Freshwater Flow and Ecological Relationships in Biscayne Bay

Contract No. C-15967-WO04-06

Prepared For:

South Florida Water Management District

Protector of the Everglades since 1949

Prepared By:

BFA Environmental Consultants

Barnes, Ferland and Associates, Inc.

In Association With:

ATM Applied Technology & Management, Inc

Lewis Environmental Services, Inc.

January 2004

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Prepared for:

SOUTH FLORIDA WATER MANAGEMENT DISTRICT
WEST PALM BEACH, FLORIDA

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EXECUTIVE SUMMARY

The State of Florida has adopted regulations, which require that Water Management Districts identify priority water bodies, establish Minimum Flows and Levels (MFLs) rules for these water bodies and implement these MFLs through water shortage plans and/or the water use permitting process. Specifically, Biscayne Bay has been identified as a priority water body in which an MFL rule is to be developed by the South Florida Water Management District (SFWMD or the District) by December 2004.

As one component of the effort to develop an MFL rule for Biscayne Bay, the SFWMD issued a work order to undertake a study entitled, *Freshwater Flow and Ecological Relationships in Biscayne Bay*. SFWMD entered into an agreement (Contract No. C-15967-WO04-06) with the consultant team of Barnes, Ferland and Associates, Applied Technology Management, Inc. and Lewis Environmental Services, Inc. to conduct a variety of activities which will assist the District in developing the MFL rule for Biscayne Bay.

The work conducted by the project team involves the following five tasks:

1) Developing a Project Work Plan
2) Conducting a Literature Search and Data Review
3) Contacting and Interviewing Experts
4) Evaluating Alternative Approaches for District MFL Development
5) Addressing/summarizing Information and Information Needs

Tasks 1-4 have been completed and the resulting deliverables for each task were transmitted to the District for review and comment. Questions raised by the District have been addressed, and the Appendices to this report contain the final deliverables for each Task. This document, the Task 5 report, builds on the results of the previous tasks and also includes summaries of pertinent portions of the previously completed tasks.

This project has sought to establish a scientific connection between various methods to establish MFLs for Biscayne Bay, and indicators of conditions in the Bay. The recommended over-all process has been to apply numerical rankings to potential indicator species and potential MFL approaches in order to determine the most appropriate approach for each of six sub-regions of the Bay. This is necessary due to the Bay being a large heterogeneous ecosystem that has undergone major anthropogenic changes in the last 100 years. Each of the six identified sub-regions has unique characteristics that demand unique treatment regarding necessary freshwater flows to either maintain existing conditions, or restore some semblance of historical conditions to allow for a particular ecological function to exist at some level that is acceptable to water managers, citizens and scientists.

Table ES-1 shows the highest rated (and therefore recommended) approach(es) for each sub-region, as summarized below:

Oleta River/Snake Creek: The recommended approach (**Indicator Species)** rated highest at 22 with a range of values from 6-22; the indicator species being the American oyster, West Indian Manatee and Johnson's seagrass.

Northern Biscayne Bay: The recommended approach (**Indicator Species)** rated highest at 22 with a range of values from 6-22; the indicator species being the spotted seatrout and manatee grass.

Miami River/Government Cut: The recommended approach (**Community Index)** rated highest at 20 with a range of values from 5-20. This approach utilizes a biodiversity index similar to that developed by Berkely and Campos (1984) for the Bay.

Central Biscayne Bay: The recommended approaches (**Indicator Species** and **Valued Ecosystem Component)** both rated highest at 22 with a range of values from 5-22. The **Indicator Species** approach was judged the better of the two by the principal scientists, and the species chosen were pink shrimp and shoal grass.

South-Central Biscayne Bay: The recommended approach (**Valued Ecosystem Component)** rated highest at 22 with a range of values from 5-22; the VEC being a sustainable pink shrimp harvest.

Southern Biscayne Bay: The recommended approach **(Food Web Support)** rated highest at 26 with a range of values from 5-26. The intent is that the forage fish food base be sustained to support: (1) nesting productivity for the Roseate Spoonbill (and several other wading bird species) and (2) high survival of first year juveniles of the American crocodile, as the target reference points.

Table ES-1

Comparison of the Relative Strength of Scientific Support for the Different MFL Approaches for Each Sub-region

POTENTIAL APPROACHES	Sub-Region					
	Oleta River Snake Creek	Northern Biscayne Bay	Miami River Gov't Cut	Central Biscayne Bay	South-Central Biscayne Bay	Southern Biscayne Bay
Valued Ecosystem Component(s)	18	18	16	22	22	16
Indicator Species	22	22	15	22	21	16
Presence/Absence/Vitality of Preferred Habitats	17	17	17	12	12	13
Ecological Preservation	14	14	8	15	15	15
Pre-development Scenario	6	6	5	5	5	5
Requirement for preferred fish communities	14	15	11	10	10	10
Community Index	12	12	20	12	12	12
Food Web Support	12	12	5	12	12	26
Soil Characteristics	12	12	6	12	12	12
Relative Strength of Scientific Support (0-5)	2	3	2	2	2	4

Shaded bocks indicate the recommended approach for each sub-region, based on it receiving the highest ranking.
It is important to note that these values represent a composite of multiple factors (see Appendix E).

SECTION 1 INTRODUCTION

PROJECT BACKGROUND

The State of Florida has adopted regulations (Section 373.042 Florida Statutes), which require that Water Management Districts identify priority water bodies, establish Minimum Flows and Levels (MFLs) rules for these water bodies and implement these MFLs through water shortage plans and/or the water use permitting process. Specifically, Biscayne Bay has been identified as a priority water body in which MFLs are to be developed by the South Florida Water Management District (SFWMD or the District) by December, 2004.

The rules pursuant to which Minimum Flows and Levels are adopted are contained in Chapter 40E-8, Florida Administrative Code. This chapter includes definitions of several terms which identify the purpose of MFLs and which are the basis for developing MFL rules for any specific water body. These include:

> *Minimum Flows* for Biscayne Bay are the limit "at which further freshwater withdrawals would be significantly harmful to the water resources or the ecology of the area".
>
> *Significant harm* is defined as "the temporary loss of water resource function, which results from a change in surface or ground water hydrology, that takes more than two years to recover, but which is considered less severe than serious harm".
>
> *Serious harm* means "the long term loss of water resource functions, as defined in Chapters 40E-21 and 40E-22 F.A.C., resulting from a change in surface or ground water hydrology".

Chapter 40E-8.011 identifies that minimum flows "are established to identify where further withdrawals would cause significant harm to the water resources, or to the ecology of the area, and that MFLs are to be established based on existing best available data." In general, it is not the goal of MFLs to address recovery strategies for ecosystems which may be experiencing harm at the time of adoption of an MFL rule. However, in Biscayne Bay, which is a part of the greater Everglades Ecosystem, there is an acknowledgment that portions of the Bay are in a degraded state, and that the MFL project for Biscayne Bay will need to interact with other past, existing and ongoing projects that are intended to facilitate ecosystem recovery, including:

- Comprehensive Everglades Restoration Plan (CERP);
- RECOVER;
- Biscayne Bay Coastal Wetlands Project;
- Surface Water Improvement & Management Plan (SWIM)
- Lower East Coast Regional Water Supply Plan

The objectives of these projects are to restore degraded conditions; whereas the MFL project is designed to prevent significant harm. Adopted MFLs will be revisited periodically.

As one component of the effort to develop an MFL rule for Biscayne Bay, the SFWMD issued a work order to undertake a study entitled, *Freshwater Flow and Ecological Relationships in Biscayne Bay*. SFWMD entered into an agreement (Contract No. C-15967-WO04-06) with the consultant team of Barnes, Ferland and Associates, Applied Technology Management, Inc. and Lewis Environmental Services, Inc. to conduct a variety of activities, which will assist the District in developing the MFL rule for Biscayne Bay.

PURPOSE AND SCOPE

The overall objectives of this project are to assist District staff in identifying significant harm and with developing the technical criteria for the Biscayne Bay MFLs, by:

1) Performing an intensive review and documentation of existing literature and information to determine the technical relationships among freshwater flow, salinity and watershed/estuary hydrodynamics that impact key indicator biological communities or species present throughout Biscayne Bay;

2) Identifying various technical approaches that have been used (or are being used) to develop MFL rules for other estuaries in Florida; and recommending the approach(es) that are most appropriate for Biscayne Bay; and

3) Identifying the criteria and/or conditions, which will signal significant harm.

Results of this study may be applied to meet the goal of protecting natural resources from significant harm, together with consideration of comments and suggestions that are expected to be offered by various stakeholders during the future public input component of the MFL rule development process.

The work conducted by the project team involves the following five tasks:

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2) Conducting a Literature Search and Data Review
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Tasks 1-4 have been completed and the resulting deliverables for each task have been transmitted to the District for review and comment. Questions raised by the District have been addressed, and the Appendices to this report contain the final deliverables for each Task. This document, the Task 5 report, which builds on the results of the previous tasks, also includes summaries of pertinent portions of the previously completed tasks.

RELATIONSHIPS OF SALINITY, ECOSYSTEMS AND POTENTIAL HARM

An estuary is a dynamic ecoregion where saltwater from the ocean meets freshwater from the watershed. Biscayne Bay supports a wide variety of estuarine plants and animals, some of which are important for recreational and/or commercial fisheries. Several rare, threatened and endangered species also inhabit this estuarine ecosystem, including manatees and crocodiles.

Marine and estuarine communities are affected by event related salinity changes and long term salinity shifts. Salinity affects these communities by being too high or too low or too variable. Biscayne Bay is a fragile ecosystem that relies on a balance of freshwater delivered in the proper amounts, with the proper timing, in the proper location. Currently, water is primarily conveyed into the Bay as point source discharge through canals and through groundwater inflows. The timing, volume and method of delivery of canal discharges can cause acute and long term chronic biologic effects (HARM), which are related to timing, volume and method of delivery.

Biological communities are affected by flows in terms of habitat, community structure and distribution, productivity, fecundity, and energy cycling through food webs. Damage to biological communities in the bay from excess amounts of freshwater occurs to varying extents in different portions of the Bay, but is primarily restricted to the vicinity of inflow points. Observed patterns of hypersalinity in Biscayne Bay suggest that parts of the system may be getting less than optimum freshwater inflows, at least during dry periods.

The relationships between salinity and environmental responses must be examined to understand how freshwater discharges and salinity variations affect the plants and animals that inhabit the system. Therefore the initial focus of the MFL development efforts is on identifying the important species (e.g., popular gamefish, economically valuable species, endangered species) and indicator species and their food sources, which normally use areas of reduced salinity during all or part of their life cycle.

MFL WORK IN OTHER FLORIDA ESTUARINE SYSTEMS

Previous efforts to establish minimum flows and levels in estuarine waters in Florida that have produced written documentation are summarized in Table 1. Most of these reports are recent, and many are not complete. As noted by Estevez (2000), "very few published or unpublished accounts exist to inform the establishment of minimum flows in highly altered riverine estuaries, especially when honoring the additional constraint that such minimum flow methods rely primarily on living resources." That has not changed much since his work, but general direction is being given with the pioneering work in the Loxahatchee, St. Lucie, Caloosahatchee and St. Johns Rivers and their associated estuaries. Lagoonal ecosystems, such as Biscayne Bay, are still basically unstudied with regard to the best approach to establishing MFLs. This discussion was further revised and published in 2002 (Estevez 2002).

Flannery and Peebles (2002) report that in examining indicators for MFL establishment in the west coast of Florida, “best professional judgment” combined with good fisheries science has resulted in the preliminary determination that a “maximum percentage removal” standard is the best approach for those riverine estuaries.

