): $9
- Fringe for faculty (24.00%): $1200

Supplies:

- Clipboards, waterproof paper, binoculars, stamped postcards, PVC pipe and glue, clam rakes, clam larvae, benthic coring devices, rose Bengal stain, etc. $2300

Travel around Florida (0.29/mile): $2500
Boat travel in Mosquito Lagoon: $6000

Overhead (Off-campus rate: 26%): $7158

Year 1 Total: $34,690

YEAR 2

Direct labor:

- Graduate student (9 months): $10,500
- Undergraduate assistant (9 months): $6500
- Faculty advisor for 1 month of summer: $5500
- Fringe for graduate student (0.30%): $32
- Fringe for undergraduate (0.03%): $17
- Fringe for faculty (24.00%): $1320

Supplies:

- Clipboards, waterproof paper, binoculars, stamped postcards, PVC pipe and glue, clam rakes, benthic coring devices, rose Bengal stain, etc. $2000

Travel around Florida (0.29/mile): $3000
Boat travel in Mosquito Lagoon: $6000

Overhead (Off-campus rate: 26%): $9066

Year 2 Total: $43,935

TOTAL FUNDING REQUESTED: $78,625

PROJECT STATEMENT #4 CANA-

Last Update: 11/01 Priority: High
Initial Proposal: 01/01 Number of pages: 10

Title: DEVELOP COORDINATED MONITORING SCHEME FOR WATER QUALITY IN CANAVERAL NATIONAL SEASHORE AND MOSQUITO LAGOON

Funding Status: Funded: 0% Unfunded: 100%

Servicewide Issues:
Cultural Resource Type:
N-RMAP Program Codes:

Problem Statement

Background

Canaveral National Seashore (CANA), established in 1975, consists of approximately 58,000 acres within the Mosquito Lagoon watershed. The National Aeronautics and Space Administration (NASA) owns approximately 40,000 acres of this park unit, and the U.S. Fish and Wildlife Service manage the majority of this area. Mosquito Lagoon is the northernmost sub-basin of the Indian River Lagoon Estuary along Florida's East Coast. This estuarine system contains the highest species diversity of any estuary in North America (Belanger et al. 1997). Several endangered species (green sea turtle, loggerhead sea turtle, West Indian manatee) occupy this important habitat. Because of its recognized importance as a habitat for aquatic fauna, the Mosquito Lagoon has been included in the National Estuary Program by the EPA.

CANA was established by federal legislation to, "… preserve and protect the outstanding natural, scenic, scientific, ecologic, and historic values of certain lands, shoreline, and waters of the State of Florida, and to provide for public outdoor recreation use and enjoyment of the same…" (Public Law 93-626). This National Park unit represents an excellent example of a relatively stable barrier beach backed by a productive lagoon system. The ecological importance of CANA has also been recognized by the State of Florida, with waters in the park being designated as Outstanding Florida Waters (62-302.700 F.A.C.), the highest level of state protection. Under this designation, ambient water quality must be maintained and protected, and any degradation must be short-term or temporary.

Water Resource Threats

The Mosquito Lagoon sub-basin includes all or part of the following cities: New Smyrna, Edgewater and Oak Hill. The total surface water area of this sub-basin is 37,853 acres, comprising an area almost equivalent to its watershed land area (47% water – 53% land) (Woodward-Clyde 1994b). This basin has one of the largest historic growth rates in the Indian River Lagoon Estuary, increasing 188% between 1970 and 1990. (Woodward-Clyde 1994a).

Industrial and recreational demands on the water resources are also increasing with the expanding population.

The Mosquito Lagoon basin is projected to receive a 58% growth rate by the year 2010. The 1990 population density for the basin was 528 people per square mile (psm), and is projected to be 839 psm by 2010. Since almost 40% of the Mosquito Lagoon watershed is federally owned and unavailable for population growth, the more representative population densities for 1990 and 2010 (estimated) are 851 psm and 1,353 psm, respectively (Woodward-Clyde et al. 1994a).

Research in the Mosquito Lagoon watershed has estimated that 51,203 kg of total nitrogen and 6,625 kg of total phosphorus is delivered annually to Mosquito Lagoon from stormwater runoff. In reviewing water quality data (through 1991), Woodward-Clyde (1994c) reported an elevation in turbidity, color, total suspended solids and chlorophyll *a* near the urbanized area of Edgewater, which could influence the productivity of submerged aquatic vegetation. Elevated heavy metals concentrations have also been reported in some drainage outfalls in this area (Sleister 1989).

Volusia County Public Health Unit identified 15 “problem areas”, containing 20,450 acres, within the Mosquito Lagoon basin, where existing on-site disposal systems (OSDS) threaten the water quality. OSDS consist primarily of private septic tank and drainfield installations. Additionally, another 17,108 acres were termed as “potential problem areas”. The Florida Shores subdivision in Edgewater, located within the Mosquito Lagoon basin, has one of the highest nutrient and BOD loading rates reported in the Indian River Lagoon system. The total nitrogen load in the Mosquito Lagoon basin is expected to increase almost 50% by the year 2010 (Woodward-Clyde 1994c).

Past studies have shown septic systems to be poorly suited for the area due to a high groundwater table, unsuitable soils, and high groundwater seepage rates. In a study to evaluate impacts from an OSDS in the park, monitoring wells down gradient from the septic system that serves CANA’s Ranger Station were found to have significantly ($p < 0.05$) higher mean soluble reactive phosphorus (SRP) concentrations than the up-gradient wells. The high groundwater seepage rate in CANA (avg. = 1251mL/m^2–hr) combined with the elevated SRP concentrations produce high nutrient loading rates for the area (Belanger et al. 1997).

Bacteria contamination has affected shellfishing waters in Mosquito Lagoon (St. Johns River Water Management District and South Florida Water Management District 1993). Mosquito Lagoon is now closed to shellfishing whenever rainfall exceeds 1.5 inches due to elevated bacteria counts (National Park Service 1997).

Disease and contaminant accumulation are present in several species within the waters of the Indian River Lagoon system. Papillomatosis (or fibropapilloma) is a disease of unknown origin, which has appeared in the Lagoon in the last ten years and affects a substantial proportion of the marine turtle population. *Lobo mycosis* is a fungal infection affecting about 10% of the bottlenose dolphin population in the Lagoon. There have been indications that these diseases are connected to water quality (Woodward-Clyde 1994d).

Declines in seagrass and other submerged aquatic vegetation beds have been reported in all Indian River Lagoon sub-basins. The declines are partially attributed to decreases in light penetration in the Indian River Lagoon waters. Factors, which likely influence light penetration, include water color, dissolved solids (i.e. salts), suspended solids (i.e. silts, organic particles), and chlorophyll *a* (Woodward-Clyde 1994e). In one case, color changes, due to tannic acids, were observed to be responsible for seagrass decline (White 1993). Woodward-Clyde (1994b) reported that total Kjeldahl nitrogen, chlorophyll *a* (corrected), color, turbidity, and total suspended solids increased in Mosquito Lagoon during the wet season, which could potentially threaten the Park's aquatic vegetation. The Florida Inland Navigation District is scheduled to dredge the Intracoastal Waterway running along CANA's western boundary within the next few years. This could further impact critical submerged aquatic vegetation habitat in the park, with potential impacts extending through the aquatic food chain.

Adequacy of Current Information

Much information has been and is currently being collected by various agencies on water quality in Mosquito Lagoon. In 1988, the Indian River Lagoon Water Quality Monitoring Network (IRL-WQMN) was established as a coordinated multi-agency project spanning the entire length of the Indian River Lagoon system (Ponce de Leon Inlet to Jupiter Inlet). Initially, under this program, 22 surface water-sampling sites were monitored in Mosquito Lagoon. NASA sampled an additional 11 sites away from major facilities and operational areas once every two months. In 1996, the number of sampling stations was reduced to become more cost effective. However, this information has not been collated, in some cases is not readily obtainable, may not meet NPS criteria and may not address Park management needs.

Without timely and comprehensive water quality information or adequate baseline data, impacts on water resources will remain undetected and changes will be difficult to document. Determining the status of contaminants on water, sediment, and biota of the park would serve as a benchmark for future comparisons and would help to identify problem contaminants and/or sites for possible remedial action. At a minimum, park waters should be in compliance with state water quality standards (surface waters are designated as Class II and OFW, ground waters are designated as Class G-II). A comprehensive water quality monitoring program for surface and subsurface waters is essential to develop adequate baseline information and to determine compliance with water quality standards. This monitoring program should satisfy the following water resource management objectives:

> Manage waters of the Park and water dependent environments in a manner designed to maintain the highest degree of biological diversity and ecosystem integrity;
>
> Acquire sufficient knowledge about water quality to effectively participate in state and local water management planning;
>
> Seek the highest level of protection under state water quality standards appropriate for the Park; and,

Acquire appropriate baseline information to adequately understand and manage water resources and meet National Park Service inventory and monitoring requirements.

Description of Recommended Project or Activity

Utilize a contractor to collate data from the long-term monitoring networks to determine the quality and usefulness of past information as to its value as information (based on techniques employed, etc.) specifically for CANA and then summarize the useful information available. This step includes a review of Park planning documents, with emphasis on CANA's Water Resources Management Plan, and other appropriate literature and an inventory and synthesis of existing data sets and other information on CANA's hydrologic systems. Evaluate monitoring data sets and sampling designs to determine if the monitoring meets Park management needs and provides reliable and credible data. Identify monitoring being conducted by other entities and summarize to help determine where comparable data sets and sampling protocols exist. Identify areas of duplicated effort and gaps in information being gathered.

The immediate objective for CANA is to establish the foundation for a sustainable long-term program for monitoring water quality. The product to accomplish this is a Surface Water and Ground Water Monitoring Issues Overview and Assessment Report for CANA. The following steps will be used to develop this product:

Develop a Surface Water and Ground Water Quality Monitoring Issues Overview and Assessment Report. The purpose of this report is to identify those Park waterbodies, including aquifers, where water quality monitoring is adequate and expose those waterbodies that need to be monitored or warrant modification of existing water quality monitoring. This report will not provide water quality monitoring design details, but rather present results from the synthesis of available information that provides the needed foundation for design of surface water and ground water quality monitoring programs for CANA. Important components of this report are listed below:

Environmental Landscape

Objective: Provide a short overview of relevant aspects of climate, physiography, geology, and atmospheric deposition relative to CANA.

Hydrography

Objective: Provide an overview of the surface water systems within and adjacent to CANA, and define the study area (i.e., park and watershed boundaries are usually not coincident). Use available, appropriately scaled geographic databases for a GIS foundation of park hydrography.

Water Quality Management Issues

Objectives: Obtain additional input and peer review of existing information; define external and internal management activities that influence water quality in CANA; understand the status of

CANA water quality and water quality issues from several perspectives, primarily from Park staff and state water quality monitoring personnel; and determine what water quality monitoring has occurred or that is ongoing that may not be captured by the information sources defined below under the Retrospective Analysis section.

Conduct a Scoping Meeting with Park staff and regional subject matter experts (other federal agency, state, NPS) to identify and prioritize water quality issues relevant to CANA's surface waters and ground waters.

Retrospective Analysis of Available Water Quality Information

Objective: To provide a historical perspective on water quality in CANA and Mosquito Lagoon, identifying strengths and weaknesses of the available information, and to evaluate initial priorities for the design of CANA's water quality monitoring program.

Identify and capture existing information sources relevant to water quality for CANA.

Information sources:

- State Stream Classifications and Associated Water Quality Standards (beneficial uses and water quality criteria): available in state administrative code.

- State Biennial Water Quality Assessment [also known as 305(b) report after the appropriate section of Clean Water Act] and State Impaired Waterbodies List [also known as 303(d) list after the appropriate section of Clean Water Act]: both the Assessment and List are usually available through the applicable website for a state's water quality agency. The water quality assessment is also a good source of information on the state's biological assessment program (i.e. multimetric indexes to track biological integrity).

- NPS-WRD Baseline Water Quality Data Inventory and Analysis Report: Available from CANA, this report presents the results of surface water quality data retrievals for each park from six of the US Environmental Protection Agency's national databases, including STORET, the primary national water quality database management system. The primary goal of these reports is to provide descriptive water quality information consistent with the goals of the NPS Inventory and Monitoring Program and useable by park resource managers. The document provides a complete inventory of all retrieved water quality parameter data, water quality stations, and the entities responsible for the data collection (e.g. the State and U.S. Geological Survey). Several graphics and tables in this report will be useful to the issues overview.

- STORET data retrieval: If new monitoring data have been generated since the publication of the Baseline Water Quality Data Inventory and Analysis Reports and have been uploaded to STORET, then those data should be captured through data retrieval.

- National Water Quality Assessment Program (NAWQA): This US Geological Survey Program describes the status and trends of ground and surface water resources in 59 river basins across the US. In particular this program was designed to assess historical, current and future water quality conditions in respective river basins. CANA is located within the Georgia Florida Coastal Plain NAWQA Study Unit.