When an estuary has a very low level of anthropogenic impacts, establishment of MFLs may look at the pre-development conditions for the estuary and watershed and determine if it is possible to restore some or all of the pre-development estuarine functions. Given the level of development in all the watersheds in Florida, this is not a common approach. Mattson (2002), however, describes the approach to the management of freshwater flows in the Suwannee River estuary and characterizes the approach as a "natural flow regime principle" which assumes that an altered hydrologic regime (i.e., the MFL) "...is still near-natural in terms of magnitude, frequency, duration and timing of freshwater inflows..."

Table 1
Other MFLs Projects in Estuarine Waters in Florida

Water Body	WMD	Status and Date	Summary of MFL	Indicators	MFL Target	Source
Northwest Fork of the Loxahatchee River	SFWMD	Final Draft Nov 2002	Prevent flows into the NW Fork less than 35 cfs for more than 20 days more than once every six years	Vegetation: Presence/absence of six freshwater swamp tree species (other than cypress)	Recovery (i.e., currently significant harm is occurring)	SFWMD 2002a. b. c
St. Lucie River and Estuary	SFWMD	Final Draft May 2002	Sufficient flows to prevent loss of oligohaline habitat (0.5 to 5.0 psu) in the estuary for two successive months during the dry season, during two years in a row	Salinity Regime: Maintain oligohaline zone as a VEC with on-going work to characterize responses of benthic plants and oysters to rapid changes in salinity and identify specific species of VEC's as indicators	Prevent Significant Harm (i.e., - currently significant harm is not occurring	SFWMD 2002d, e
Lake Okeechobee, the Everglades and Biscayne Aquifer	SFWMD	Draft Feb 2000	Only the Everglades has an estuarine component. Sufficient flows are designated to maintain desired salinities in coastal estuaries	Soils: Meet limits on low water levels and duration to maintain appropriate conditions in the two dominant soil types in freshwater portions of the ecosystem	Recovery (i.e., Currently significant harm is occurring)	SFWMD 2000
Caloosahat-chee River and Estuary	SFWMD	Draft May 2003	An MFL exceedance occurs...when (a) a 30 day average salinity...exceeds 10 ppt...or (b) a single, daily average...exceeds...20...for two consecutive years.	Vegetation: The resource at risk is a 640 acre bed of tapegrass, *Vallisneria americana*, located downstream of structure S-79	Recovery (i.e., Currently significant harm is occurring)	SFWMD 2003a, b
Lower Hillsborough River	SWFWMD	Under Study	A study is underway to reevaluate a proposed MFL to maintain existing biological communities	Test discharges of low salinity (<0.5 psu) water below the dam from various sources and biological sampling to determine what biological communities can be maintained	Recovery (i.e., Currently significant harm is occurring,)	Montagna (1999), Janicki Env. Inc. (2002)
Lower St. Johns River	SJRWMD	Being developed	MFL identifies flows and levels that will prevent the 5 ppt isohaline from being moved more than 0.8 miles upstream	Flora and fauna: Considered salinity tolerances of 60 species fish, one arthropod and one plant (i.e., *Vallisneria americana*)	Prevent Sig.Harm (i.e., acknowledges 'stress' on 1,130 ac of freshwater plants)	ECT (2002)

SECTION 2
BISCAYNE BAY CHARACTERISTICS

PROJECT BOUNDARIES AND SUB-REGIONS

Biscayne Bay is a large, shallow sub-tropical estuary located in eastern Miami-Dade County, in close proximity to a highly urbanized coastal area (Figure 1). On the east side of Biscayne Bay, several miles off the coast, are a number of narrow, offshore barrier islands. In 1974, the entire Bay was designated as an Aquatic Preserve by the Florida legislature, and a draft management plan for the aquatic preserve was developed, but never adopted. The Bay has also been designated as an “Aquatic Park and Conservation Area” by the Miami-Dade Board of County Commissioners. Biscayne National Park encompasses a large portion of the Bay and along the mainland shoreline lies the longest stretch of mangrove forest on Florida's east coast. Inland, hardwood hammocks grow with various native and non-native vegetation. Seagrasses grow in beds throughout the bay wherever conditions are favorable. The Biscayne Bay watershed also includes 83,000 acres of agricultural lands that are located to the west and southwest. Vegetables, tropical fruit and nursery plants are grown within this agricultural area.

The project area (Figure 1) being examined includes all of Biscayne Bay extending from the Miami-Dade/Broward County line south to the Miami-Dade/Monroe County line, and from the western shoreline of the Bay to the eastern near-shore areas located east of the barrier islands, keys, and Sandy Shoals. In the central and southerly portions of the Bay, the effects of freshwater inflows are experienced in areas to the west of the mangrove-lined shoreline. In these areas, the project area also includes the vegetated communities that extend westward from the shoreline to the L-31 Canal.

Biscayne Bay varies considerably in a variety of physical characteristics, including width, depth, water quality and degree of connection to the open marine waters of the Straights of Florida and the Atlantic Ocean. The bay varies in width from being extremely narrow in the most northerly reaches to over nine miles wide in the central areas. Water depths within the project area vary from comparatively shallow (i.e., less than 1 foot) in intertidal shoreline areas to over 40 feet in dredged navigation channels. Within the project area, water quality varies from very poor, in deep areas that are subjected to heavy pollutant loading and little mixing, to very good, in east-central areas where there is little overland pollution and good exchange with marine waters. Surface waters of Biscayne Bay are directly connected with open marine waters in some central bay areas,

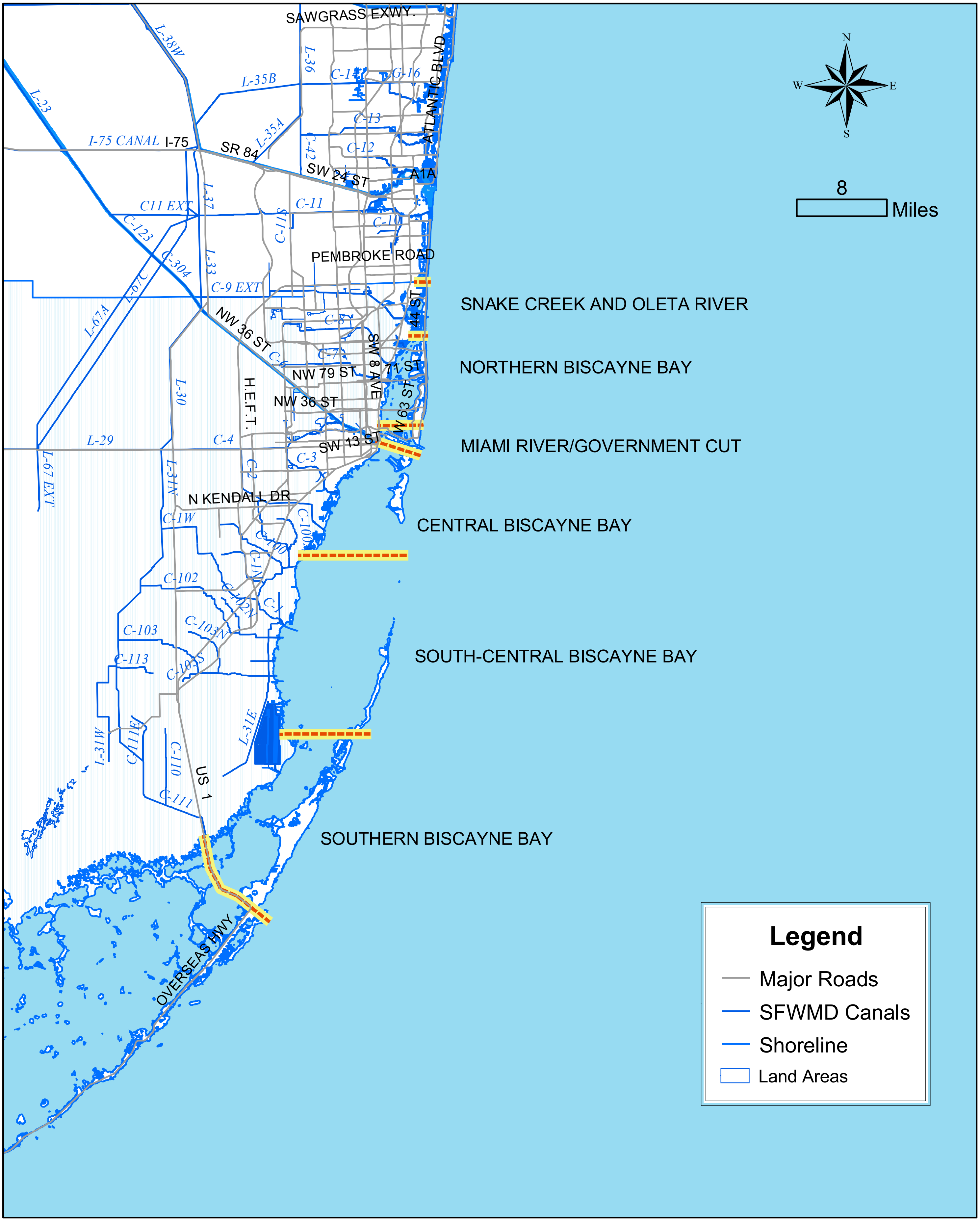

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Figure 1
Biscayne Bay Approximate Sub-Regions

and are connected via a series of natural, man-made and / or man-enhanced inlets at other locations where there are barrier islands.

Of significant importance in the development of an MFL rule for the Bay, is the extent to which different portions of the Bay currently serve as the receiving waters for discharges of freshwater from inland areas. Eleven major watercourses (i.e., canals, rivers) and a number of smaller ditches and other surface-water conveyances transport water directly into the Bay.

These varying physical characteristics result in the presence of highly variable floral and faunal communities being present in different areas of the Bay. Some species, such as Johnson's seagrass (*Halophila johnsonii*) have a spatial distribution such that they are present only in portions of the Bay. Others, such as red mangroves (*Rhizophora mangle*) and many species of fish may be found in all regions of the Bay.

In recognition of these differences in physical characteristics, for the purposes of establishing a meaningful MFL rule, Biscayne Bay has been separated into six sub-regions (Figures 1 -7):

- Snake Creek / Oleta River
- Northern Biscayne Bay
- Miami River / Government Cut
- Central Biscayne Bay
- South-Central Biscayne Bay
- Southern Biscayne Bay

The distinctly varying conditions in these sub-regions also led to the Bay being subdivided into approximately these same units in the Comprehensive Everglades Restoration Plan (CERP) (USACE and SFWMD 1999). For the purposes of establishing MFL rules, the CERP boundaries have been modified slightly based on the influence of canal discharges, tidal inlets and the presence / absence of submerged aquatic vegetation. Brief descriptions of the six sub-regions and highlights of the characteristics that separate each one from other areas of the Bay follow, in sequential order from north to south. More detailed descriptions of the ecological conditions in each sub-region follow in Section 2.c.

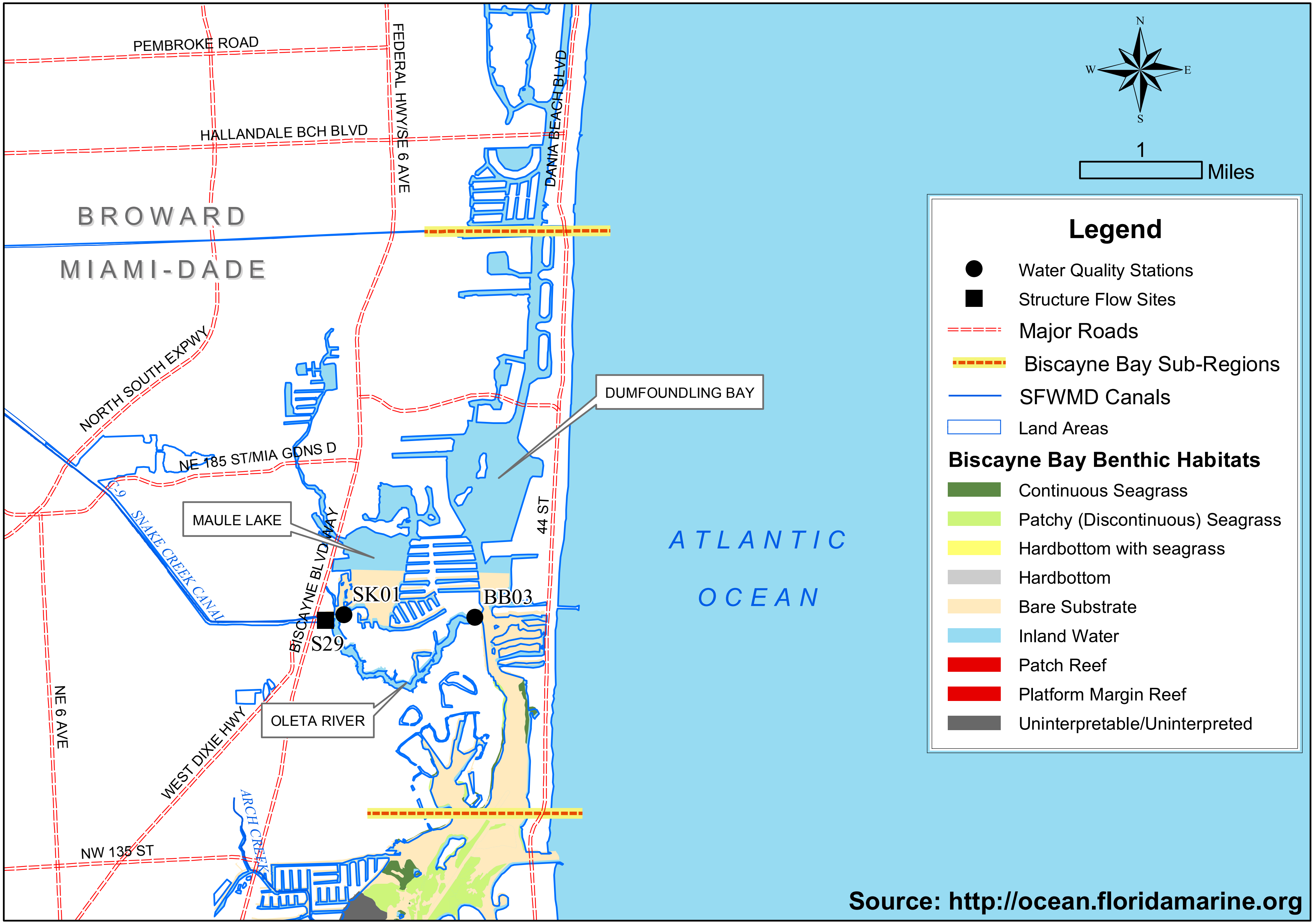

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Figure 2
Approximate Snake Creek/Oleta River Sub-Region

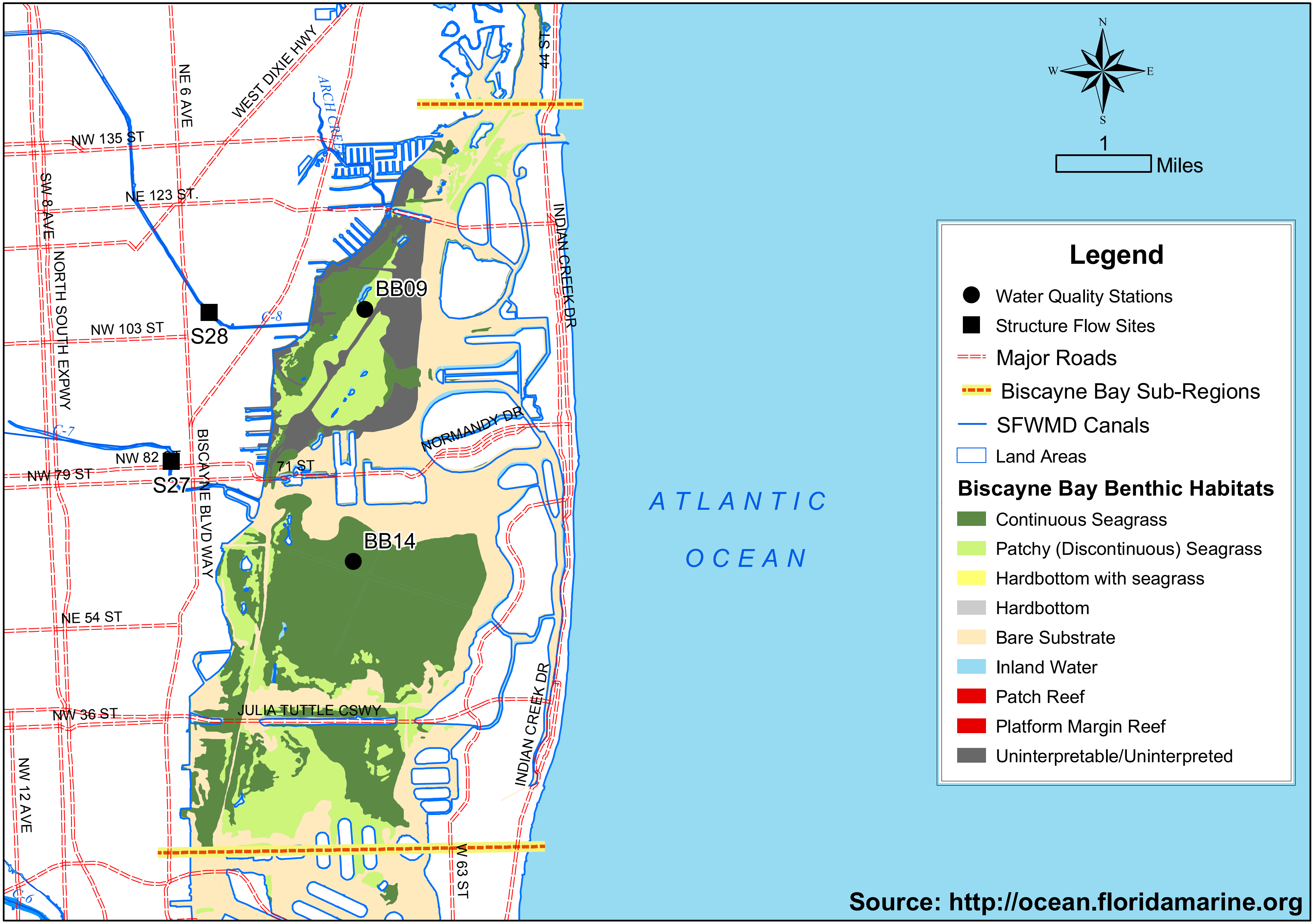

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Figure 3
Approximate Northern Biscayne Bay Sub-Region

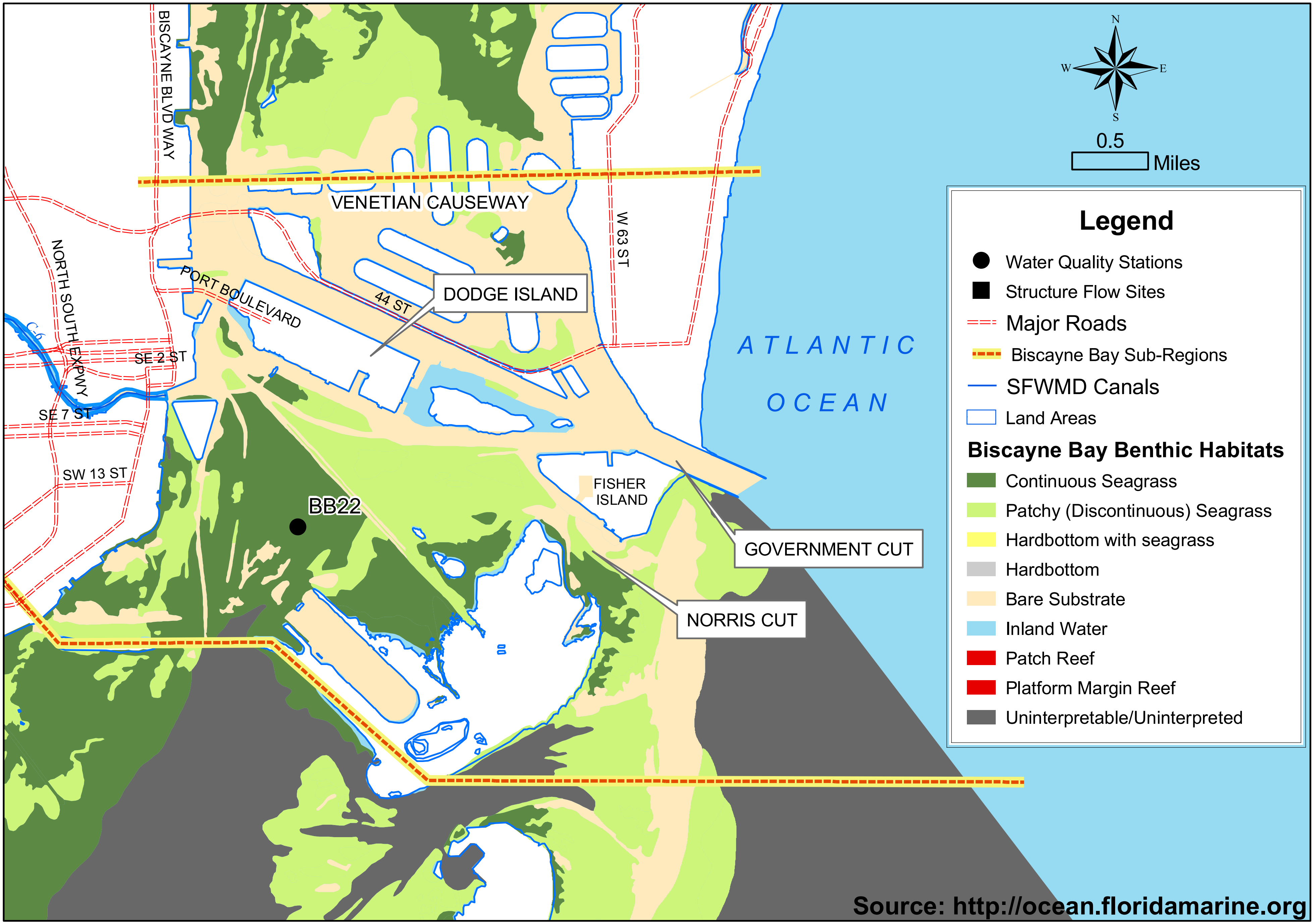

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Figure 4
Approximate Miami River/Government Cut Sub-Region