- Land use and Permitted Activities within CANA: Park and regional GIS databases should provide some of this needed information, along with local, county, state and/or other federal agencies [e.g. USGS land use and land cover (LULC) data files]. Another source is the NPS-WRD Baseline Water Quality Data Inventory and Analysis Report, which includes GIS-based maps (1:100,000) that locate some of the permitted activities including industrial/municipal facilities discharges and drinking water intakes.

- Superfund Sites: Sites are listed on the National Priorities List (NPL), which is Appendix B of the National Contingency Plan under CERCLA, commonly referred to as the Superfund law. The NPL is readily accessible through the national or many regional US Environmental Protection Agency websites. The NPL is available as a GIS coverage that can be integrated into ARCView.

Analysis and Integration of Information sources:

Information obtained from the above sources should be analyzed, integrated and displayed via various tables and figures with associated text. Examples include:

- Develop land use maps (preferably geo-referenced) that are compatible with CANA hydrography.
- Develop table that lists the CANA surface water and ground water classification types, beneficial uses, and state criteria for protecting these uses. Develop figure that shows locations of these classification types.
- Develop figure based on above table that distinguishes between long-term, active monitoring stations versus long-term, discontinued stations.
- Develop table, cross-referenced to this figure that lists each active, long-term monitoring station, its period of record, the total number of observations taken at each station and the frequency of observations.
- Develop table listing impaired waterbodies in CANA, where are they located (geo-referenced), what are the pollutants or stressors of concern for these impaired waterbodies and what are the impaired beneficial uses.
- Develop figure showing locations of impaired waterbodies, cross-referenced to the above table and associated long-term, active monitoring stations. If possible, also display land uses.
- Develop table listing long-term, active monitoring stations associated with impaired and unimpaired waterbodies and showing the suite of parameters that have been monitored for these waters.
- Develop table that lists the active long-term monitoring stations and compares their water quality data to the applicable water quality criteria. Use protocols defined in CANA's *Baseline Water Quality Data Inventory and Analysis Report*.

- For each active monitoring station associated with an impaired waterbody or special resource water, determine the significance of any existing measures of annual and/or seasonal variability of monitored parameters.

Other:

Identification of other significant surface water quality studies/data not captured in CANA's *Baseline Water Quality Data Inventory and Analysis Report* or uploaded to STORET. Summarize these studies in an abstract-like format and reference database(s)/report(s).

The above analysis will assist in providing answers to the following questions. These questions and answers provide the needed synthesis and interpretation:

For impaired waters [303(d) list]

- What are the land uses (point and nonpoint sources) associated with each impaired waterbody? Are there associated factors (geology, air quality, etc.) that need to be considered?

- Are water quality monitoring stations associated with impaired waterbodies? If so, are these stations extant and what are the monitored parameters and their associated water quality criteria? What parameters have exceeded their associated water quality criteria and what is the frequency of exceedance? Are the monitored parameters adequate to assess the potential impacts of land uses? If not, what parameters should be added or deleted and give rationale, i.e. what suite of land use-specific parameters should be monitored?

- Are there extant monitoring stations, associated with impaired waters, where the network could possibly partner (i.e. cost-share) with the agency performing the monitoring? Are there impaired waters that, based on analysis of water quality data, should not be on the impaired list?

- If there is no water quality station(s) does then the establishment of a monitoring station appear warranted?

<u>For unimpaired waters (including special resource waters)</u>

- What are the land uses (point and nonpoint sources) associated with each unimpaired waterbody? Are there associated factors (geology, air quality, etc.) that need to be considered?

- Are water quality monitoring stations associated with unimpaired waterbodies? If so, are these stations extant and what are the monitored parameters and their associated water quality criteria? What parameters have exceeded their associated water quality criteria and what is the frequency of exceedance? Are the monitored parameters adequate to assess the potential impacts of land use? If not, what parameters should be added or deleted and give, rationale, i.e. what suite of land-use specific parameters should be monitored?

- Are there extant monitoring stations, associated with unimpaired waters, where the network could possibly partner (i.e. cost-share) with the agency performing the monitoring?

- Given the spatial analysis of land uses, are there unimpaired waterbodies that are not being monitored, but should be? What parameters should be considered given the land use? Given the existing land uses and/or available water quality data (and exceedance analyses), are there park waterbodies that are not on the 303(d) list but should be?

How do the water quality issues identified in the Scoping Workshop affect the answers to the above question? Have and/or are the 'most significant waterbodies', identified in the Scoping Meeting(s), been adequately monitored?

<u>Design a Surface Water and Ground Water Quality Monitoring Program.</u> After completion of the overview-assessment report, the next step in the process, which extends beyond this project proposal, will require formulating a design for a long-term water quality monitoring program. Building from the overview-assessment report, this design will be firmly grounded to historical and current water quality monitoring efforts, while addressing the highest-priority water quality issues identified in CANA-Local Agency (e.g., USFWS, KSC, USGS, SJRWMD) Scoping Meeting(s). In the end, a Water Quality Monitoring Plan is to be completed that will include decisions and rationale on location and prioritization of water quality monitoring stations, sampling frequency, parameter selection, methodology, and appropriate QA/QC.

Literature Cited

Belanger, T.V., H.H. Heck, M.S. Andrews, 1997. *Groundwater Flow Characteristics of the Mosquito Lagoon, FL.* Final Report (Draft), Project # CANA-N-027.000, Florida Institute of Technology. 2-3, 40, 67, 86 pp.

National Park Service, 1997. *Resource Management Plan, Canaveral National Seashore*. pp. 39.

St. Johns River Water Management District and South Florida Water Management District, 1993. *Surface Water Improvement and Management (SWIM) Plan for the Indian River Lagoon.* Draft. St. Johns River Water Management District, Palatka, Florida and South Florida Water Management District, West Palm Beach, Florida.

Sleister, R.K., 1989. *Analysis of Heavy Metals in Sediments from Indian River Lagoon/Mosquito Lagoon Stormwater Outfalls.* Environmental Management Department, County of Volusia. Deland, Florida.

White, C.B., 1993. Personal Communication reported in Woodward-Clyde Consultants, et. al., 1994e.

Woodward-Clyde 1994a. *Uses of Indian River Lagoon*. Indian River Lagoon National Estuary Program, Melborne, Florida. 3-8 – 3-10, 4-4 pp.

Woodward-Clyde 1994b. *Preliminary Water and Sediment Quality of the Indian River Lagoon*. Indian River Lagoon National Estuary Program, Melbourne, Florida. 5-6 – 5-7, 8-1 pp.

Woodward-Clyde 1994c. *Loadings Assessment of the Indian River Lagoon.* Indian River Lagoon National Estuary Program, Melbourne, Florida. 2-31 – 2-32, 3-26 pp.

Woodward-Clyde 1994d. *Biological Resources of the Indian River Lagoon*. Indian River Lagoon National Estuary Program, Melbourne, Florida. 7-52 p.

Woodward-Clyde 1994e. *Historical Imagery Inventory and Seagrass Assessment, Indian River Lagoon.* Indian River Lagoon National Estuary Program, Melbourne, Florida. 7-7, 8-2 pp.

Budget and FTEs

FUNDED

Date	Source	Activity	Budget ($1000)	FTEs
FY 1	PKBASE	MGT	2.0	0.2
		Total	**2.0**	**0.2**

UNFUNDED

Date	Source	Activity	Budget ($1000)	FTEs
FY 1	WRD	Contractor + Overhead	17.0	0.5
	WRD	Scoping Meeting Support	3.0	
	WRD	GIS Support	5.0	
		Total	**25.0**	**0.5**

Compliance

The planning and study phases of this project is categorically excluded from NEPA compliance, Department Categorical exclusions, 516DM, Ch. 2, Appendices 1 & 7, U.S. Department of the Interior.

PROJECT STATEMENT #5 CANA-

Last Update:11/01 Priority: High
Initial proposal: 9/01 Number of pages: 5

Title: EVALUATE THE EFFECT OF MOSQUITO IMPOUNDMENT RECONNECTION AND RESTORATION ON AQUATIC BIODIVERSITY IN CANA

Funding Status: Funded: 0% Unfunded: 100%

Servicewide Issues:
Cultural Resource Type:
N-RMAP Program Codes:

Problem Statement

Background

Canaveral National Seashore (CANA) was established in 1975 by federal legislation to, "… preserve and protect the outstanding natural, scenic, scientific, ecologic, and historic values of certain lands, shoreline, and waters of the State of Florida, and to provide for public outdoor recreation use and enjoyment of the same…" (Public Law 93-626). Canaveral National Seashore consists of approximately 58,000 acres within the Mosquito Lagoon watershed. This National Park unit represents an excellent example of a relatively stable barrier beach backed by a productive lagoon system. This estuarine system contains the highest species diversity of any estuary in North America (see references in 1995 special issue of *Bulletin of Marine Science*, Vol. 57) and provides critical habitat for 14 federally listed threatened and endangered species, including green sea turtles, loggerhead turtles, and West Indian manatees. The far-reaching, ecological importance of this area has been demonstrated by the EPA in listing the Indian River Lagoon, including Mosquito Lagoon, as an Estuary of National Significance. Mosquito Lagoon has also been classified by the state of Florida as a Florida Outstanding Waterway and Aquatic Preserve, the highest level of state protection. Under this designation, ambient water quality must be maintained and protected, and any degradation must be short-term or temporary.

History of Mosquito Impoundments in Indian River Lagoon

The importance of wetlands to the Indian River Lagoon ecosystem was not always understood. Seventy-five percent (75%) of the Lagoon's 40,400 acres of wetlands, once dismissed as worthless land, were impounded during the 1950's and 1960's for mosquito control. Mosquitoes require moist exposed substrates for oviposition sites and then subsequent flooding of the area to produce a successful brood. Impoundments are a non-chemical (biological), highly effective method for controlling mosquito reproduction in shallow water areas by creating areas where oviposition cannot occur because these areas are either continuously dry or continuously flooded. However, these impoundments dramatically altered estuarine habitats by removing natural tidal flow and connections between the open waters and the wetlands. Vegetation changes were dramatic, with much loss of high-marsh meadows of *Batis/Salicornia*, *Spartina alterniflora,* and mangrove communities due to flood frequency and salinity (Montague and Wiegert 1990). These plant communities are adapted to fluctuating water levels rather than continuous inundation. Permanent closure of impoundments can also greatly decrease salinity if rainfall replaces saltwater tidal exchange as the main source of water or significantly increase salinity if evaporation creates hypersaline conditions. Some impoundment effects are, however, considered positive. For example, some wading birds preferentially frequent these open water ponds. Some larger fishes requiring "deeper water" habitats may be excluded if ditches are removed (G. Gilmore, pers. comm., NASA, 2001). Overall, however, most researchers agree that the negative impacts of mosquito impoundments (reduced water quality and biodiversity, loss of fish nursery habitats) outweigh their benefits and as a result much effort and money has been recently placed on reconnecting or restoring impoundments (e.g. Brockmeyer et al. 1997).

Restoration of Impoundments

As of May 2001, St. Johns River Water Management District (SJRWMD) had reconnected more than 27,770 of the 40,400 impounded acres to the Lagoon through one of the following management methods:

1) Rotational impoundment management (RIM) involves gated culverts that are installed in the berms of the impounded marshes. Water levels are manipulated by closing the culvert gates for mosquito control approximately four months each year. The structures remain open the remainder of the year.
2) Wildlife aquatic management (WAM) is a technique beneficial to waterfowl and wading birds that preferentially visit open water ponds. Water levels are manipulated 8-10 months of the year via culverts using this strategy.
3) Open management restoration involves digging open culverts or fully restoring the wetlands (see 4). In both cases, water moves freely throughout the area 12 months of the year.
4) Full restoration involves removing the dike from select impoundments by pushing the material back into the adjacent ditch from which it came.

Results of these efforts are encouraging. Water levels in impoundments and the open waters of the Lagoon are similar when the culverts are opened or open management techniques have been employed (R. Brockmeyer, pers. comm., SJRWMD, 2001). SJRWMD staff and other scientists have also documented increased diversity in plants, fish and wildlife in many areas where impoundments have been reconnected to the Lagoon. SJRWMD plans to connect an additional 7000 acres of impounded marshes, including a number within the boundaries of CANA. Collaborations between CANA and SJRWMD on the biological impacts of restoration will provide the timely opportunity to directly quantify aquatic biodiversity within this National Park unit before, during and after restoration. This project will focus on specific groups of organisms and their response (diversity and abundance).

Description of Recommended Project or Activity

Work with SJRWMD to learn types of restorations planned within Park boundaries and when restoration activities will occur. Collaboratively, the two agencies will determine what organisms should be monitored and the best monitoring protocols for the study. This will depend on the location of the restoration activity and dominant, adjacent habitat type(s) (seagrass beds, intertidal oyster reefs, etc.).