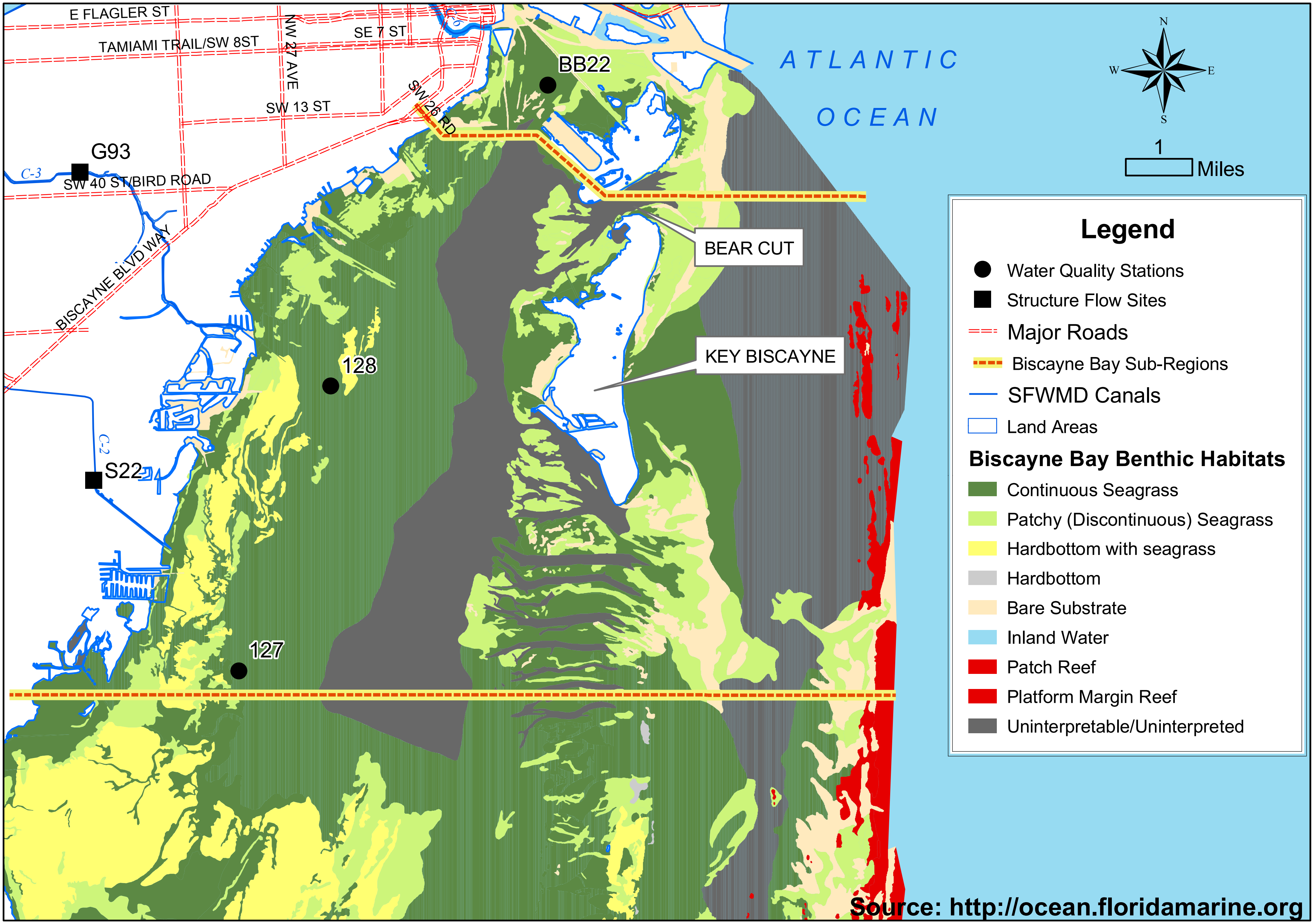

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Figure 5
Approximate Central Biscayne Bay Sub-Region

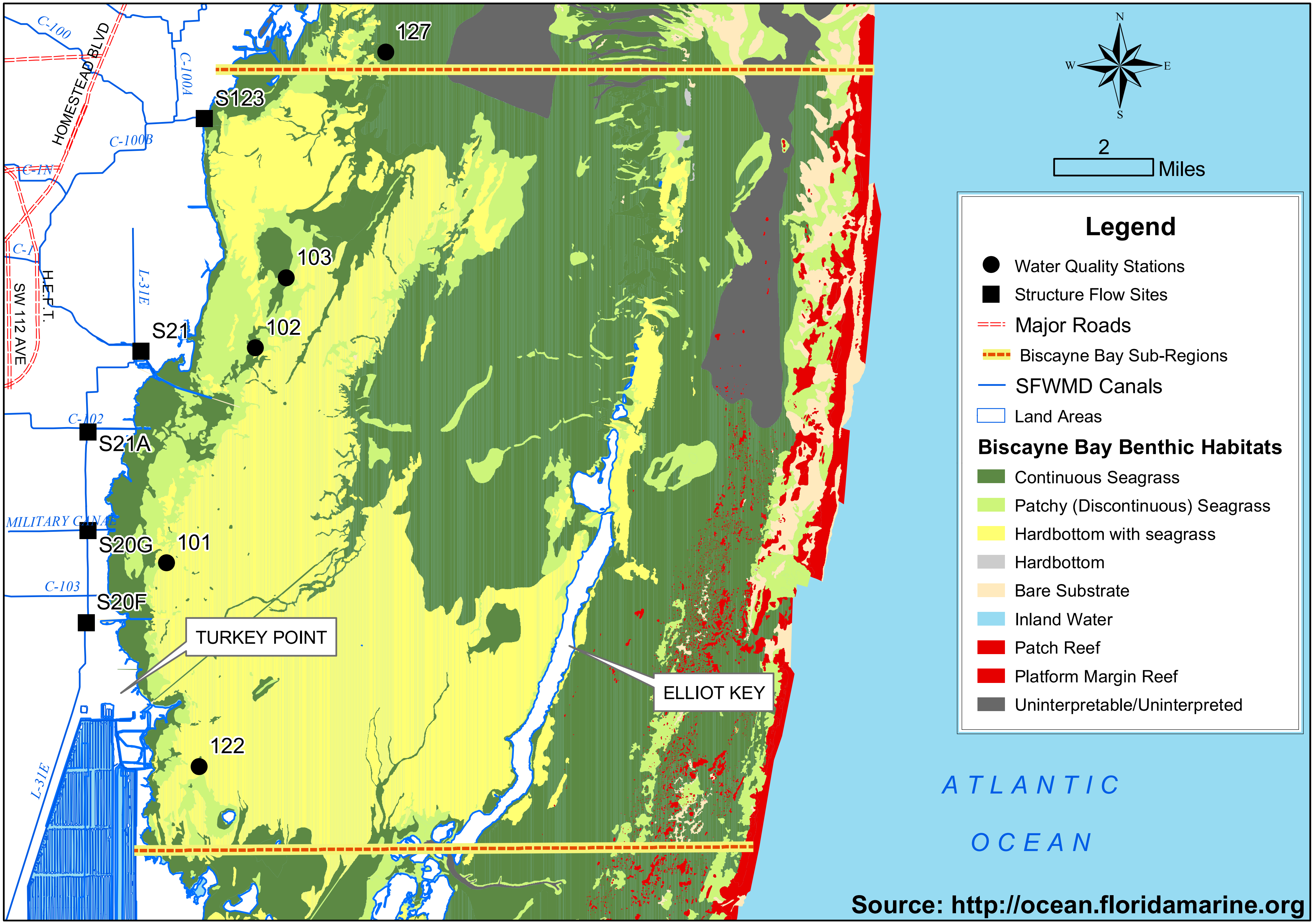

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Figure 6
Approximate South-Central Biscayne Bay Sub-Region

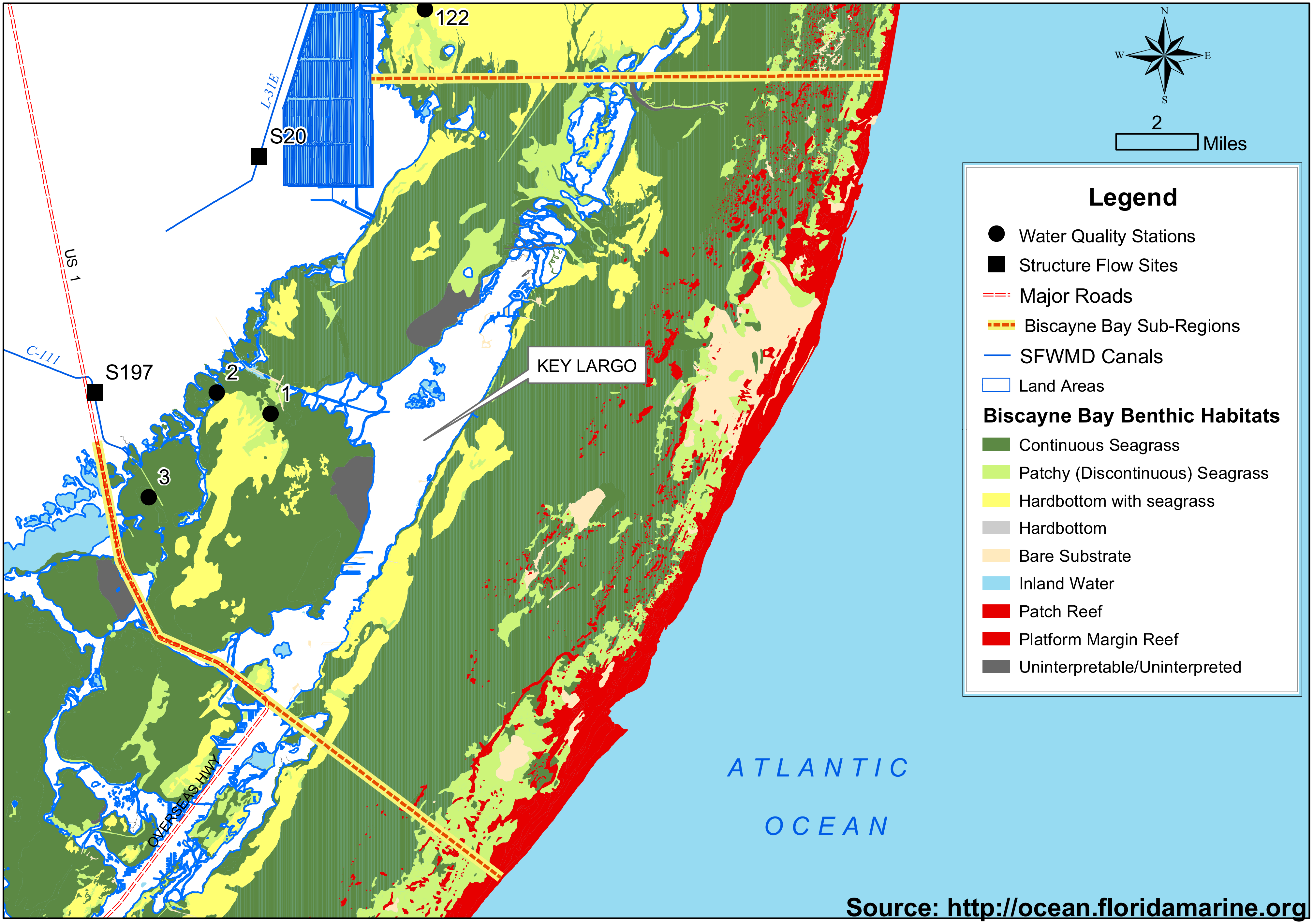

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Figure 7
Approximate Southern Biscayne Bay Sub-Region

Snake Creek/Oleta River

Located at the far northern end of Biscayne Bay, this sub-region extends approximately 4.8 miles from the Broward / Miami-Dade County line southward to Oleta River State Park and Haulover Beach Park (Figure 2). This area includes Dumfoundling Bay, Maule Lake, and the Oleta River. The Bay is extremely narrow in this area; there are no direct connections to marine waters, and the Atlantic Intracoastal Waterway (ICWW), which is maintained at a depth of -10 ft. MLW. Seagrasses are largely absent from this sub-region, with the exception of narrow grassbeds that fringe the few shoreline areas where there are no vertical bulkheads / seawalls. Shoreline mangroves are also nearly non-existent within this area, with the exception of shoreline mangroves within Oleta River State Park.

Northern Biscayne Bay

Immediately south of the Snake Creek / Oleta River sub-region, Northern Biscayne Bay (Figure 3) extends approximately 7.8 miles from the Oleta River / Haulover Beach Park area south to the northern edge of the Venetian Causeway area. The Bay widens considerably in this sub-region when compared with the Snake Creek / Oleta River area, varying in width from approximately one-half mile to 2.5 miles. Seagrasses are present throughout much of this area, which also includes one inlet, Baker's Haulover. Shoreline mangroves are nearly non-existent within this sub-region.

Miami River/Government Cut

Located immediately south of the Northern Biscayne Bay sub-region, the Miami River / Government Cut sub-region (Figure 4) extends southward approximately 3.2 miles south to the south side of the Rickenbacker Causeway. Natural conditions in this portion of the Bay are limited, with nearly all of the substrate having been dredged or filled. Seagrass and shoreline mangrove communities are largely absent from this sub-region except in its most southerly reaches, and water quality is heavily influenced by both tidal action through Government Cut and Bear Cut, and freshwater discharges from the highly modified Miami River.

Central Biscayne Bay

Immediately south of the Miami River / Government Cut sub-region, the Central Biscayne Bay sub-region (Figure 5) extends approximately 9.5 miles southward to the Cutler area. Two major canals (i.e., C-3 and C-2) empty into the Bay within this sub-region, which varies from approximately 1.5 miles to over 7 miles in width. Seagrasses are a prominent component of the sediment surface in this area, and mangroves are present sporadically along the shoreline. South of the barrier island of Key Biscayne, there is a direct connection with marine waters along the majority of the eastern portion of the Bay.

South-Central Biscayne Bay

Immediately south of the Central Biscayne Bay sub-region, the South-central sub-region (Figure 6) extends approximately 15.8 miles southward to the Turkey Point / Cutter Banks area. Five major canals (i.e., C-100, C-1, C-102, Military Canal and C-103) empty into the Bay within this sub-region, which varies in width from approximately seven miles in the north to approximately five miles in the south. The substrate in this area is largely hardbottom interspersed with seagrasses and the western shoreline is primarily mangrove-lined.

Southern Biscayne Bay

Immediately south of the South-central sub-region, the Southern Biscayne Bay sub-region (Figure 7) extends approximately 17.2 miles southward from the Turkey Point area to the U.S. Highway 1 bridge that serves as the project's southern boundary. There is one major canal (C-111) that discharges into the Bay in this sub-region. Seagrasses are a prominent feature in this sub-region, mangroves line the majority of the western shoreline, and direct tidal connection with marine waters is reduced by the natural obstructions of the offshore barrier island of North Key Largo, which is approximately five miles from the mainland shoreline.

FRESHWATER FLOWS AND SALINITY CONDITIONS

Freshwater flows and salinity conditions are described in detail in the SFWMD 1995 *Biscayne Bay SWIM Plan* (Alleman et al. 1995) and the 1999 *Issue Paper on Freshwater Flows into Biscayne Bay* by Bellmund, et. al. (1999). The following provides some background taken from these references. During 2004, the District will be evaluating these freshwater flow and salinity relationships as part of MFL development for Biscayne Bay.

Biscayne Bay is the largest estuary on the coast of southeast Florida and is contiguous with the southern Everglades and Florida Bay system. Historically, the Everglades, Biscayne Bay, and Florida Bay were part of a larger hydrologically connected natural system of coastal lagoons and wetlands. Biscayne Bay served as the eastern outlet of the Everglades (Davis, 1943; Parker *et al*., 1955). Historically, freshwater flowed overland to the Bay through natural sloughs and rivers, and as groundwater through the Biscayne Aquifer (Buchanan and Klein, 1976; Kohout and Kolipinski, 1967; Parker *et al*., 1955). This pattern has been altered by regional drainage, canal construction and operation, urban development, as well as construction of roads, levees, and other hydrologic barriers to surface flow. The Bay currently receives freshwater inflow as canal flow, minor overland flow, and groundwater (Alleman et al., 1995, Kohout and Kolipinski 1967, Buchanan and Klein 1976.

Biscayne Bay is a shallow generally well mixed system in which circulation is primarily controlled by tidal action, proximity to inlets, water depth, salinity and wind speed and direction. Salinity is maintained by the amount of freshwater inflow and rainfall, tidal movements of sea water, and evaporation. Changes to physical features of the bay have occurred over time, resulting in changes in circulation and flushing patterns, salinity structure and the creation of different habitats. Much of the upper bay has been modified and dredged, so that depths now average six to 10 feet and include some dredged areas and channels up to 40 feet deep. Construction of inlets, channels, islands, causeways and deep holes (as sources of fill) have altered the natural circulation patterns of the bay resulting in areas that are stagnant and have poor water quality or high salinities and bottom conditions that will not support stable, viable or desirable benthic communities.

A basin of about 840 square miles drains to the bay. Drainage of surface waters from eastern Miami-Dade County into Biscayne Bay is primarily controlled by the system of canals, levees, and control structures constructed as part of the Central and Southern Florida Flood Control Project (C&SF Project). C&SF Project control structures regulate the flow of water in the canals, facilitate the discharge of excess water during flooding and control water levels during drought periods. Historically, during wet periods, large amounts of water entered the bay as surface water that flowed across adjacent freshwater marshes. Today, the construction and operation of canals has accelerated the rate at which ground water levels recede at the end of the wet season, because surface water now discharges from the canals at a much faster rate than under natural conditions. Seventeen canals in eastern Miami-Dade County operated by the SFWMD provide most of the surface flows of freshwater into the bay.

Changes made by man have altered the timing of flows to the bay increasing the amount and rate of runoff that occurs. Generally, more water now flows to the bay during the wet season and less water flows to the bay during the dry season, but freshwater can be delivered to the Bay, via the water management system, at any time. During extreme rainfall events, large volumes of water can be released over very short periods of time. Low salinity, poor quality water that is delivered in this manner may not mix well with surrounding higher salinity water and may persist for long periods of time (Brook 1982, Szmant 1997, Serafy et al. 1997). Other problems occur due to reduction of freshwater flows during the dry season and droughts. High demands for water, to meet urban and agricultural needs, result in discharges of water from the regional system during the dry season to protect coastal well fields.

Watershed land use changes have resulted in concurrent changes to the water quality of the surface and groundwater flows to Biscayne Bay. Although overall water quality in Biscayne Bay has improved in recent years (Alleman et al 1995), water quality is still a substantial concern in the watershed. Water quality ranges from severely degraded in the Miami River to very good near the Featherbed Banks (Alleman et al 1995). The 1995 Biscayne Bay SWIM Plan reports the trend analysis for a variety of constituents.

EXISTING SPECIES AND ECOLOGICAL CONDITIONS

In its ± 57 mile length, Biscayne Bay varies considerably in physical conditions. From its narrow northerly extreme, the Bay widens to a maximum width of over seven miles in the south-central region. Flora and faunal communities vary considerably throughout the Bay, and are generally determined by a variety of environmental factors and physical characteristics (e.g., water depths, water quality, extent of tidal exchange with the ocean), some of which are fairly static, others of which are very dynamic. As a result of these varying conditions, benthic and epibenthic habitats vary considerably. In some areas, ecologically valuable seagrasses are present in lush grassbeds. In other areas, seagrasses are absent, or are interspersed with macroalgae and/or hardbottom. Since 1966, over 512 species of fishes have been documented to occur within Biscayne Bay (R. Alleman, pers. comm.).

In addition to the salinity-related variability described above, other water quality parameters also vary considerably in different areas of Biscayne Bay. In some eastern areas, the absence of barrier islands that would restrict tidal exchange, create marine conditions which provide habitat for a wide diversity of naturally-occurring sub-tropical floral and faunal assemblages.

In other areas, due to a combination of factors, including the presence of barrier islands that reduce tidal exchange with the Atlantic Ocean and significant destruction of naturally-occurring shoreline communities, water quality is comparatively poor and species richness, abundance, distribution and health is considerably reduced.

Although conditions in a natural, unaltered Biscayne Bay would be highly variable, human-related changes in the recent past (i.e., ± 100-150 years) have significantly altered the Bay. These changes, which have included construction of tidal inlets, replacement of mangrove shorelines with seawalls and bulkheads, and dredging of shallow bay bottoms to create navigation channels, marinas, and deep-water ports have resulted in Biscayne Bay being in a highly modified condition. In general, these activities have had adverse impacts on the environmental value and quality of the Bay, but it some areas, the creation of new and/or different habitats than what had previously existed may have resulted in increased biodiversity.

Although the floral and faunal assemblages at any given site may be considerably different than at other sites, the species that are present are largely the result of the combination of available habitat and ambient water quality. Some species that are tolerant of extremely variable conditions are likely present throughout the entire Bay. Other species may be restricted to certain areas based upon their individual habitat requirements. As described in Sections 2.a-c above, for the purposes of establishing a rule for Minimum Flows and Levels, Biscayne Bay has been separated into six distinct sub-regions. In the remainder of this section, information is provided about the ecological conditions and/or notable species that are present in each of the sub-regions.

Snake Creek/Oleta River Sub-region

In addition to Snake Creek and the Oleta River, this northern-most sub-region of Biscayne Bay also includes Dumfoundling Bay, Maule Lake and Oleta River State Park.

There are no direct surface water connections between these waters and the Atlantic Ocean within this sub-region, although Haulover Inlet is a short distance to the south. Prior to the opening of Haulover Inlet during the 1920s, this area was primarily a freshwater system (FDEP, 2002). Much of the historic shoreline has been altered, and previously existing native vegetation has been replaced with seawalls and bulkheads. An exception to this, however, is the ± 1043-acre Oleta River State Park, which is located on the west side of the Bay, immediately south of S.R. 826. The most extensive current ecological information that is available for this region is the Unit Management Plan for Oleta River State Park (FDEP 2002) The Management Plan identifies and describes the four vegetative communities that exist within the park, including: beach dune, maritime hammock, estuarine tidal swamp and estuarine unconsolidated substrate, in addition to ruderal/disturbed and developed areas. Floral and faunal inventories conducted within the state park have documented the presence of approximately 290 species of plants and 95 animal species, consisting of six species of invertebrates, nine species of fish, one amphibian, ten reptiles, 59 species of birds and ten species of mammals.

Eighteen plant species that are designated as threatened or endangered by the State of Florida are present within the park, none of which designated as threatened or endangered by the federal government. Only one of these species, golden leather fern (*Acrostichum aureum*) is an emergent wetland-related species. The typical habitat for this herbaceous species is the low-salinity muck soils along the Oleta River. Johnson's seagrass, a submerged species that is designated as 'threatened' by the federal government, is present in shallow waters in this sub-region of the Bay. Submerged lands within this sub-region from S.R. 826 southward to the south boundary of this sub-region have been designated as critical habitat for Johnson's seagrass (Figure 8).

Twelve animal species that are listed as endangered, threatened, or species of special concern by the state are known to exist within the state park. Three of these, (i.e., bald eagle, wood stork, and West Indian Manatee) are also listed as threatened or endangered by the federal government. Several of the designated species are species that forage in, or otherwise inhabit coastal areas. These include: roseate spoonbill, mangrove cuckoo, various herons and egrets, bald eagle, wood stork, brown pelican and West Indian Manatee.