Organisms that should be considered in these monitoring efforts include wading birds and waterfowl, juvenile and adult fishes, mobile invertebrates that live amongst submerged aquatic vegetation such as shrimp and crabs, invertebrates that burrow into the mud (polychaete worms, clams, etc.), sessile invertebrates that grow attached to hard surfaces (barnacles, sponges, etc.), marine angiosperms (salt marsh grasses, including *Spartina alterniflora*) and submerged vegetation (seagrasses, macroalgae). Organisms most likely to be significantly impacted by the restoration should be chosen for the study. Federal bioassessment protocols to determine diversity and abundance of these taxa have been established for most of these aquatic groups by the Department of the Interior and The Environmental Protection Agency (Barbour et al. 1999, Gibson et al. 2000). These techniques will be used as appropriate. If needed, experts will be consulted for the remaining groups of flora and fauna.

Biodiversity in Mosquito Lagoon varies dramatically throughout the year. Thus, monitoring should commence a minimum of 6 months prior to the start of restoration activities. Monitoring should then continue at 3-month intervals for 2 years past the completion of impoundment restoration. It is expected that a graduate student can undertake the bulk of this research and the project will be completed within 3 years. At the end of this project, CANA will have data documenting the effects of mosquito impoundment restoration on CANA flora and fauna. Additionally, if species diversity is not restored with one type of restoration (e.g. RIM), then the Park would be in a position to request funding for additional restoration measures (e.g. open culverts or full restoration of the habitat). Costs listed in the budget section of the project statement are for the study of one restored impoundment or a small group of areas that are restored simultaneously in close proximity.

Literature Cited

Barbour, M.T., Gerritsen, J., Snyder, B.D. and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition*. Environmental Protection Agency, Office of Water, EPA-841-B-99-002.

Brockmeyer, R.E., Rey, J.R., Virnstein, R.W., Gilmore, R.G., and L. Earnest. 1997. Rehabilitation of impounded estuarine wetlands by hydrologic reconnection to the Indian River Lagoon, Florida (USA). Wetlands Ecology and Management 4: 93-109.

Gibson, G.R., Bowman, M.L., Gerritsen, J., and B.D. Snyder. 2000. *Estuarine and Coastal Marine Waters: Bioasessment and Biocritera Technical Guidance.* Environmental Protection Agency, Office of Water, EPA-822-B-00-024.

Montague, C.L. and Wiegert, R.G. 1990. Salt marshes. *Ecosystems of Florida*. Myers, R. and Ewel, J. (eds.) University of Central Florida Press. Orlando, Florida.

Budget and FTEs

The following budget reflects use of a graduate student through a Memorandum of Understanding with a university; however, use of a contractor will also be considered.

100% UNFUNDED

YEAR 1

Direct labor:

Graduate student (3 months): $5000
Undergraduate assistant (3 months): $3000
Fringe for graduate student (0.30%): $15
Fringe for undergraduate (0.30%): $9

Supplies: Seines, sieves, sediment coring devices, dip-nets, transect tapes, PVC and PVC glue for quadrats, waterproof paper, binoculars, etc. $2000

Travel (0.29/mile): $600
Boat travel in Mosquito Lagoon: $600

Overhead (Off-campus rate: 26%): $2918

Total for Year 1: $14,142

YEAR 2

Direct labor:

Graduate student (3 months): $5000
Undergraduate assistant (3 months): $3000
Fringe for graduate student (0.30%): $15
Fringe for undergraduate (0.30%): $9

Travel (0.29/mile): $600
Boat travel in Mosquito Lagoon: $600

Overhead (Off-campus rate: 26%): $2398

Total for Year 2: $11,622

YEAR 3

Direct labor:

Graduate student (3 months): $5000
Undergraduate assistant (3 months): $3000
Fringe for graduate student (0.30%): $15

Fringe for undergraduate (0.30%): $9

Travel (0.29/mile): $600
Boat travel in Mosquito Lagoon: $600

Overhead (Off-campus rate: 26%): $2398

Total for Year 3: $11,622

TOTAL FUNDING REQUESTED: $37,386

PROJECT STATEMENT #6 CANA-

Last Update: 11/01 Priority: High
Initial proposal: 6/01 Number of pages: 5

Title: DETERMINE PRIMARY USE AREAS OF THE ENDANGERED WEST INDIAN MANATEE *TRICHECHUS MANATUS LATIROSTRIS* IN CANA WATERS

Funding Status: Funded: 0% Unfunded: 100%

Servicewide Issues:
Cultural Resource Type:
N-RMAP Program Codes:

Problem Statement

CANA was established by federal legislation to, "… preserve and protect the outstanding natural, scenic, scientific, ecologic, and historic values of certain lands, shoreline, and waters of the State of Florida, and to provide for public outdoor recreation use and enjoyment of the same…" (Public Law 93-626). The outstanding natural resources include 14 species which are listed as federally threatened or endangered. One of these is the West Indian manatee (*Trichechus manatus latirostris*) which can be found in Mosquito Lagoon foraging on huge expanses of seagrass during warmer months of the year. At one time, manatees were thought to frequent only the west side of the Lagoon, as they used the Intracoastal Waterway as a travel corridor to move between areas to the north and south. However, frequent sightings by Park staff in recent years show that manatees spend significant amounts of time on the east side of Mosquito Lagoon near the North District boat launch and Eldora State House (CANA Wildlife Observation Cards).

A statewide census in 2001 reported 1520 manatees, approximately 1/2 of Florida's population, along the east coast of Florida (FMRI 2001). While opinions differ on the status of the manatee population, USFWS scientists are concerned that the adult survival rate of the Atlantic population is at best stable (USFWS 2000b). One of the major threats is collisions with watercraft; this has been responsible for an average of 25% of the manatee deaths recorded each year since 1976 (30 percent in 1999) (USFWS 2000b). Factors that make the manatee vulnerable to boat collisions are its large size (up to 3500 pounds) and habit of foraging in shallow water, where the manatee is unable to dive to escape approaching boats (Van Meter 1989). Locally, in the year 2000, 13 of 49 manatee deaths in Brevard County and 3 of 12 deaths in Volusia County were the result of boat collisions (FMRI 2001). These numbers are significant in light of the small population total and low reproductive rate (13 months gestation period; interval between births: 2-5 years). Many living individuals bear scars or wounds from vessel strikes.

Several factors may influence the vulnerability of manatees to boat collisions in Mosquito Lagoon. The Lagoon is quite shallow, averaging less than 1.5 meters in depth (Provancha et al 1992). A boat ramp was constructed in the North District in 1991, which has been heavily utilized. This and other new ramps have contributed to a significant increase in recreational boating activity in Mosquito Lagoon over the past 10 years. As an example, within a three-hour time period in May, 2001, observers at the North District boat ramp sighted 11 manatees, including two mother/calf pairs. During this time, over 25 boats per hour passed through the shallow waters (L. Walters, pers. obs). Boaters may be detouring through the shallower waters of CANA to avoid a five-mile long slow speed zone along the Intracoastal Waterway (ICW).

Although no reported manatee deaths have occurred in CANA as a result of boat contact, such an event is quite possible. Measures to protect manatees such as slow speed zones are highly controversial. The Park needs good science to make management decisions that ensure protection of the manatee in CANA waters. Primary manatee use areas need to be identified, as well as any locations which may pose a high risk of manatee/boat collisions.

Description of Recommended Project or Activity

A three-pronged approach will be used to obtain information on primary manatee use areas. First, data already being collected by several agencies will be collated and plotted onto CANA maps utilizing ArcView software. Second, replicate counts will be made from boat and shore, adding the observations to the maps. Third, to actively involve park visitors in manatee protection, visitors will be given information, including manatee observation cards to be returned to the Park.

For the first objective, collaborations will be established with Florida Marine Research Institute (FMRI), St. Johns River Water Management District, NASA, the USGS Sirenia Project, and Mote Marine Laboratory. The first three agencies regularly fly over CANA waters to collect data on a variety of topics, including manatees. It will be a straightforward task to obtain coordinates from manatee sightings and plot them onto a map of CANA using ArcView. Information will also be requested from USGS Sirenia Project, based in Gainesville. These researchers are responsible for radio-tracking individual manatees on the east coast of Florida and can provide coordinates for sightings. Finally, a working partnership will be established with the manatee photo-identification group at FMRI and Mote Marine Laboratory. Presently, they have records of over one-third of the manatee population. Additionally, trained individuals submit manatee-sighting data on a regular basis. This information will also be incorporated into the CANA manatee database.

While information from other agencies will help identify manatee use areas, their efforts focus on the Intracoastal Waterway and the west side of Mosquito Lagoon. Additional ground level surveys are needed to incorporate pockets of manatee use, particularly along the east side of the Lagoon. Scientists will conduct replicated manatee surveys of Park waters from boats and shore. These surveys will be run twice weekly from May to November, when manatee activity is the highest, and twice a month during the remainder of the calendar year. Trained volunteers will be used to assist with this research. Surveys will last for 1.5 years.

The third approach to determine manatee use in CANA waters will include a significant public outreach component. Informational sheets on manatees will be made available to Park visitors, especially boaters. The sheet will include life history details and information on mortality statistics and manatee-safe boating guidelines. The information will also contain cards to be returned to designated boxes with detailed descriptions of sighted manatees (time, date, location, # of individuals, behaviors, distinctive markings on individuals, adults versus calves, etc.). As appropriate, this data will also be added to the CANA manatee database. More important, this approach should engage visitors, making them more aware and protective of manatees.

Information on areas of greatest boating activity will be obtained from two sources: 1) a boating survey of Mosquito Lagoon being conducted by MINWR, with support from CANA, and 2) data from ground-level observers, mentioned above, who in addition to manatee sightings will record information on number and types of boats.

Boater use information will be compared with data on manatee locations, utilizing ArcView maps and ground level observations, to identify any areas with high potential for manatee/boat collisions. The Park area adjacent to the ICW will be monitored to see if a significant number of boaters are cutting through the Park to avoid a lengthy slow speed zones.

Literature Cited

Florida Marine Research Institute 2001. Web site: http://www.floridamarine.org/.

Provancha, J.A., Hall, C.R. and Oddy, D.M. 1992. *Mosquito Lagoon Environmental Resources Inventory*. NASA Technical Memorandum 107548. The Bionetics Corporation. Kennedy Space Center, Florida.

USFWS 2000b. *Merritt Island National Wildlife Refuge Annual Narrative Report, Calendar Year 1999*. Unpublished. Merritt Island National Wildlife Refuge, Titusville, FL.

Van Meter, V.B. 1989. *The West Indian Manatee in Florida.* Florida Power and Light Company, Miami, FL.

Budget and FTEs:

100% UNFUNDED

The following budget reflects use of a graduate student through a Memorandum of Understanding with a university; however, use of a contractor will also be considered.

Year 1
Direct labor:
- Graduate student (6 months): $7500
- Undergraduate assistant (3 months): $3000
- Faculty advisor for 1 month of summer: $5000
- Fringe for graduate student (0.30%): $23
- Fringe for undergraduate (0.62%): $19

Fringe for faculty (24.55%): $1228

Supplies:

Training materials, informational cards, binoculars, ArcView software, computer disks, clipboards, waterproof paper, etc: $3500

Travel:

Car travel around Florida (@ 0.29/mile): $3000
Boat travel in Mosquito Lagoon (@ 0.29/mile): $2000

Overhead (Off-campus rate: 26%): $6570

Year 1 Total: $31,840

Year 2

Direct Labor:

Graduate student (9 months): $10,500
Undergraduate assistant (3 months): $3250
Faculty advisor for 1 month of summer: $5500
Fringe for graduate student (0.30%): $32
Fringe for undergraduate (0.62%): $20
Fringe for faculty (24.55%): $1350

Supplies:

Training materials, informational cards, computer disks, clipboards, waterproof paper, etc.: $1000

Travel:

Car travel around Florida (@ 0.29/mile): $3000
Boat travel in Mosquito Lagoon (@ 0.29/mile): $3000

Overhead (Off-campus rate: 26%): $7190

Year 2 Total: $34,842

TOTAL FUNDING REQUESTED: **$66,682**

PROJECT STATEMENT #7 CANA-

Last Update:11/01 Priority: High
Initial proposal: 8/01 Number of pages: 4

Title: EVALUATE THE EFFECT OF THE BLUE CRAB FISHERY ON CANA BIODIVERSITY

Funding Status: Funded: 0% Unfunded: 100%

Servicewide Issues:
Cultural Resource Type:
N-RMAP Program Codes:

Problem Statement

Background

Canaveral National Seashore (CANA) consists of approximately 58,000 acres within the Mosquito Lagoon watershed. This National Park unit represents an excellent example of a relatively stable barrier beach backed by a productive lagoon system. This estuarine system contains the highest species diversity of any estuary in North America (see references in 1995 special issue of *Bulletin of Marine Science*, Vol. 57) and provides critical habitat for 14 federally listed threatened and endangered species, including green sea turtles, loggerhead turtles, and West Indian manatees. The far-reaching, ecological importance of this area has been demonstrated by the EPA in listing it as an Estuary of National Significance and by the state of Florida in classifying it as a Florida Outstanding Waterway and Aquatic Preserve, the highest level of state protection. Under this designation, ambient water quality must be maintained and protected, and any degradation must be short-term or temporary.