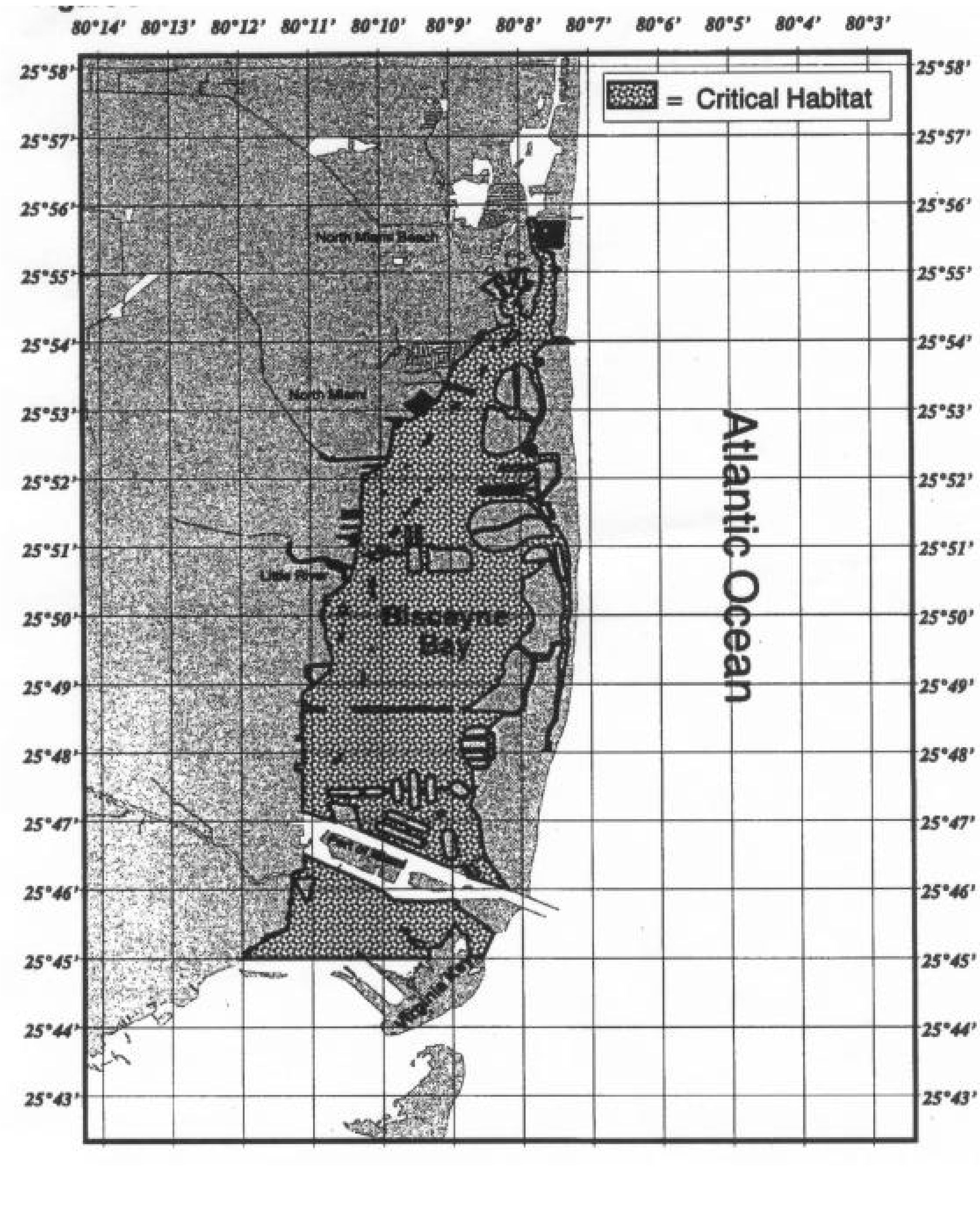
The majority of the substrate in this sub-region is barren, although seagrasses are present in some shallow areas. An oyster bioherm exists near the mouth of the Snake Creek canal. This oyster community is notable in that, although oysters, which prefer salinities between 5 and 20 ppt, were thought to have been fairly common historically, are presently nearly non-existent in other areas of Biscayne Bay.

Northern Biscayne Bay

In the Northern Biscayne Bay sub-region, which extends southward from the Oleta River sub-region to the northern edge of the Venetian Causeway, Biscayne Bay is considerably wider than it is to the north. Although the presence of the barrier island of Miami Beach separates the Bay from the Atlantic Ocean, Haulover Inlet is within this sub-region, and this tidal connection allows significant tidal exchange.

The majority of the natural shoreline vegetation in this area has been replaced by vertical seawalls, and a considerable portion of the bay bottoms have been altered by dredge and fill activities. In spite of these conditions, seagrass communities are abundant and in fairly good condition in much of this sub-region. To the north of the 79th Street Causeway, seagrasses are primarily in the western portion of the Bay. A notable feature in this area is a dense manatee grass (*Syringodium filiforme*) community, possibly the largest and healthiest manatee grass community in the Bay (Markley and Milano 1985). This grassbed

Figure 8
Designated Critical Habitat for Johnson's Seagrass (*Halophila johnsonii*)



Source: Federal Register; Vol. 65, No. 66, Wed., April 5, 2000, p17804 covers much of the Bay bottom from the 79th Street Causeway south to the Venetian Causeway. It is possible that the freshwater inputs from the Biscayne Canal and Little River result in the lower salinities which are favored by manatee grass as opposed to turtle grass (*Thalassia testudinum*) which typically prefers higher salinity areas. Another option is that this large area persists due to a tolerance for higher turbidities by manatee grass.

These extensive grassbeds, which do also include Johnson's seagrass (*Halophila johnsonii*), provide habitat for a variety of other organisms, including various fishes. The entire bay bottom in this sub-region has been designated as critical habitat for Johnson’s seagrasss (Figure 8). Spotted seatrout *(Cynoscion nebulosus*), which have well-documented salinity preferences of less than 25 ppt during their juvenile stages, are documented to occur in this sub-region, which is notable in that this species is largely absent from other areas of the Bay (Serafy et al. 1997).

Manatees are documented to occur in this area, and it is believed that manatees that are attracted to the warm water discharge from the coastal power plant at Ft. Lauderdale travel to this region to forage in the dense grassbeds (DERM 1995).

Miami River/Government Cut

In comparison to the other sub-regions, the Miami River / Government Cut sub-region is a relatively narrow northwest-southeast corridor that extends from the Venetian Causeway on the north to the south side of Rickenbacker Causeway on the south. This portion of the Bay has been highly altered. The Miami River, which has been channelized, is intensively used for commercial purposes. Through the years, heavy metals and other contaminants have accumulated in the sediments of the river, which presently has a comparatively low diversity of flora and fauna. Much of the natural bottom contour in this sub-region has been modified as a result of dredging and filling activities. The Port of Miami, and its associated navigation channels are within this sub-region, which also extends eastward and includes Government Cut, the tidal inlet and navigation channel that links the Bay to the Atlantic Ocean. Although seagrasses are present in the southern portion of this sub-region, large areas of dredged bottom are primarily barren.

Surprisingly, in spite of these significant alterations, from a fish diversity perspective, this sub-region actually is one of the most highly diverse regions of Biscayne Bay (Serafy et. al. 1997). This fish diversity is likely a direct result of the varying salinity regimes of the different areas within this sub-region. From upstream areas in the Miami River, where salinities are minimal, there is a salinity increase until marine conditions are encountered at the direct connections to the ocean at Government Cut and Norris Cut.

This variety of salinity regimes provides habitat for varying floral and faunal assemblages and benthic communities, including species that frequent oligohaline areas (e.g., mullet, *Mugil* spp.), those that inhabit mesohaline areas (e.g., blue crab, *Callinectes sapidus*, shoal grass, *Halodule wrightii*), those that inhabit areas with marine salinities (e.g., paddle grass, *Halophila decipiens*, blue-striped grunt, sailor's choice) and of course, those species that can tolerate highly variable salinity conditions (e.g., manatees).

During baseline studies related to potential modifications at the Port of Miami (Dial Cordy and Assoc., 2001), seagrasses mapped based on inspections of 35 transects within a portion of this sub-region documented the presence of shoalgrass, paddle grass, manatee grass and turtle grass, in decreasing order of abundance. Although not reported by Cordy and Associates as occurring within their study area, Johnson's seagrass is known to be present within this sub-region. With the exceptions of the Miami River itself and the deepwater areas of the Port of Miami, the bay bottoms within this area are designated as critical habitat for Johnson's seagrass (Figure 8).

The marine water quality conditions, including salinity, that result from the direct connections between the Bay and the Atlantic Ocean also create suitable habitat for a variety of typically marine macroalgae, including *Caulerpa prolifera*, *Halimeda* sp., *Udotea* sp., *Penicillus* sp. (Dial Cordy and Assoc., 2001, Zieman, 1982). Queen conch, long-spined sea urchins, nudibranchs, mollusks, and crustaceans, including spiny lobster and blue crab, and various soft corals and sponges were also noted within this sub-region (Dial Cordy and Assoc., 2001).

Aerial surveys and telemetry tracking have documented the presence of West Indian Manatees within this sub-region (DERM, 1995). These monitoring efforts have also documented the presence of manatees in upstream reaches of the Miami River. The extent to which fresh water and/or comparatively warmer water temperatures during winter months are the attracting features for manatees is not known.

Dial Cordy and Associates (2001) also note the presence of loggerhead turtles (*Caretta caretta*), green turtles (*Chelonia mydas*), and leatherback turtles (*Dermochelys coriacia*) within their study area, and the nesting of these species along suitable beaches within this sub-region, including Fisher Island. These species are designated as threatened (loggerhead) and endangered (green and leatherback) by both the State of Florida and federal resource agencies.

Central Biscayne Bay

The Central Biscayne Bay sub-region extends from the Fisher Island / Virginia Key area on the north, southward to the Cutler area. Although the barrier island of Key Biscayne is present in the northerly portion of this sub-region, the absence of barrier islands to the south make this sub-region the most well-flushed area of Biscayne Bay. Freshwater inputs, which enter the west side of the Bay through the Coral Gables Waterway and Snapper Creek, result in estuarine salinities (17-32 ppt (FIU, 2002)) along the west shoreline. Salinities increase toward the east, and are marine on the east side of the project area. This salinity gradient, together with a westerly shoreline that includes mangroves and other naturally-occurring vegetation provides habitat for a comparatively high diversity of flora and fauna.

Seagrasses are a major component of the benthos, and where seagrasses are not continuous, hardbottom is interspersed with seagrasses. Seagrasses are primarily dense beds of turtle grass in the east, but shoalgrass, paddle grass and manatee grass are also present, primarily in the western areas. The southernmost extent of the known range of Johnson's seagrass is present in the northern portion of this sub-region. Designated critical habitat for Johnson's seagrass ends in this sub-region, with the 25^0 45' North latitude line (which crosses through Virginia Key) serving as the southern boundary for the critical habitat area (Figure 8).

Attached macroalgae are abundant within this sub-region, particularly on hardbottom and / or in eastern portions.

The combination of dense seagrass beds and grassbeds interspersed with hardbottom create ideal habitat conditions for a variety of crustaceans and fishes. This portion of Biscayne Bay sustains a major commercial pink shrimp (*Farfantepenaeus duorarum*) fishery. Reported landings increased greatly from 1990 (<100,000 lbs) through 1999 (> 600,000) pounds (Harper et. al., 2000).

Aerial surveys and telemetry tracking have documented the presence of West Indian Manatees within this sub-region (DERM, 1995). These monitoring efforts have also documented the presence of manatees in manatee-accessible areas of the Coral Gales waterway, Snapper Creek and the Kings Bay / Cutler area. The extent to which fresh water and / or comparatively warm water during the winter, are the attracting features for manatees is not known, however the presence of manatees in these waterways at different times of the year suggest that both fresh water and warm water may be attracting features to varying extents throughout the year.

Loggerhead turtles, green turtles, and leatherback turtles are known to occur within this sub-region, although nesting habitat for these species in this sub-region is exceedingly small. These species are designated as threatened (loggerhead) and endangered (green and leatherback) by both the State of Florida and federal resource agencies.