CANA was established in 1975 by federal legislation to, "… preserve and protect the outstanding natural, scenic, scientific, ecologic, and historic values of certain lands, shoreline, and waters of the State of Florida, and to provide for public outdoor recreation use and enjoyment of the same…" (Public Law 93-626). The blue crab *Callinectes sapidus* plays a major role in the ecology of the Indian River Lagoon because of its widespread occurrence and abundance, broad diet, and importance as prey to numerous other species. Blue crabs are heavily preyed upon by virtually all carnivorous animals large enough to catch and ingest them, including a number of CANA's threatened and endangered species. Loggerhead and Kemp's Ridley sea turtles are known to consume large quantities of blue crabs, as are many wading birds. Among fishes, some of the most significant predators on blue crabs are American eels, catfish, sciaenids (especially the large drums), several types of sharks, and cownose rays. Mammalian predators include dolphins and raccoons.

The blue crab is also an important commercial fisheries species. Harvesting of the blue crab *Callinectes sapidus* existed in Mosquito Lagoon waters long before it became a National Park and crab harvesting has increased significantly in these waters in recent years. Many fishermen switched to crab harvesting after the statewide gill net ban went into effect in 1995. Additionally, the number of out-of-state crabbers fishing in central Florida waters has greatly increased. For example, the number of crab harvesting licenses in Brevard County increased from 257 to 981 between 1987 and 1997 (Noke 1999). During this same period, Volusia County licenses increased from 153 to 450 (Noke 1999). Along the Atlantic coast of Florida, there were 3.5 million traps pulled annually during the period between 1990 and 2000, with an annual harvest averaging 4.5 million pounds (Murphy et al. 2001). From 1998-2000, the highest blue crab landings made on this coast in Florida were made in Brevard County (Murphy et al. 2001). There are no estimates available for the recreational fishery harvest or by-catch, but anecdotal evidence suggests they may be substantial (Murphy et al. 2001). Since *C. sapidus* is listed by the state as a restricted species, commercial harvesters in Florida are subject to regulations concerning crab pot design, marking trap buoys, individual crab sizes, and reproductive status. However, there is no limit on the number of crabs that may be harvested. Recreational harvesters are subject to the same size and reproductive status restrictions as commercial harvesters. Recreational harvesters are also limited to five or fewer traps and 10 gallons of blue crabs per day.

Researchers in Florida disagree about whether the Florida blue crab stock is currently being harvested at rates above maximum sustainable yield. Some suggest overharvesting has occurred, while others suggest that this is not the case (see Murphy et al. 2001 for examples). In order to fulfill its mandate to preserve and protect the ecological value of Mosquito Lagoon, the Park must determine if crabs are being overharvested locally and if any harvesting regulations are warranted.

Description of Recommended Project or Activity

To determine if harvesting of the blue crab *Callinectes sapidus* in CANA waters is occurring in sustainable numbers, two types of data must be collected. First, updated *C. sapidus* population density measures are needed. Second, a better understanding of harvesting levels within the Park is needed to determine how quickly this resource is being removed. Comparing these two amounts will enable researchers to determine if the population is sustainable.

In past IRL studies that involved blue crab ecology, crabbers have allowed researchers to join them on their boats and record catch data (undersized and marketable crabs) (Noke 1999). This method of collection will be used again. A researcher will travel with different fisherman 2-3 times/week for one year recording the number and size of crabs collected within CANA. One hundred larval collectors (submerged air conditioning filters) distributed throughout Mosquito Lagoon waters will also be monitored on a weekly basis to follow densities of the smallest blue crabs recruiting to Mosquito Lagoon (J. Welch, pers. comm., Wittenberg University, 2000). By combining the larval data with the boat-collected data on undersize and harvestable crabs, it will be possible to estimate the density of three size classes of *C. sapidus* in Mosquito Lagoon. The number of harvestable crabs collected on boats plus additional harvest data obtained from the trip ticket data harvesters are required to provide to the Florida Marine Fisheries Information System, will provide an estimate of the rate which crabs are being removed from the system. Using appropriate fisheries models, it will then be possible to calculate if the blue crab population is sustainable or if protective measures should be considered.

Literature Cited

Murphy, M.D., Meyer, C.A. and McMillen-Jackson, A.L. 2001. *A stock assessment for the blue crab, Callinectes sapidus, in Florida waters*. Florida Marine Research Institute, 56 pages.

Noke, W. 1999. *Interactions Between the Indian River Lagoon Blue Crab Fishery and the Bottlenose Dolphin Tursiops truncatus.* Masters Thesis, University of Central Florida.

Budget and FTEs

The following budget reflects use of a graduate student through a Memorandum of Understanding with a university; however, use of a contractor will also be considered.

100% UNFUNDED

YEAR 1

Direct labor:

Graduate student (3 months): $4500
Undergraduate assistant (3 months): $3000
Faculty advisor for 0.5 month of summer: $2500
Fringe for graduate student (0.30%): $14
Fringe for undergraduate (0.30%): $9
Fringe for faculty (24%): $600

Supplies:

Clipboards, waterproof paper, binoculars, stamped postcards, air conditioning filters, buoys, rope, etc. $2000

Travel around Florida (0.29/mile): $2100
Boat travel in Mosquito Lagoon: $3000

Overhead (Off-campus rate: 26%): $4608

Year 1 Total: $22,331

YEAR 2

Direct labor:

Graduate student (9 months): $10,500
Undergraduate assistant (3 months): $3000

Faculty advisor for 0.5 month of summer: $2750
Fringe for graduate student (0.30%): $32
Fringe for undergraduate (0.03%): $9
Fringe for faculty (24.00%): $715

Supplies:
Clipboards, waterproof paper, binoculars, stamped postcards, air conditioning filters, buoys, rope, etc. $2000

Travel around Florida (0.29/mile): $2100
Boat travel in Mosquito Lagoon: $3000

Overhead (Off-campus rate: 26%): $6268

Year 2 Total: $30,374

TOTAL FUNDING REQUESTED: $52,705

PROJECT STATEMENT #8 CANA-

Last Update: 11/01 Priority: High
Initial proposal: 9/01 Number of pages: 5

Title: DETERMINE IMPACT OF BOAT PROPELLER SCARRING ON SEAGRASS BEDS IN CANA WATERS

Funding Status: Funded: 0% Unfunded: 100%

Servicewide Issues:
Cultural Resource Type:
N-RMAP Program Codes:

Problem Statement

Background

Canaveral National Seashore (CANA) consists of approximately 58,000 acres within the Mosquito Lagoon watershed. This National Park unit represents an excellent example of a relatively stable barrier beach backed by a productive lagoon system. This estuarine system contains the highest species diversity of any estuary in North America (see references in 1995 special issue of *Bulletin of Marine Science*, Vol. 57) and provides critical habitat for 14 federally listed threatened and endangered species, including green sea turtles, loggerhead turtles, and West Indian manatees. The far-reaching, ecological importance of this area has been demonstrated by the EPA in listing it as an Estuary of National Significance and by the state of Florida in classifying it as a Florida Outstanding Waterway and Aquatic Preserve, the highest level of state protection. Under this designation, ambient water quality must be maintained and protected, and any degradation must be short-term or temporary.

CANA was established in 1975 by federal legislation to, "… preserve and protect the outstanding natural, scenic, scientific, ecologic, and historic values of certain lands, shoreline, and waters of the State of Florida, and to provide for public outdoor recreation use and enjoyment of the same…" (Public Law 93-626). Boating activity in CANA waters has resulted in propeller scars in many ecologically and economically important seagrass beds. This is primarily due to the shallow nature of the Lagoon (mean depth: 1.5 m). As boating activity within Park boundaries continues to increase, CANA needs to determine: 1) the extent of this problem, 2) if protection of the resource is warranted, and 3) if so, what protective actions should be taken.

Ecology of seagrasses in CANA and their relationship to endangered species

Seagrasses are totally submerged, rooted angiosperms that reproduce sexually by seeds and asexually by vegetative propagation. Seagrass beds are critical to the health of estuaries (e.g. Zieman 1982; Virnstein et al. 1983). They are nursery habitats for many juvenile fish species as well as recruitment and refuge sites for a diversity of benthic invertebrates. Seagrass beds are also responsible for clearing the water of suspended sediments. They act as sediment traps by slowing down currents and taking smaller particles out of suspension.

The Indian River Lagoon system is classified as a seagrass-based ecosystem and seven species of grasses are found in the system (Provancha et al. 1992). This diversity is greater than that of any other estuary in the United States. Within Mosquito Lagoon, the primary grasses are *Halodule wrightii*, *Ruppia maritima* and *Syringodium filiforme*. *Halodule wrightii* (shoal grass) is generally the first seagrass to invade disturbed areas and rapidly forms dense beds (Williams 1990). In terms of succession, *S. filiforme* follows *H. wrightii* in recolonizing disturbed habitats.

Seagrasses have been used as estuarine health indicators in many estuaries around the globe, including the Indian River Lagoon. Thus, various regulatory organizations map and monitor seagrasses in Mosquito Lagoon and CANA on an on-going basis (SJRWMD, NASA). Seagrass coverage distributions vary widely throughout Mosquito Lagoon. The southern reaches of Mosquito Lagoon (SJRWMD sections: ML2, ML3-4) boast some of the most extensive coverage in the IRL, with approximately 758 acres of seagrass per linear mile of Lagoon. This southern reach has lost only 12.5% of seagrass coverage since 1943. However, the northern portion of Mosquito Lagoon (SJRWMD: ML1) has seen some of the greatest loss of seagrass acreage in the IRL system; a 97% loss of seagrass has occurred here since 1943 (Steward et al. in prep.).

The endangered West Indian manatee (*Trichechus manatus latirostris*) and endangered, juvenile green turtles (*Chelonia mydas*) can be found in CANA waters. Seagrasses generally form the largest component of the manatee's diet in most areas throughout their coastal range in Florida and the Caribbean (e.g. Thayer et al. 1984), and individuals feed on both the shoots above the sediments and the rhizome-root biomass below the sediment surface (Smith 1993). To help promote survival of these two endangered species, CANA must ensure that seagrass beds are both productive and sustainable.

<u>Seagrass scarring</u>

The productivity and diversity of estuaries in the southeastern United States are threatened by explosive coastal population growth and associated recreational development and utilization. One major area of recreational growth at CANA has been the number of people with Class A (< 16 feet) and Class 1 (16-25 feet) motorboats utilizing Park waterways. Associated with this increase in boating activity is the number of seagrass beds with visible signs of scarring in shallow waters. Anchors or propellers from small boats cause the most common type of scarring to seagrasses from small boats. However, larger craft, which are usually confined to deeper waters, may have much larger individual effects when they run aground (Sargent et al. 1995). The recent development of flats boats has allowed boaters to motor in shallow water grass beds that were previously inaccessible. The popularity of fishing for redfish on grass flats using motorized vessels has increased use of these areas.

Scarring occurs when propellers damage seagrass beds by ripping up a path of shoots and rhizomes and exposing bottom sediments. Recovery and re-growth of seagrasses from such damage can take months to years (Durako et al. 1992). Durako et al. (1992) found that 0.9 to 1.8

years was required for recovery of *Halodule wrightii* in experimental prop scars. Extensive scarring exposes the beds to further disruption from storms and other natural erosional forces, thereby increasing cumulative loss. Also, resuspension of sediments into the water column further contributes to habitat loss by inhibiting future growth of seagrasses and smothering associated organisms, such as juvenile oysters.

Previous statewide research by FMRI in the early-middle 1990's involved aerial surveys and characterization of seagrass bed scarring intensity (Sargent et al. 1995). Nearly all shallow seagrass beds in Florida had some level of propeller damage, with severe scarring visible within CANA boundaries. This report provides a basis for further, more refined research of areas subject to high levels of boat traffic as well as management agendas to reduce this problem.

Coastal zone managers in Biscayne National Park (south Florida) and Galveston Bay, Texas are among the leaders in using management techniques to reduce recreational boating impacts on seagrass beds. In both areas, multifaceted approaches have been applied. At Biscayne National Park, they consider the best tool for seagrass protection to be education on: 1) the ecological and economic importance of seagrass beds, and 2) how best to get out of the seagrass bed without causing further damage if a grounding occurs. Other important protection measures, including more and better navigational aids (especially in narrow channels), limiting powerboat access in certain sensitive areas, reporting of vessel groundings, and more effectively enforcing existing laws are being used to protect seagrass beds. Replanting of seagrass in scars by volunteers also speeds recovery as does lining the scarred areas with stakes to attract birds that will then fertilize these areas.