South-Central Biscayne Bay

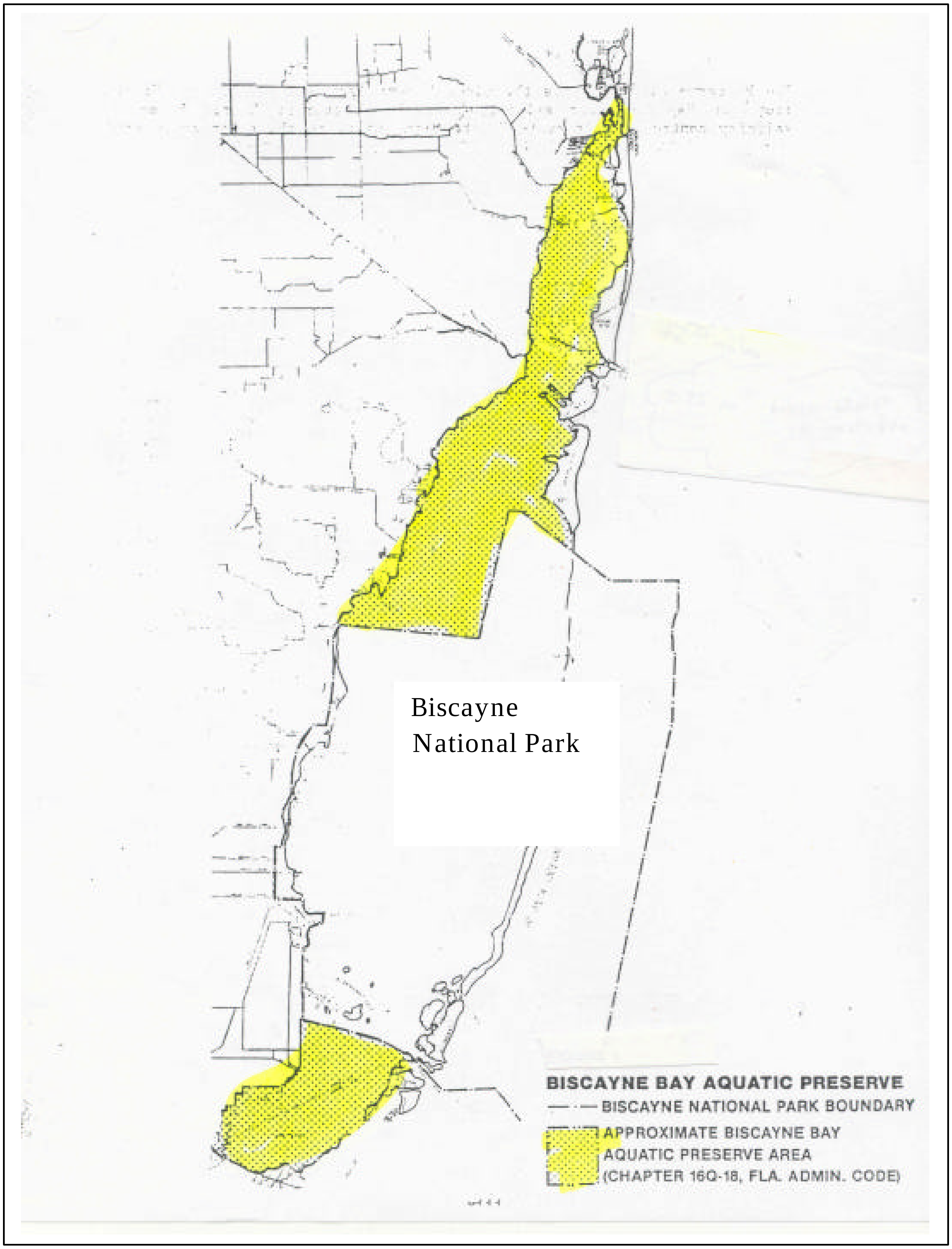
The South-Central sub-region extends from the Cutler area on the north to the Turkey Point – Cutter Bank area on the south. Several features along the western shore of the Bay differentiate this sub-region from others to the north and south. These features include: 1) the presence of a mangrove community for almost the entire length of the sub-region, and 2) the presence of several major canals (C-100, C-1, C-102, Military Canal, and C-103) that discharge fresh water into the Bay. The majority of this sub-region is also within the boundary of Biscayne National Park, the boundary of which is shown in relation to the Biscayne Bay Aquatic Preserve on Figure 9. The National Park extends from the landward extent of the red mangrove forest on the west to the 60-foot bathymetric contour (approximately 14 miles) on the east. A natural off-shore barrier island community consisting of Ragged Keys to the north and Elliot Key to the south extends in a north northeast direction varying from approximately three miles to 4.5 miles east of the western shore.

Natural resources in this sub-region of the Bay are extremely diverse, although the more intensive scientific investigations that have occurred as a result of the national park status may partially contribute to the higher level of knowledge and awareness of the biota in this region when compared with other areas of the Bay. Seagrasses and mixed seagrass – hardbottom communities are present throughout this sub-region. Although shoalgrass, paddle grass and manatee grass are present, primarily in the western areas, extensive beds of turtle grass are the primary grassbed communities. Johnson's seagrass has not been documented to occur in this sub-region. It is widely believed that the increasing salinities that have resulted from reductions in fresh water inflows (both surface and sub-surface) into this region of Biscayne Bay during this century have resulted in changes in the submerged aquatic vegetation community; namely that turtle grass, which prefers comparatively high salinities, has gradually replaced shoalgrass and perhaps wigeon grass that prefer comparatively lower salinities, in sizable portions of this sub-region.

Graduate-level research presently being conducted by Danielle Mir-Gonzalez, a student at Florida International University, involves mapping the spatial distribution of the different species of seagrasses along the western shore of this

Figure 9

Boundaries of Biscayne Bay Aquatic Preserve and Biscayne National Park



Source: Draft Biscayne Bay Aquatic Preserve Management Plan, Metro-Dade Department of Environmental Resources Managment portion of Biscayne Bay. Her research also includes monitoring of sub-surface freshwater inputs into the Bay through the installation and monitoring of seepage wells. As soon as these data become available, they should be obtained and analyzed, as the results of these efforts will likely be helpful in identifying the amounts of freshwater input that will be necessary to prevent harm to these submerged aquatic vegetation communities. Modeling will likely be necessary, using the results of the Mir-Gonzalez research, to determine the timing and volumes of fresh water flows that will be necessary to maintain a salinity envelope that will prevent harm to the existing seagrass community or change the community as a preference by managers to a more estuarine character.

As in the Central region, above, the combination of dense seagrass beds and grassbeds interspersed with hardbottom create ideal habitat conditions for a variety of crustaceans and fishes. This portion of Biscayne Bay sustains a major commercial pink shrimp fishery. Reported landings increased greatly from 1990 (<100,000 lbs) through 1999 (> 600,000 pounds) (Harper et. al., 2000). Shrimp are valuable both for the economic value of the fishery and for their contribution to the food web. Many species of fish that are valuable either commercially or recreationally feed on pink shrimp. And although sustaining an economically viable pink shrimp fishery is dependant on a variety of factors (including some that are far outside the purview of this salinity-regime study), due to their value to both the ecosystem and the economy, preventing significant harm to the pink shrimp fishery as a result of reductions in fresh water flow should be a goal of the minimum flows and levels program for this region of the Bay.

Although this area has not been designated as critical habitat for the American crocodile (*Crocodylus acutus*), surveys by Mazzotti and Cherkiss (1998) indicate that this species is present in this sub-region of the Bay, and that their population may be expanding.

Similarly, surveys and telemetry tracking have documented the presence of West Indian Manatees within this sub-region (DERM, 1995). These monitoring efforts indicate that manatees have most often been observed along the western shore of the Bay, and have also documented the presence of manatees in manatee-accessible areas of Black Creek and the C-103 (Mowry Canal). The extent to which fresh water and/or comparatively warm water during the winter, are the attracting features for manatees is not known, however the presence of manatees in these waterways at different times of the year suggests that both fresh water and warm water may be attracting features to varying extents throughout the year.

Southern Biscayne Bay

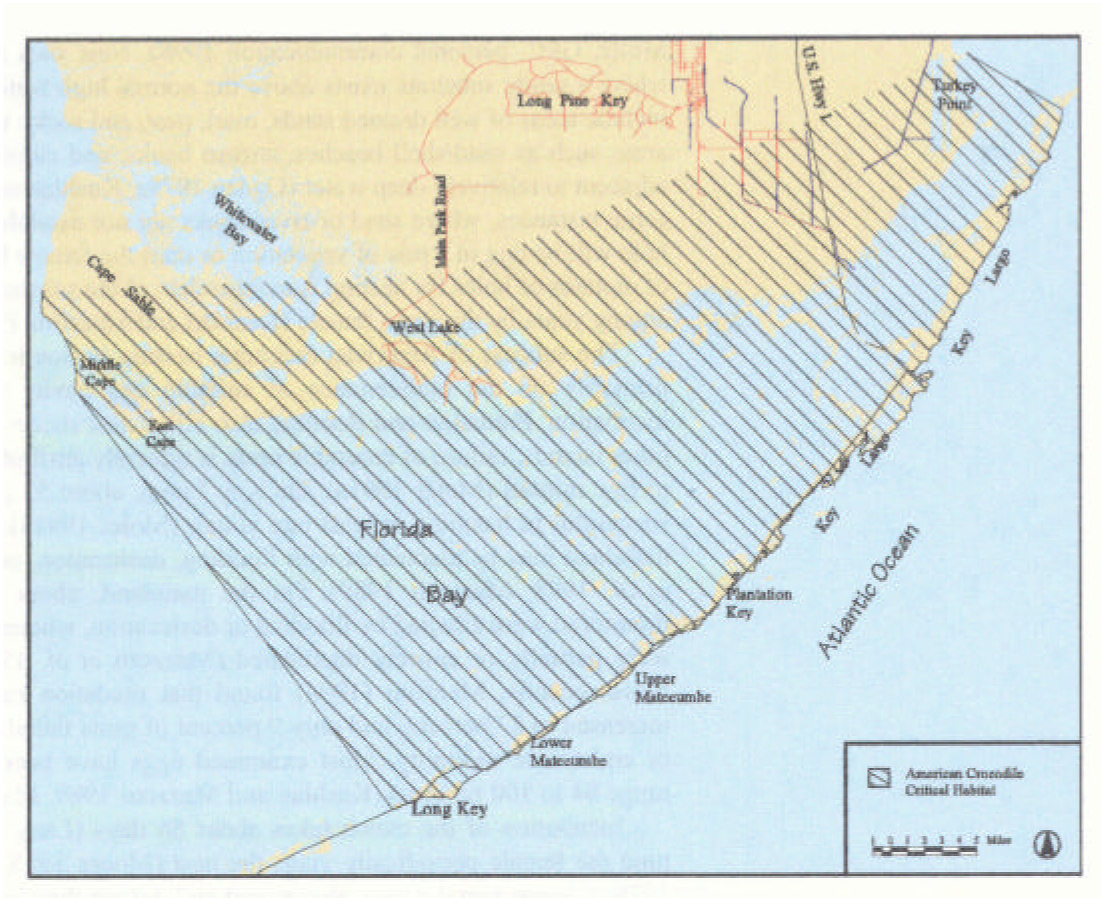
The Southern Biscayne Bay sub-region extends from the Turkey Point area on the north southwesterly to the U.S. 1 corridor that separates Biscayne Bay from Florida Bay. It includes Card Sound, Barnes Sound and Manatee Bay, and the southern boundary is also the southern boundary of the project area. The boundaries for this sub-region have been selected based on several unique features that set this area off from other sub-regions. These include the presence of a sizable scrub mangrove and brackish marsh vegetative community that exists to the west and northwest of the mangrove-lined shoreline up to the L-31E levee and canal. Although inflows of freshwater have been significantly altered as a result of dredge and fill operations, construction of Card Sound Rd. and U.S. 1 and other modifications upstream in the watershed, the changes are largely more distant than in other areas of the Bay. Florida Power and Light (FPL) Company's Turkey Point Power Plant, and its associated radiator-type system of cooling canals is present immediately adjacent to the western shoreline of the Bay at the north end of this sub-region.

The only substantive canal that delivers fresh water into this sub-region of the Bay is the Aerojet Canal (C-111). The offshore barrier island of north Key Largo, which extends parallel to the shoreline approximately 3-5 miles to the east, is connected to the mainland via two man-made roads; Card Sound Road and U.S. 1. Partially because there is no direct connection to the Straights of Florida as there is in other sub-regions to the north, recorded salinity values in this portion of the Bay have been documented to exceed 40 ppt. (DERM 1987).