Description of Recommended Project or Activity

CANA needs to determine the present extent of seagrass scarring within its boundaries and identify areas most at risk to propeller scar damage. St. Johns River Water Management District (SJRWMD) flies over CANA waters annually to access seagrass distribution in the Indian River Lagoon system. Unfortunately, these 1:24,000 scale aerial photographs do not provide sufficient detail to observe scarring. Lower altitude photos are needed. A CANA-sponsored researcher will photograph CANA seagrass beds twice per year. From the photos, new and recovering scars can be mapped onto CANA ArcView overlays that can be readily updated. Ground-truthing from boats will also be needed, especially in monitoring recovery.

If areas are found where persistent damage is evident, protection strategies will be evaluated. Other coastal managers, charged with protecting seagrass beds throughout the United States, will be consulted to determine what protocols will be most effective for CANA. Possible actions to examine include posting navigational aids, boater education and establishment of no-propeller zones. Any efforts to protect seagrass beds in and near the jointly managed portions of Mosquito Lagoon will be coordinated with Merritt Island National Wildlife Refuge.

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Budget and FTEs

The following budget reflects use of a graduate student through a Memorandum of Understanding with a university; however, use of a contractor will also be considered.

100% UNFUNDED

YEAR 1

Direct labor:

Graduate student (3 months): $5000
Undergraduate assistant (3 months): $3000
Faculty advisor for 0.5 month of summer: $2500
Fringe for graduate student (0.30%): $15
Fringe for undergraduate (0.30%): $9
Fringe for faculty (24.00%): $600

Supplies: ArcView software, zip disks, waterproof paper, DGPS unit, etc. $2500
Aerial photography (6 trips): $6000

Travel (0.29/mile): $1000
Boat travel in Mosquito Lagoon: $1500

Overhead (Off-campus rate: 26%): $5752

TOTAL FUNDING REQUESTED: $27,876

PROJECT STATEMENT #9 CANA-

Last Update:11/01 Priority: High
Initial proposal: 9/01 Number of pages: 3

Title: DETERMINE IF CRITICAL FINFISH SPAWNING AND JUVENILE NURSERY AREAS REQUIRE ADDITIONAL PROTECTION

Funding Status: Funded: 0% Unfunded: 100%

Servicewide Issues:
Cultural Resource Type:
N-RMAP Program Codes:

Problem Statement

Mosquito Lagoon, within Canaveral National Seashore, is part of the most diverse estuary in the United States. The 40,000-acre Lagoon has been designated an Outstanding Florida Water, and has been included in the EPA National Estuary Program, along with the remainder of the Indian River Lagoon system. This estuarine system contains the highest species diversity of any estuary in North America (see references in 1995 special issue of *Bulletin of Marine Science*, Vol. 57) and provides critical habitat for 14 federally listed threatened and endangered species, including green sea turtles, loggerhead turtles, and West Indian manatees. It also is home to over 788 fish species and supports a multi-million dollar commercial and recreational fisheries, including clams, oysters, crabs, sea trout, redfish and shrimp. Mosquito Lagoon is one of only two known locations in the United States where spawning of redfish, weakfish, spotted sea trout, black drum and silver perch occurs. It is also the only known estuarine system where redfish and weakfish spend their entire life-cycles. Dr. Grant Gilmore (NASA) recently located the primary spawning locations for several fish species in CANA waters. Additionally, his group has examined the boundaries and predictability of nursery zones for these species.

CANA was established in 1975 by federal legislation to, "… preserve and protect the outstanding natural, scenic, scientific, ecologic, and historic values of certain lands, shoreline, and waters of the State of Florida, and to provide for public outdoor recreation use and enjoyment of the same…" (Public Law 93-626). Recreational boating activity in CANA waters has increased dramatically as Mosquito Lagoon's reputation as a recreational fishery has gained national recognition. Boaters can access the Lagoon 24 hours a day from CANA ramps, municipal ramps and private slips. Thousands more boats annually pass through CANA on the Intercoastal Waterway, which runs adjacent to and inside the Park. Flats boats now regularly run into shallow seagrass areas, which were formerly considered inaccessible, in an attempt to flush out schools of fish, especially redfish. This activity may be disturbing critical spawning and juvenile nursery grounds for spotted sea trout and silver perch, as well as disturbing schools of other foraging fish (G. Gilmore, pers. comm., NASA, 2001). Local fishing clubs and environmental groups have contacted CANA requesting that restrictions be implemented to protect these critical habitats. The United States Fish and Wildlife Service, who manages the southern portion of Mosquito Lagoon, is presently considering such options as push-pole or trolling motor only zones, catch and release zones and seasonal closures in select areas (USFWS 2001). As boating activity within Park boundaries continues to increase, CANA needs to determine if current management practices are adequate to protect significant spawning and juvenile nursery areas.

Approximately 70% of the world's major fisheries are either fully exploited, depleted or recovering from depletion (Garcia and Newton 1998). In the United States, overfishing and habitat degradation have decimated many fish populations and thousands of jobs and millions of dollars in revenue have been lost as a result. Fishing in Mosquito Lagoon waters is outstanding, particularly for redfish which has gained national prominence (R. Day, pers. comm., IRLNEP, 2001). CANA must continuously evaluate current threats and trends, and take appropriate actions if necessary, to ensure it stays this way.

Description of Recommended Project or Activity

Organize a workshop with representatives from Florida Fish and Wildlife Conservation Commission, SJRWMD, MINWR, IRLNEP, Dr. Grant Gilmore and other renown fisheries biologists to evaluate the sustainability of the Mosquito Lagoon fishery and the vulnerability of identified spawning and nursery areas to anthropogenic disturbances. If this group determines that specific areas are potentially threatened based on existing data, then the group will explore management options and/or determine what types of additional research is needed to ensure protection of Mosquito Lagoon's outstanding fishery.

Literature Cited

Garcia, S. and C. Newton. 1998. Global trends in fisheries management. Amer. Fish. Soc. Monogr.

Budget and FTEs

100% UNFUNDED

YEAR 1

Direct Labor: One CANA employee working at 0.15 FTE for two months to organize Mosquito Lagoon fisheries workshop.

PROJECT STATEMENT #10 CANA-

Last Update:11/01 Priority: High
Initial proposal: 6/01 Number of pages: 3

Title: COMPLETE SPILL CONTINGENCY PLANNING AND REGULATED WASTE MANAGEMENT PLAN

Funding Status: Funded: 0% Unfunded: 100%

Servicewide Issues:
Cultural Resource Type:
N-RMAP Program Codes:

Problem Statement

Canaveral National Seashore (CANA), established in 1975, consists of approximately 58,000 acres within the Mosquito Lagoon watershed. The National Aeronautics and Space Administration (NASA) owns approximately 40,000 acres of this park unit, and the U.S. Fish and Wildlife Service manage the majority of this area. Mosquito Lagoon is the northernmost sub-basin of the Indian River Lagoon (IRL) estuary along Florida's East Coast. This estuarine system contains the highest species diversity of any estuary in North America (Belanger et. al. 1997). Several endangered species (green sea turtle, loggerhead sea turtle, West Indian manatee) occupy this important habitat. Because of its recognized importance as a habitat for aquatic fauna, the Mosquito Lagoon has been included in the National Estuary Program by the EPA.

CANA was established by federal legislation to, "… preserve and protect the outstanding natural, scenic, scientific, ecologic, and historic values of certain lands, shoreline, and waters of the State of Florida, and to provide for public outdoor recreation use and enjoyment of the same…" (Public Law 93-626). This National Park unit represents an excellent example of a relatively stable barrier beach backed by a productive lagoon system. The ecological importance of CANA has also been recognized by the State of Florida, with waters in the park being designated as Outstanding Florida Waters (62-302.700 F.A.C.), the highest level of state protection. Under this designation, ambient water quality must be maintained and protected, and any degradation must be short-term or temporary.

Hazardous waste spills have the potential to adversely affect CANA's water resources. Three major transportation routes are found adjacent to CANA's boundary. Located along the National Seashore's western boundary is the Intercoastal Waterway (ICW) and U.S. Highway 1. The former is heavily trafficked by large numbers of vessels (large and small) and the latter is heavily traveled by motorists and large cargo trucks. Materials transported by trucks along this highway include fuel oil, gasoline, and a variety of agricultural and industrial chemicals. Several miles off CANA's eastern coastal boundary are the shipping lanes that are common transportation routes for large vessels. Hazardous materials are associated with these vessels, include both fuels to power the ships and the actual payload being transported for delivery. With these active transportation routes in proximity to CANA, accidental spills of toxic materials will always threaten the National Seashore's water resources.

CANA has two maintenance facilities, one located outside the NPS boundary and one located inside the boundary. These facilities store regulated materials that require specific storage and disposal procedures. The facility inside the boundary includes a very large, above-ground petroleum storage tank for NPS fueling needs. CANA has completed a Standard Operating Procedure (SOP) for flammable liquids storage, however the potential for accidental releases still exists.

The NPS is severely limited in qualified personnel and spill response equipment to effectively respond to hazardous waste spills in CANA. However, expert assistance is available from KSC to the south and Volusia County to the north. Based upon the existing communication process that is currently in place, a release of hazardous material into environments south of North District Parking Area #4 should first be reported to KSC. North of Parking Area #4, reports of hazardous waste releases should first be directed to Florida's Bureau of Emergency Response (FBER) [24-hr contact: 1-850-413-9911 or 1-800-320-0519]. FBER will contact the U.S. Coast Guard if coastal environments are affected in a spill. The FBER can provide incident assessment, identify hazards, and immediate actions to contain a release. Response objectives include containment, site stabilization, source removal, technical assistance, damage assessment, sampling, analysis, waste disposal and cost recovery. The NPS Regional Office (Southeast Region) should also be contacted (NPS Southeast Regional Environmental Officer: 1-404-331-4524) if a spill threatens any of CANA's natural resources.

In addition to the FBER, an Environmental Emergency Response Team (EERT) was formed in 1997 to provide technical assistance to the Volusia County Hazardous Material Team. The purpose of the EERT is to minimize the environmental impacts resulting from hazardous and non-hazardous material incidents. This response team is also available 24-hours per day, 7 days a week.

A specific communication process (i.e., Spill Prevention Control and Countermeasure (SPCC) Plan) should be established by CANA so designated park staff can request assistance from qualified federal, state, county, and/or private contractor personnel in a time-efficient manner. The plan should also include an inventory of regulated materials being used, environmental compliance procedures, best management practices and routine inspection procedures.

Description of Recommended Project or Activity

Complete a Spill Prevention Control and Countermeasure (SPCC) Plan as required by 40 CFR 112.

Literature Cited

Belanger, T., Heck, H., Andrews, M. 1997. *Groundwater Flow Characteristics of the Mosquito Lagoon, FL (Draft)*. NPS Project No. CANA-N-027.000. Florida Institute of Technology. Melbourne, Florida.

Budget and FTEs:

Direct Labor: 0.12 FTE
Cost: $3000

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APPENDICES

APPENDIX A

PARAMETER	FDER GROUND WATER POTABLE WATER STANDARDS	FDER SURFACE WATER QUALITY CLASSIFICATIONS CLASS I POTABLE	CLASS II SHELLFISH	CLASS III RECREATION FISH AND WILDLIFE	CLASS IV AGRICULTURAL	CLASS V INDUSTRIAL
Aldrin- Dieldrin		0.003 µg/l	0.003 µg/l	0.003 µg/l		
Alkalinity		20 mg/l min. as CaCO		20 mg/l min. as CaCO (fresh)	600 mg/l max. as CaCO	
Aluminum			1.5 mg/l	1.5 mg/l (marine) 0.02 mg/l (fresh)		
Ammonia, Un-ionized		0.02 mg/l				
Antimony			0.2 mg/l	0.2 mg/l (marine)		
Arsenic	0.05 mg/l (P)	0.05 mg/l	0.05 mg/l	0.05 mg/l	0.05 mg/l	0.05 mg/l
Bacteriological Quality	Total Coliform 4/100 ml (P)	1000/100 ml mean; 200/100 ml mean fecal	70/100 ml median; 14/100 ml median fecal	1000/100 ml mean; 200/100 ml mean fecal		
Barium	1 mg/l (P)	1 mg/l				
Benzene	1 µg/l (P)					
Beryllium		0.011 mg/l soft 1.10 mg/l hard		0.011 mg/l soft 1.10 mg/l hard (fresh)	0.1 mg/l soft 0.5 mg/l hard	
Biological Intergrity		min. 75% of Diversity Index	min. 75% of Diversity Index	min. 75% of Diversity Index		

APPENDIX A

PARAMETER	FDER GROUND WATER POTABLE WATER STANDARDS	FDER SURFACE WATER QUALITY CLASSIFICATIONS CLASS I POTABLE	CLASS II SHELLFISH	CLASS III RECREATION FISH AND WILDLIFE	CLASS IV AGRICULTURAL	CLASS V INDUSTRIAL
Boron					0.75 mg/l	
Bromine & Bromates			0.1 mg/l free bromine, 100 mg/l bromates	0.1 mg/l free bromine, 100 mg/l bromate (marine)		
Cadmium	0.010 mg/l (P)	0.0008 mg/l soft 0.0012 mg/l hard	0.005 mg/l	0.0008 mg/l soft (fresh) 0.0012 mg/l hard (fresh) 0.005 mg/l (marine)		
Carbon Tetra-chloride	3 µg/l (P)					
Chlordane		0.01 µg/l	0.004 µg/l	0.01 µg/l (fresh) 0.004 µg/l (marine)		
Chlorides	250 mg/l (S)	250 mg/l	10% above background	10% above back-ground (marine)		10% above back-ground (marine)
Chlorine, Residual		0.01 mg/l	0.01 mg/l	0.01 mg/l		
Chromium	0.05 mg/l (P)	0.05 mg/l total	0.05 mg/l total	0.05 mg/l total	0.05 mg/l total	0.05 mg/l total
Color	15 color units (S)	no nuisance conditions	no nuisance conditions	no nuisance conditions	suitable for use	no nuisance conditions

APPENDIX A

	FDER GROUND WATER	FDER SURFACE WATER QUALITY CLASSIFICATIONS				
PARAMETER	POTABLE WATER STANDARDS	CLASS I POTABLE	CLASS II SHELLFISH	CLASS III RECREATION FISH AND WILDLIFE	CLASS IV AGRICULTURAL	CLASS V INDUSTRIAL
Copper	1 mg/l (S)	0.03 mg/l	0.015 mg/l	0.03 mg/l (fresh) 0.015 mg/l (marine)	0.05 mg/l	0.05 mg/l
Corrosivity	Non-corrosive (S)					
Cyanide		0.005 mg/l	0.005 mg/l	0.005 mg/l	0.005 mg/l	0.005 mg/l
2,4 – D		100 μg/l (P)				
DDT		0.001 μg/l	0.001 μg/l	0.001 μg/l		
Demeton		0.1 μg/l	0.1 μg/l	0.01 μg/l		
1,2 Dichloro-ethane	3 μg/l (P)					
Detergents		0.5 μg/l	0.5 μg/l	0.5 μg/l	0.5 μg/l	0.5 μg/l
Dissolved Solids	500 mg/l (S) (total)	500 mg/l mo. avg 1000 mg/l max.				
Endosulfan		0.003 μg/l	0.001 μg/l	0.003 μg/l (fresh) 0.001 μg/l (marine)		
Endrin	0.2 μg/l (P)	0.004 μg/l	0.004 μg/l	0.004 μg/l		
Ethylene Dibromide	0.02 μg/l (P)					
Fluorides	1.4-2.4 mg/l	1.5 mg/l	1.5 mg/l	5.0 mg/l (marine) 10.0 mg/l as fluoride ion	10.0 mg/l as fluoride ion	10.0 mg/l as fluoride ion

APPENDIX A

PARAMETER	FDER GROUNDED WATER: POTABLE WATER STANDARDS	FDER SURFACE WATER QUALITY CLASSIFICATIONS: CLASS I POTABLE	CLASS II SHELLFISH	CLASS III RECREATION FISH AND WILDLIFE	CLASS IV AGRICULTURE	CLASS V INDUSTRIAL
Foaming Agents	0.5 mg/l (S)					
Guthion		0.01 μg/l	0.01 μg/l	0.01 μg/l		
Heptachlor		0.001 μg/l	0.001 μg/l	0.001 μg/l		
Iron	0.3 mg/l (S)	0.3 mg/l	0.3 mg/l	1.0 mg/l (fresh) 0.3 mg/l (marine)	1.0 μg/l	
Lead	0.05 mg/l (P)	0.03 mg/l	0.05 mg/l	0.03 mg/l (fresh)	0.05 mg/l	0.05 mg/l
Lindane	4 μg/l (P)	0.01 μg/l	0.004 μg/l	0.01 μg/l (fresh) 0.004 μg/l (marine)		
Malathion		0.1 μg/l	0.1 μg/l	0.1 μg/l		
Manganese	0.05 mg/l (S)		0.1 mg/l			
Mercury	0.002 mg/l (P)	0.0002 mg/l	0.0001 mg/l	0.0002 mg/l (fresh) 0.0001 mg/l (marine)	0.0002 mg/l	0.0002 mg/l
Methoxy-Chlor	100 μg/l (P)	0.03 μg/l	0.03 μg/l	0.03 μg/l		
Mirex		0.001 μg/l	0.001 μg/l	0.001 μg/l		
Nickel		0.1 mg/l	0.1 mg/l	0.1 mg/l	0.1 mg/l	
Nitrates (as N)	10 mg/l (P)	10 mg/l				
Nitrogen Total (as N)				See 17-3.011(11)		

APPENDIX A

PARAMETER	FDER GROUND WATER POTABLE WATER STANDARDS	FDER SURFACE WATER QUALITY CLASSIFICATIONS CLASS I POTABLE	CLASS II SHELLFISH	CLASS III RECREATION FISH AND WILDLIFE	CLASS IV AGRICULTURAL	CLASS V INDUSTRIAL
Nutrients		varies	varies	varies	discharge limited	discharge limited
Odor	threshold odor number 3 (S)	no nuisance conditions	threshold odor number 24	no nuisance conditions	suitable for use	suitable for use
Oils & Grease		5.0 mg/l; no taste or odor	5.0 mg/l; no taste or odor	5.0 mg/l; no taste or odor	5.0 mg/l; no taste or odor	5.0 mg/l no taste or odor
Parathion		0.04 µg/l	0.04 µg/l	0.04 µg/l		
pH	6.5 minimum (S)	1 unit variation 6.9-8.5	1 unit variation 6.5-8.5	1 unit variation 6.0-8.5 (fresh) 6.5-8.5 (marine)	1 unit variation 6.0-8.5	5.0-9.5
Phenolic Compounds		0.001 mg/l	0.001 mg/l	0.001 mg/l	0.001 mg/l	0.001 mg/l
Phosphorus Elemental			0.0001 mg/l	0.0001 mg/l (marine)		
Phosphorus Total (as P)				See 17-3.011(11)		
Phthalate Esters		0.003 mg/l		0.003 mg/l (fresh)		
PCBs		0.001 µg/l	0.001 µg/l	0.001 µg/l		
Radioactive Substances	Ra: 5 pCi/l (P) a: 15 pCi/l	Ra: 5 pCi/l a: 15 pCi/l	Ra: 5 pCi/l a: 15 pCi/l	Ra: 5 pCi/l a: 15 pCi/l	Ra: 5 pCi/l a: 15 pCi/l	Ra: 5 pCi/l a: 15 pCi/l
Selenium	0.01 mg/l	0.01 mg/l	0.025 mg/l	0.025 mg/l		

APPENDIX A

PARAMETER	FDER GROUND WATER POTABLE WATER STANDARDS	FDER SURFACE WATER QUALITY CLASSIFICATIONS CLASS I POTABLE	CLASS II SHELLFISH	CLASS III RECREATION FISH AND WILDLIFE	CLASS IV AGRICULTURAL	CLASS V INDUSTRIAL
Silver	0.05 mg/l	0.00007 mg/l	0.000005 mg/l	0.00007 mg/l (fresh) 0.00005 mg/l (marine)		
Sodium	160 mg/l					
Specific Conductance		varies	varies	varies	varies	varies
Sulfates	250 mg/l (S)					
Suspended Solids 2,4,5- TP	10 μg/l (P)	10 μg/l				
Temperature		no nuisance conditions	no nuisance conditions	no nuisance conditions	no nuisance conditions	no nuisance conditions
Tetrachloro-ethylene	3 μg/l (P)					
Total Dissolved Gases		110% of satura-tion value	110% of satura-tion value	110% of satura-tion value		
Toxaphene	5 μg/l (P)	0.005 μg/l	0.005 μg/l	0.005 μg/l		
Transparency		min. 90% of background	min. 90% of background	min. 90% of background		
1,1,1-Trichoroethane	200 μg/l (P)					

APPENDIX A

	FDER GROUND WATER	FDER SURFACE WATER QUALITY CLASSIFICATIONS				
PARAMETER	POTABLE WATER STANDARDS	CLASS I POTABLE	CLASS II SHELLFISH	CLASS III RECREATION FISH AND WILDLIFE	CLASS IV AGRICULTURAL	CLASS V INDUSTRIAL
Trichloro-ethylene	3 µg/l (P)					
Trihalomethanes	0.10 mg/l (P)					
Turbidity	1 NTU month av. 5 NTU 2-day av. (P)	29 NTU above background	29 NTU above background	29 NTU above background	29 NTU above background	29 NTU above background
Vinyl Chloride	1 µg/l (P)					
Zinc	5 mg/l (S)	0.03 mg/l	1.0 mg/l	0.03 mg/l (fresh)	1.0 mg/l	1.0 mg/l

[1] Actual standards are more complex than numbers displayed in chart (see Chapter 17-3 F.A.C.)
[2] These values are based on 6000 samples from 94 lake, stream, and estuary sampling stations collected from 1974-1982 by FDER. The first value is the tenth percentile, the second value is the median, and the last value is the ninetieth percentile.
(P) Primary Drinking Water Standard
(S) Secondary Drinking Water Standard

Appendix B

** USGS HYDROLOGIC UNIT: 03080202 EAST COAST, MIDDLE
SURFACE WATER QUALITY DATA FOR 1980-1995
MEDIAN VALUES FOR EACH WATERSHED
SCREENING LEVEL EXCEEDENCES (*)
CURRENT PERIOD OF RECORD (1990-1995) USED WHERE AVAILABLE
PERIOD PRIOR TO 1990 IS EVALUATED AS HISTORICAL INFORMATION

INDEX	GOOD	FAIR	POOR
WQI-RIVER	0-44	45-59	60-90
TSI-ESTUARY	0-49	50-59	60-100
TSI-LAKE	0-59	60-69	70-100

WATERSHED ID	NAME	WATERSHED DATA RECORD MAX #OBS	BEG YR	END YR	DATA PERIOD	WATER CLARITY TURB*	TSS*	SD	COLOR	DISSOLVED OXYGEN DO*	DOSAT	OXYGEN DEMAND BOD*	COD*	TOC*	PH ALKALINITY PH	ALK	TROPHIC STATUS NITRO*	PHOS*	CHLA*	COLIFORM BACTERIA TOTAL*	FECL*	COND COND	WATER QUALITY INDICES WQI	TSI
* WATER BODY TYPE: ESTUARY																								
7	GOAT CREEK	44	90	92	Current	5.4	8	0.5	60	5.5	67	6.0	.	8	7.3	.	1.15	0.08*	7	.	.	23700	.	58
8	INDIAN R. AB SEB INLET	394	90	95	Current	3.5	11	1.0	20	6.6	76	1.9	.	17	8.0	171	0.98	0.04	5	.	.	31140	.	46
13	TURKEY CREEK	284	90	95	Current	5.7	14	0.7	50	6.0	68	2.1	.	7	7.5	.	1.10	0.07*	18	.	.	17370	.	57
19	CRANE CREEK	188	90	92	Current	5.9	22	0.9	28	5.2	65	2.4	.	2	7.8	143	1.26*	0.12*	16	.	118	10300	.	60
20	INDIAN R. AB MELB CSWY	224	90	95	Current	3.3	12	1.5	20	6.3	80	3.0	.	10	8.0	106	1.24*	0.07	18	30	1	39280	.	55
22	EAU GALLIE RIVER	156	90	94	Current	5.6	22	0.8	28	6.1	72	3.0	.	8	7.9	121	1.37*	0.10*	19	.	.	26000	.	62
25	INDIAN R. AB MELB CSWY	193	90	90	Current	3.0	9	1.3	13	7.1	85	.	.	.	8.1	.	1.23*	0.05	13	.	.	.	.	55
27	NEWFOUND HARBOR	115	90	93	Current	4.8	27	1.1	24	7.0	79	3.1	.	.	8.3	.	1.65*	0.04	10	.	.	.	.	58
28	BANANA R. AB 520 CSWY	22	92	95	Current	5.5	6	1.1	39	8.0	85	2.7	.	13	7.8	124	1.45*	0.05	10	.	.	34803	.	58
29	SYKES CREEK/BARGE CAN.	268	90	93	Current	2.9	22	1.0	28	7.1	86	2.7	.	.	8.2	.	1.38*	0.04	14	.	.	.	.	56
30	INDIAN R. AB 520 CSWY	156	90	95	Current	5.4	13	1.2	15	6.5	72	3.0	.	12	7.9	111	1.41*	0.06	11	.	.	34550	.	57
31	BANANA R. AB BARGE CAN	98	81	87	Historical	2.3	4	0.6	18	6.7	80	1.9	.	.	8.4	138	1.27*	0.04	8	.	1	44600	.	48
33	INDIAN R. AB NASA CSWY	73	90	90	Current	3.4	10	1.7	18	7.2	82	.	.	.	8.3	.	1.21	0.03	15	.	.	.	.	57
34	INDIAN R. AB H. BREWER	46	90	95	Current	3.7	13	1.6	19	6.3	77	2.5	.	12	8.0	127	1.21	0.04	7	15	5	42375	.	50
35	MOSQUITO LAGOON	153	90	95	Current	4.7	10	1.1	12	6.3	71	.	.	7	8.0	127	1.06	0.04	6	4	3	48625	.	49
37	MOSQUITO LAGOON	3235	90	95	Current	6.1	13	1.0	13	6.2	72	2.1	.	7	7.9	118	0.92	0.06	7	13	5	50490	.	50
* WATER BODY TYPE: STREAM																								
4	TROUT CREEK	4	85	87	Historical	1.7	5	0.5	80	3.9*	47	0.7	.	.	7.2	107	0.81	0.05	1	.	.	1679	35	.
6	KID CREEK	4	87	87	Historical	1.6	1	0.7	60	3.6*	41	0.6	.	.	7.1	112	0.68	0.04	0	.	.	1300	36	.
9	LITTLE TURKEY CREEK	15	88	88	Historical	13.5*	7	.	208	4.9	58	1.2	.	15	7.4	.	0.70	0.08	.	.	.	810	37	.
10	DRAINED FARMLAND	86	91	92	Current	4.7	4	1.2	53	5.6	61	.	.	13	6.9	177	1.12	0.03	2	80	30	1185	36	.
18	CRANE CREEK	83	91	95	Current	4.9	6	0.7	150	5.2	63	.	.	15	7.1	193	1.18	0.13	0	1350*	1300*	714	61	.
23	HORSE CREEK	122	90	94	Current	3.1	4	0.6	85	4.0*	67	1.6	.	14	6.9	.	0.91	0.06	2	.	.	2325	59	.

LEGEND:
ALK-ALKALINITY MG/L
BEG YR-BEGINNING SAMPLING YEAR
BOD-BIOCHEMICAL OXY DEMAND MG/L
CHLA-CHLOROPHYLL UG/L
COD-CHEMICAL OXY DEMAND MG/L
COLOR-COLOR PCU
COND-CONDUCTIVITY UMHOS
DO-DISSOLVED OXYGEN MG/L
DOSAT-DO % SATURATION
END YR-ENDING YEAR
FECL-FECAL COLIFORM MPN/100ML
MAX #OBS-MAXIMUM NUMBER OF SAMPLES
NITRO-TOTAL NITROGEN MG/L
PH-PH STANDARD UNITS
PHOS-TOTAL PHOSPHORUS MG/L
SD-SECCHI DISC METERS
TOC-TOTAL ORGANIC CARBON MG/L
TOTAL-TOTAL COLIFORM MPN/100ML
TSI-TROPHIC STATE INDEX
TSS-TOTAL SUSPENDED SOLIDS MG/L
TURB-TURBIDITY NTU/L
WQI-WATER QUALITY INDEX

(*) SCREENING LEVELS ARE PRESENTED IN TABLE 10, INTRODUCTION AND METHODS; '*'=EXCEEDS SCREENING CRITERIA

BIOLOGY MONITORING ASSESSMENT

** USGS HYDROLOGIC UNIT : 03080202 EAST COAST, MIDDLE

BIOLOGY DATA ASSESSMENT

WATERSHED INFORMATION		OVERALL RATING	HESTER DENDY DIVERSITY INDEX*	TAXA*	#OBS	PONAR DREDGE DIVERSITY INDEX*	TAXA*	#OBS	EKMAN DREDGE DIVERSITY INDEX*	TAXA*	#OBS	PHYTOPLANKTON DIVERSITY INDEX*	TAXA*	#OBS	DATA RECORD BEG YEAR	END YEAR	ECOREGION STREAM BIOASSESSMENT OVERALL RATING	STREAM CONDITION INDEX RATING SUMMER 1992	WINTER 1993	SUMMER 1993	WINTER 1994	SUMMER 1994	BIOREGION
*WATER BODY TYPE: ESTUARY																							
8	INDIAN R. AB SEB INLET	GOOD	.	.	0	3.28	28.25	8	.	.	0	.	.	0	1983	1987							
20	INDIAN R. AB MELB CSWY	FAIR	.	.	0	1.50*	15.50	8	.	.	0	.	.	0	1983	1987							
25	INDIAN R. AB MELB CSWY	FAIR	.	.	0	1.32*	11.50	4	.	.	0	.	.	0	1983	1987							
26	BANANA R. NL MATHERS	GOOD	.	.	0	2.18	30.00	4	.	.	0	.	.	0	1983	1987							
27	NEWFOUND HARBOR	GOOD	.	.	0	2.34	27.50	4	.	.	0	.	.	0	1983	1987							
28	BANANA R. AB 520 CSWY		.	.	0	.	.	0	2.96	14.00	1	.	.	0	1983	1987							
30	INDIAN R. AB 520 CSWY	GOOD	1.16	19.50	3	3.43	21.00	3	3.64	26.67	6	.	.	0	1974	1976							
31	BANANA R. AB BARGE CAN	GOOD	.	.	0	3.47	28.00	8	.	.	0	.	.	0	1973	1986							
33	INDIAN R. AB NASA CSWY	FAIR	.	.	0	1.83*	22.00	7	.	.	0	.	.	0	1983	1987							
34	INDIAN R. AB H. BREWER	GOOD	.	.	0	3.07	16.50	4	.	.	0	.	.	3	1983	1987							
35	MOSQUITO LAGOON	FAIR	.	.	0	2.60	19.50	4	.	.	0	.	.	0	1983	1987							
37	MOSQUITO LAGOON	FAIR	.	.	0	2.67	15.50	8	.	.	0	.	.	0	1983	1987							
											0			0	1978	1987							

LEGEND: '*' INDICATES THAT THE DATA VALUE EXCEEDS POOR WATER QUALITY ASSESSMENT CRITERIA

Appendix C

http://tlhdwf2.dep.state.fl.us/ambient/triennial/stats/sjcstats.htm

St. Johns River Reporting Unit C - Surficial Aquifer System Background Network Summary Statistics 1994-1997

Parameter	Units	# of Grid Cells	# of Wells	Minimum Value	Lower Quartile	Median Value	Upper Quartile	Maximum Value
Oxygen, Dissolved, Field	mg/L	22	28	0.08	0.14	0.3	0.49	4.32
Specific Conductance, Field	uS/cm	30	43	85	149.5	256	455	5523
Temperature	°C	30	43	10.6	22.6	23.375	24.1	27.15
pH, Field	s.u.	30	43	4.13	5.505	5.97	6.395	7.31
Alkalinity, Dissolved (as CaCO3)	mg/L	29	40	<1	22.3	64	144.2	220
Calcium, Dissolved	mg/L	30	43	0.9	9.2	31.45	62	247
Chloride, Dissolved	mg/L	29	40	5.3	10.65	19	33	1600
Fluoride, Dissolved	mg/L	29	40	<0.1	<0.1	<0.1	0.1	0.27
Magnesium, Dissolved	mg/L	30	43	0.71	1.36	2.32	7.58	109
Organic Carbon, Total	mg/L	30	43	<1	3.7	9.4	13	46
Potassium, Dissolved	mg/L	30	43	0.3	0.59	0.985	1.98	46
Sodium, Dissolved	mg/L	30	43	2.31	6.835	15	21	910
Sulfate, Dissolved	mg/L	29	40	<0.2	2	12	24	510
Sulfide, Total	mg/L	28	38	<0.2	<0.2	0.215	0.595	8
Turbidity	ntu	28	39	0.55	10.5	38.75	107.5	850
Aluminum, Dissolved	ug/L	30	42	<30	38.75	69	204.5	654
Aluminum, Total	ug/L	30	43	<70	430	919	2425	68800
Antimony, Total	ug/L	30	43	<4	<4	<4	<4	<4
Arsenic, Total	ug/L	30	43	<4	<4	<4	<4	9.6
Barium, Dissolved	ug/L	30	43	3.2	9.95	16.75	33	123
Barium, Total	ug/L	30	43	4.2	13	23.95	56.4	190
Beryllium, Total	ug/L	30	43	<1	<1	<1	<1	1
Cadmium, Total	ug/L	30	43	<1	<1	<1	<1	11.3
Chromium, Total	ug/L	30	43	<5	<5	<5	5.8	78.1
Copper, Dissolved	ug/L	30	43	<10	<10	<10	<10	<10
Copper, Total	ug/L	30	43	<20	<20	<20	<20	60
Iron, Dissolved	ug/L	30	43	1.5	244	919.5	4350	35000
Iron, Total	ug/L	30	43	38	722	1657.5	10400	155000
Lead, Dissolved	ug/L	30	42	<2	<2	<2	<2	2.15
Lead, Total	ug/L	30	43	<1	1.18	6.2325	35.7	591
Manganese, Dissolved	ug/L	30	43	<1	11	17.75	79	889
Manganese, Total	ug/L	30	43	2	11	22.5	83	2110
Mercury, Total	ug/L	30	43	<0.1	<0.1	<0.1	<0.1	1.6
Nickel, Total	ug/L	30	43	<10	<10	<10	<10	45
Selenium, Total	ug/L	30	43	<1	<1	<1	<1	16
Silver, Total	ug/L	30	43	<1	<1	<1	<1	<1
Strontium, Dissolved	ug/L	30	43	18	40	82	310	16400
Strontium, Total	ug/L	30	43	18	57	184.5	347	7610
Thallium, Total	ug/L	30	43	<3	<3	<3	<3	<3

Vanadium, Total	ug/L	30	43	<8	<8	<8	<8	31
Zinc, Dissolved	ug/L	30	43	<4	5	17	48	1668.5
Zinc, Total	ug/L	30	43	<20	<20	<20	33.5	5100
Ammonia+Organic Nitrogen, Dissolved	mg/L	28	39	<0.06	0.2875	0.465	0.91	1.9
Ammonia, Dissolved (as N)	mg/L	29	42	<0.01	0.0925	0.21	0.405	1.3
Nitrate+Nitrite, Dissolved (as N)	mg/L	29	42	<0.02	<0.02	0.026	0.047	1.3755
Orthophosphate, Dissolved (as P)	mg/L	28	41	<0.02	0.0243	0.0435	0.0775	0.243
Phosphorus, Dissolved (as P)	mg/L	30	42	<0.004	0.03	0.0505	0.08	0.335
Silica, Dissolved	mg/L	28	39	0.4	4.65	8.7	11.975	50

St. Johns River Reporting Unit C - Intermediate Aquifer System Background Network Summary Statistics 1994-1997

Parameter	Units	# of Grid Cells	# of Wells	Minimum Value	Lower Quartile	Median Value	Upper Quartile	Maximum Value
Oxygen, Dissolved, Field	mg/L	18	22	<0.03	0.06	0.14	0.19	4.6
Specific Conductance, Field	uS/cm	19	26	271	507.5	613	1329	6110
Temperature	°C	19	26	11.9	22.85	23.2	23.95	25.2
pH, Field	s.u.	19	26	6.06	6.9575	7.13	7.42	8.4
Alkalinity, Dissolved (as CaCO3)	mg/L	18	21	115.5	140	196	265	302
Calcium, Dissolved	mg/L	19	26	33	61.775	100	133	194.5
Chloride, Dissolved	mg/L	18	21	6.9	11	26.15	340	1800
Fluoride, Dissolved	mg/L	18	21	<0.1	0.1	0.1575	0.2	0.67
Magnesium, Dissolved	mg/L	19	26	1.41	5.13	7.375	17.5	94.3
Organic Carbon, Total	mg/L	18	25	1.2	3.5	4.95	9.7	12
Potassium, Dissolved	mg/L	19	26	0.72	1.14	2.4	6.26	38.6
Sodium, Dissolved	mg/L	19	26	4.4	10.3325	31	70.8	1100
Sulfate, Dissolved	mg/L	18	21	<0.2	0.49	2.3	29	270
Sulfide, Total	mg/L	16	19	<0.05	<0.05	<0.05	0.1463	3
Turbidity	ntu	17	20	1	4.7	5.9	26	330
Aluminum, Dissolved	ug/L	19	25	<40	<40	<40	<40	1500
Aluminum, Total	ug/L	19	26	<150	<150	<150	580.5	7400
Antimony, Total	ug/L	18	25	<4	<4	<4	<4	<4
Arsenic, Total	ug/L	19	26	<20	<20	<20	<20	<20
Barium, Dissolved	ug/L	19	26	3.3	10.35	18.6	31.4	79
Barium, Total	ug/L	19	26	3.3	10.65	22.9	34.3	170
Beryllium, Total	ug/L	18	25	<2	<2	<2	<2	<2
Cadmium, Total	ug/L	19	26	<1	<1	<1	<1	<1
Chromium, Total	ug/L	19	26	<20	<20	<20	<20	<20
Copper, Dissolved	ug/L	19	26	<10	<10	<10	<10	<10
Copper, Total	ug/L	19	26	<10	<10	<10	<10	<10
Iron, Dissolved	ug/L	19	26	3	40.5	220	506.5	1800
Iron, Total	ug/L	19	26	55	456.5	940	1940	19600
Lead, Dissolved	ug/L	18	24	<2	<2	<2	<2	5
Lead, Total	ug/L	19	26	<1	<1	2.01	7.855	121
Manganese, Dissolved	ug/L	19	26	<1	8.5	15	29	180
Manganese, Total	ug/L	19	26	6.25	13.25	25	31	220
Mercury, Total	ug/L	19	26	<0.1	<0.1	<0.1	<0.1	<0.1

Nickel, Total	ug/L	19	26	<40	<40	<40	<40	<40
Selenium, Total	ug/L	19	26	<10	<10	<10	<10	<10
Silver, Total	ug/L	19	26	<1	<1	<1	<1	<1
Strontium, Dissolved	ug/L	19	26	141	326	754	1710	13900
Strontium, Total	ug/L	19	26	157	423.5	742	1535	13500
Thallium, Total	ug/L	18	25	<0.2	<0.2	<0.2	<0.2	<0.2
Vanadium, Total	ug/L	18	25	<10	<10	<10	<10	30
Zinc, Dissolved	ug/L	19	26	<4	<4	10	14	275
Zinc, Total	ug/L	19	26	<40	<40	<40	<40	8360
Ammonia+Organic Nitrogen, Dissolved	mg/L	17	20	<0.06	0.36	0.67	0.835	2.2
Ammonia, Dissolved (as N)	mg/L	19	26	<0.01	0.225	0.5	0.7	1.8
Nitrate+Nitrite, Dissolved (as N)	mg/L	19	26	<0.02	<0.02	<0.02	0.045	1.1
Orthophosphate, Dissolved (as P)	mg/L	18	22	0.007	0.045	0.13	0.27	1.3
Phosphorus, Dissolved (as P)	mg/L	18	24	<0.02	0.0555	0.155	0.3	9.7
Silica, Dissolved	mg/L	17	20	9.7	14	16.6	30	71

St. Johns River Reporting Unit C - Floridan Aquifer System Background Network Summary Statistics 1994-1997

Parameter	Units	# of Grid Cells	# of Wells	Minimum Value	Lower Quartile	Median Value	Upper Quartile	Maximum Value
Oxygen, Dissolved, Field	mg/L	29	55	0.04	0.08	0.115	0.25	2.02
Specific Conductance, Field	uS/cm	29	58	163	325	613	865	5725
Temperature	°C	29	58	21.6	22.8	23.55	24.3	28.2
pH, Field	s.u.	29	58	6.43	7.15	7.35	7.71	8.21
Alkalinity, Dissolved (as CaCO3)	mg/L	26	55	71.8	112.5	136	168	334
Calcium, Dissolved	mg/L	29	58	21.2	39.3	52.6	69.5	209
Chloride, Dissolved	mg/L	26	55	5.15	9.8	23	121	1700
Fluoride, Dissolved	mg/L	26	55	<0.1	<0.1	0.1675	0.285	0.83
Magnesium, Dissolved	mg/L	29	58	2.4	7.75	10.515	17.115	117
Organic Carbon, Total	mg/L	29	58	<1	1.4	2.6	3.75	11
Potassium, Dissolved	mg/L	29	58	0.5	1	1.5	3.06	26
Sodium, Dissolved	mg/L	29	58	4.06	7.5	26	69.795	810
Sulfate, Dissolved	mg/L	26	55	<0.2	1.56	7.1	70	510
Sulfide, Total	mg/L	26	55	<0.05	<0.05	0.1638	1.1625	8.2
Turbidity	ntu	26	55	<0.3	0.475	1.7	9.9	29
Aluminum, Dissolved	ug/L	29	55	<40	<40	<40	<40	<40
Aluminum, Total	ug/L	29	58	<300	<300	<300	<300	388
Antimony, Total	ug/L	29	58	<4	<4	<4	<4	<4
Arsenic, Total	ug/L	29	58	<20	<20	<20	<20	<20
Barium, Dissolved	ug/L	29	58	2.7	7.85	12.3	26.8	140
Barium, Total	ug/L	29	58	2.4	7.4	16.8	30.1	151
Beryllium, Total	ug/L	29	58	<3	<3	<3	<3	<3
Cadmium, Total	ug/L	29	58	<1	<1	<1	<1	<1
Chromium, Total	ug/L	29	58	<20	<20	<20	<20	<20
Copper, Dissolved	ug/L	29	58	<10	<10	<10	<10	<10
Copper, Total	ug/L	29	58	<20	<20	<20	<20	82.8
Iron, Dissolved	ug/L	29	58	<6	8	29	130	2201.5

Iron, Total	ug/L	29	58	<20	46	323	1310	9700
Lead, Dissolved	ug/L	29	53	<2	<2	<2	<2	<2
Lead, Total	ug/L	29	58	<2	<2	<2	2.88	102.23
Manganese, Dissolved	ug/L	29	58	<2	2.5	6	11	37.5
Manganese, Total	ug/L	29	58	<10	<10	<10	14	170
Mercury, Total	ug/L	29	58	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel, Total	ug/L	29	58	<40	<40	<40	<40	<40
Selenium, Total	ug/L	29	58	<10	<10	<10	<10	16
Silver, Total	ug/L	29	58	<1	<1	<1	<1	<1
Strontium, Dissolved	ug/L	29	58	31	181	670	1200	6985
Strontium, Total	ug/L	29	58	28	250	601	1220	9760
Thallium, Total	ug/L	29	58	<3	<3	<3	<3	<3
Vanadium, Total	ug/L	29	58	<20	<20	<20	<20	<20
Zinc, Dissolved	ug/L	29	58	<4	<4	7	24	50
Zinc, Total	ug/L	29	58	<40	<40	<40	<40	1240
Ammonia+Organic Nitrogen, Dissolved	mg/L	28	55	<0.1	0.16	0.3725	0.63	1.2
Ammonia, Dissolved (as N)	mg/L	28	57	<0.01	0.0902	0.295	0.4745	0.96
Nitrate+Nitrite, Dissolved (as N)	mg/L	28	57	<0.02	<0.02	<0.02	0.02	0.32
Orthophosphate, Dissolved (as P)	mg/L	28	57	<0.02	<0.02	0.04	0.1093	0.19
Phosphorus, Dissolved (as P)	mg/L	28	57	<0.02	<0.02	0.0523	0.1128	0.22
Silica, Dissolved	mg/L	28	55	5.2	10	12.5	16	38

APPENDIX D

Family Carcharhinidae

Carcharhinus leucas	bull shark
Carcharhinus limbatus	blacktip shark
Carcharhinus plumbeus	sandbar shark
Negaprion brevirostris	lemon shark

Family Sphyrnidae

Sphyrna lewini	scalloped hammerhead

Family Pristidae

Pristis pectinata	smalltooth sawfish

Family Dasyatidae

Dasyatis americana	southern stingray
Dasyatis sabina	Atlantic stingray
Dasyatis sayi	bluntnose stingray
Gymnura micrura	smooth butterfly ray

Family Myliobatidae

Aetobatus narinari	spotted eagle ray
Rhinoptera bonasus	cownose ray

Family Lepisosteidae

Lepisosteus platyrhincus	Florida gar

Family Amiidae

Amia calva	bowfin

Family Elopidae

Elops saurus	ladyfish
Megalops atlanticus	tarpon

Family Albulidae

Albula vulpes	bonefish

Family Anguillidae

Anguilla rostrata	American eel

Family Ophichthidae

Myrophis punctatus	speckled worm eel
Ophichthus gomesi	shrimp eel

Family Clupeidae

Brevoortia smithi	yellowfin menhaden
Brevoortia tyrannus	Atlantic menhaden
Dorosoma cepedianum	gizzard shad
Harengula jaguana	scaled sardine
Opisthonema oglinum	Atlantic thread herring

Family Engraulidae

Anchoa cubana	Cuban anchovy
Anchoa hepsetus	striped anchovy

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Anchoa mitchilli	bay anchovy
Anchoa nasuta	longnose anchovy
Family Synodontidae	
Synodus foetens	inshore lizardfish
Family Cyprinidae	
Notemigonus crysoleucas	golden shiner
Family Catostomidae	
Erimyzon sucetta	lake chubsucker
Family Ictaluridae	
Ictalurus natalis	yellow bullhead
Family Ariidae	
Arius felis	hardhead catfish
Bagre marinus	gafftopsail catfish
Family Batrachoididae	
Opsanus tau	oyster toadfish
Family Gobiesocidae	
Gobiesox strumosus	skilletfish
Family Ophidiidae	
Ophidion marginatum	striped cusk-eel
Family Exocoetidae	
Cypselurus melanurus	Atlantic flyingfish
Hyporhamphus unifasciatus	halfbeak
Family Belonidae	
Strongylura marina	Atlantic needlefish
Strongylura notata	redfin needlefish
Strongylura timucu	timucu
Family Cyprinodontidae	
Cyprinodon variegatus	sheepshead minnow
Floridichthys carpio	goldspotted killifish
Fundulus chrysotus	golden topminnow
Fundulus confluentus	marsh killifish
Fundulus grandis	gulf killifish
Fundulus heteroclitus	mummichog
Fundulus seminolis	Seminole killifish
Fundulus similis	longnose killifish
Jordanella floridae	flagfish
Lucania goodei	bluefin killifish
Lucania parva	rainwater killifish
Family Poeciliidae	
Gambusia affinis	mosquitofish
Heterandria formosa	least killifish
Poecilia latipinna	sailfin molly

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Family Atherinidae

Membras martinica	rough silverside
Menidia beryllina	inland silverside
Menidia peninsulae	tidewater silverside

Family Syngnathidae

Hippocampus erectus	lined seahorse
Hippocampus zosterae	dwarf seahorse
Syngnathus louisianae	chain pipefish
Syngnathus scovelli	gulf pipefish

Family Centropomidae

Centropomus undecimalis	snook

Family Serranidae

Cetropristis philadelphica	rock sea bass
Mycteroperca microlepis	gag

Family Centrarchidae

Lepomis gulosus	warmouth
Lepomis macrochirus	bluegill
Lepomis marginatus	dollar sunfish
Lepomis microlophus	redear sunfish
Lepomis punctatus	spotted sunfish
Micropterus salmoides	largemouth bass
Pomoxis nigromaculatus	black crappie

Family Pomatomidae

Pomatomus saltatrix	bluefish

Family Echeneidae

Echeneis naucrates	sharksucker
Echeneis neucratoides	whitefin sharksucker

Family Carangidae

Caranx crysos	blue runner
Caranx hippos	crevalle jack
Caranx latus	horse-eye jack
Chloroscombrus chrysurus	Atlantic bumper
Oligoplites saurus	leatherjacket
Selene setapinnis	Atlantic moonfish
Selene vomer	lookdown
Trachinotus carolinus	Florida pompano
Trachinotus falcatus	permit

Family Lutjanidae

Lutjanus griseus	gray snapper

Family Lobotidae

Lobotes surinamensis	tripletail

Family Gerreidae

Diapterus auratus	Irish pompano
Diapterus plumieri	striped mojarra

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Eucinostomus argenteus	spotfin mojarra
Eucinostomus gula	silver jenny
Family Haemulidae	
Orthopristis chrysoptera	pigfish
Family Sparidae	
Archosargus probatocephalus	sheepshead
Lagodon rhomboides	pinfish
Family Sciaenidae	
Bairdiella chrysoura	silver perch
Cynoscion nebulosus	spotted seatrout
Cynoscion regalis	weakfish
Leiostomus xanthurus	spot
Menticirrhus americanus	southern kingfish
Micropogonias undulatus	Atlantic croaker
Pogonias cromis	black drum
Sciaenops ocellata	red drum
Family Ephippidae	
Chaetodipterus faber	Atlantic spadefish
Family Scaridae	
Nicholsina usta	emerald parrotfish
Family Mugilidae	
Mugil cephalus	striped mullet
Mugil curema	white mullet
Family Sphyraenidae	
Sphyraena barracuda	great barracuda
Sphyraena borealis	northern sennet
Family Uranoscopidae	
Astroscopus y-graecum	southern stargazer
Family Blenniidae	
Chasmodes saburrae	Florida blenny
Hypleurochilus geminatus	crested blenny
Family Eleotridae	
Dormitator maculatus	fat sleeper
Family Gobiidae	
Bathygobius soporator	frillfin goby
Evarthodus lyricus	lyre goby
Gobioides broussoneti	violet goby
Gobionellus boleosoma	darter goby
Gobionellus oceanicus	highfin goby
Gobionellus smaragdus	emerald goby
Gobiosoma bosci	naked goby
Gobiosoma robustum	code goby
Microgobius gulosus	clown goby