This entire sub-region has been designated as critical habitat for the American crocodile (Figure 10).

Figure 10

Critical Habitat for the American Crocodile (*Crocodylus acutus*)



Source: U.S. Fish & Wildlife Service; Multi-species Recovery Plan for South Florida

SECTION 3
SUMMARY OF PROJECT TASKS

TASK 2 - LITERATURE AND DATA REVIEW

In project Task 2, a detailed literature review was performed and a bibliographic database was prepared. A separate Task 2 report was prepared that provides a detailed summary of the literature review methods and contents (Appendix A). The bibliography is a result of a literature survey and represents the readily identifiable body of knowledge concerning freshwater flow and ecological relationships with respect to establishing Minimum Flows and Levels (MFLs) in Biscayne Bay. Numerous information sources were used to develop this bibliography, including various libraries and Internet web-based information. These references support various portions of the final report and recommendations.

The bibliographic database was prepared in Microsoft Access 2000 software, which allows a search of the documents through various listings and tables. The database contains 299 total bibliographic entries considered to have *some direct relevance* to the project.

A list of key words was developed for selecting bibliographic entries. These keywords were grouped into topic categories and can be used to query the database. The references contained in this MS Access database can be queried to generate the following reports:

- A listing of 86 Biscayne Bay specific references;
- A listing of 99 references that are considered most relevant;
- Topic Category 1 - Animal Species (146 references);
- Topic Category 2 - Aquatic Plants and Habitats (98 references);
- Topic Category 3 - Ecological Indicators (45 references);
- Topic Category 4 - Impact Approach (70 references);
- Topic Category 5 - Water Quality Data (89 references);
- Topic Category 6 - Hydrologic Data (40 references);
- An alphabetical listing by author of all 299 references;

In general, the literature search revealed that:

- A considerable amount of scientific data is available for Biscayne Bay.

- The majority of directly applicable data is the result of research that has been conducted, or is being conducted by personnel associated with academic institutions and / or state or federal governmental entities.

- The majority of site-specific data are the result of work that has been done within the physical boundaries of Biscayne National Park and / or Everglades National Park. With the exception of some individual sites (e.g., Oleta River State Park) there is comparatively less information concerning flora, fauna and ecological conditions in areas of Biscayne Bay outside Biscayne National Park.

- There is a considerable amount of information concerning water quality within Biscayne Bay, and some studies have documented that non-salinity related water quality parameters in inflows to the Bay have reached lethal limits for some biota.

- There is a reasonably detailed database concerning the presence, absence and distribution of American crocodiles and West Manatees, two species that are designated as ‘endangered’ by the State of Florida and the federal government.

TASK 3 – INTERVIEWS WITH EXPERTS

In Task 3, members of the project team interviewed and obtained information and data from local contacts and experts in the areas of estuarine / marine water chemistry, phytoplankton, zooplankton, algae, seagrasses, invertebrates, fisheries, ecology, and paleoecology. In completing these interviews, the project team has:

- Confirmed the literature review information and obtained recommendations for additions to the literature database (which were subsequently incorporated into the Task 2 bibliography),

- Identified additional recent and / or ongoing relevant research and data collection, and new information, and

- Identified additional sources of information (i.e., unpublished documentation, personal opinion, etc.) regarding ecological dependencies on freshwater in Biscayne Bay or other south Florida estuaries and / or other estuaries where such information could be helpful.

Interviews were conducted by senior ecologist project team members Roy R. "Robin" Lewis and Greg Braun, during September and October, 2003. These experts were grouped by three major categories: Governmental Entities, Academia, and Other Non-Governmental Organizations. A separate Task 3 report was prepared that provides a detailed summary of these interviews with experts (Appendix B). The most substantive of findings are that:

- Most interviewees recommended that particular species (e.g., pink shrimp, oysters, shoal grass) be considered as bio-indicators.

- Other interviewees suggested that consideration be given to several individual species that occur in Biscayne Bay and which are designated as endangered or threatened species by the federal government and / or the State of Florida (e.g., West Indian Manatees, Johnson's seagrass), as Valued Ecosystem Components, regardless of the extent to which these species are useful as bio-indicators.

- Interviewees with expertise in water quality and / or relationships between water quality and biota, suggested that identifying individual species of flora and fauna that would be indicators of salinity change alone (without consideration of non salinity-related water quality parameters) would be a challenging, if not impossible, endeavor.

- Individual interviewees had varying opinions as to the extent to which sub-surface inflows of freshwater affect salinity regimes in the nearshore areas of the Bay. In reality, these potentially contradictory viewpoints may be indicative of actual conditions in the Bay; subsurface in-flows may be inconsequential in certain areas of the Bay, and of significance in other areas of the Bay. Additionally, subsurface inflows in any individual area of the Bay may vary considerably at different times of the year. Field monitoring studies using seepage wells are currently under way at a number of sites in the Bay to measure sub-surface inflows. As soon as they are available, the results of these and other on-going projects should be obtained and reviewed by SFWMD, and to the extent warranted, modifications to the MFL rule should be considered.

TASK 4 - ALTERNATIVE MFL APPROACHES

Task 4 of this contract has sought to establish a scientific connection between various methods to establish Minimum Flows and Levels for Biscayne Bay, and indicators of conditions in the Bay. Approaches used by other Florida water management districts, as well as other MFL projects within the SFWMD, were evaluated for their applicability to Biscayne Bay (Table 1). A focus of this task was to identify salinity-habitat-species relationship(s) to define significant harm for various sub-regions of Biscayne Bay.

Based on the results of Tasks 1-3, information was compiled on the salinity tolerances, preferred habitats and life cycles of potential indicator species or suites of organisms that are currently present in Biscayne Bay, and whose continued existence, abundance and / or spatial distribution is affected by or dependant on deliveries of fresh water into the Bay. This task includes evaluations of the advantages and disadvantages of using various MFL approaches and provides information on the applicability of using various species of plants and animals as potential biological indicators.

The recommended over-all process has been to apply numerical rankings to potential indicator species and potential MFL approaches in order to determine the most appropriate approach for each of six sub-regions of the Bay. This is necessary due to the Bay being a large heterogeneous ecosystem that has undergone major anthropogenic changes in the last 100 years. Each of the six identified sub-regions has unique characteristics that demand unique treatment regarding necessary freshwater flows to either maintain existing conditions, or restore some semblance of historical conditions to allow for a particular ecological function to exist at some level that is acceptable to water managers, citizens and scientists.

SECTION 4
VALUED ECOSYSTEM COMPONENTS

SFWMD (2002d) defines valued ecosystem components as "…a species, community, or set of environmental conditions and associated biological communities that is considered to be critical for maintaining the integrity…" of a given estuarine ecosystem. In this section, descriptions are provided of the major ecosystems and species that are present in Biscayne Bay which have significant value in the ecological functioning of the Bay.

HABITATS

Mangrove Forests

Biscayne Bay's mangrove forests are composed of three species of true mangroves: the red mangrove, black mangrove (*Avicennia germinans*) and white mangrove (*Laguncularia racemosa*). Mangrove forests are important ecological components, providing a source of fixed carbon in the form of detritus to local and adjacent marine communities, and habitat for aquatic, arboreal and canopy resident flora and fauna (Odum et al. 1982). Fish use of mangroves and the role of mangroves as nursery habitat for fish and invertebrates is described in Lewis et al. (1985).

Harlem (1979) reported that northern Biscayne Bay had lost 82% of its mangrove forest cover with a decline to 27,417 acres from 156,351 acres, and additional mangrove losses have been experienced subsequent to the Harlem report.

McIvor et al. (1994) summarize the effects of freshwater flow on mangroves and note that moderate salinities produce the optimum conditions within the mangrove community and maximize primary productivity.

Tidal Marshes

Located landward of the mangrove zone are various transitional zones. The vegetation makeup of these transitional zones depends upon local topography, historical rates of sea level rise, frequency of fire, surface water flows and surface and subsurface soil salinities. Historically, there were greater surface and subsurface freshwater flows near the coast, and thus descriptions of the coastal vegetation of the Bay describe freshwater marshes composed of herbaceous vegetation located immediately behind a narrow fringe of mangroves. Ross et al. (2000) describes changes to this "white zone" in the "Southeast Saline Everglades" 50 years after the original description by Engler (1952), and describes four marsh types starting with the coastal prairie behind a mangrove fringe, then the *Rhizophora* scrub, *Cladium-Eleocharis-Rhizophora* marsh, and finally the *Cladium* marsh located farthest from the coast. A total of 29 species of plants are documented to occur in these zones.

Ross et al. (2002) further documents the characteristics of the "white zone" and adds details about the microflora, specifically the distribution of 154 diatom species along a salinity gradient from coast to inland saline marsh.

Grossenbacker (pers. comm.) has indicated that for most of Biscayne Bay proper, less than 70 acres of true tidal marsh may still exist based upon the "Advanced Identification of Possible Future Disposal Sites…" (ADID) study conducted in 1994 jointly by the U.S. Environmental Protection Agency, U.S. Army Corps of Engineers and Dade County (U.S. E.P.A. 1994).

Tidal marshes perform similar functions to mangroves, and often have lower salinities than mangrove areas, thus overlapping the important oligohaline habitat type where water flows are sufficient to reduce salinities to 5 psu or less. In other parts of Florida, the oligohaline salt or tidal marsh is often a critical nursery habitat for commercially and recreationally important fish and shellfish including snook (*Centropomus undecimalis*), tarpon (*Megalops atlanticus*), redfish (*Scieanops ocellatus*), and blue crab. In addition, these habitats support the forage fish food base (*Fundulus* spp., *Cyprinodon variegatus, Lucania parva, Floridichthys carpio, Peocilia latipinna*) for many other species (Lewis et al. 1985) (Durako et al. 1985). Documentation of this functional role in salt marshes of Biscayne Bay is only well documented for the forage fish food base (Lorenz 1999, 2000, Lorenz et al. 2002).

Seagrass Meadows and Macroalgae

Seven species of seagrass occur in the Bay: turtlegrass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), manatee grass (*Syringodium filiforme*), paddlegrass (*Halophila decipiens*), stargrass (*Halophila englemanii*), Johnson's seagrass (*Halophila johnsonii*), and wigeon grass (*Ruppia maritima*).

Macroalgae occur mixed with seagrass meadows, and as dominant macrophytes where sediment thickness is too shallow to support seagrass (< 15 cm), or water depths too great to support seagrass which typically require more light (i.e., 25% of the light striking the water's surface), or too turbid to transmit the required levels of light. Generally, macroalgae fall into three categories as to life-form: epiphytic on other plants, drift and attached. Epiphytic algae on mangrove prop roots and pneumatophores include *Bostrychia montagnei*. Drift algae include *Hypnea* spp., *Laurencia* spp. and *Gracilaria* spp. Attached green algae are very common mixed with seagrasses, or as stand-alone communities in hardbottom areas mixed with sponges and soft corals and include *Halimeda* spp., *Penicillus* spp., and *Caulerpa* spp.

Seagrass distribution consists of few meadows around the mouth of the Oleta River, large areas of shoal grass and manatee grass in the northern portion of the Bay transitioning to predominantly turtlegrass in the southern three sub-regions. A band of shoal grass occurs along the western shore of the central and south-central portions of the Bay. Recent work indicates that some wigeon grass occurs where the lowest salinities occur (D. Mir-Gonzalez, pers. comm.). It appears that Johnson's seagrass, a species designated as "threatened" by the federal government, does not occur south of Virginia Key (NMFS, 2002), but the reasons for this pattern of spatial distribution are not known.

As noted by Alleman et al. (1995), many species of small shrimp (both caridian shrimp and juvenile penaeid shrimp), crabs, polycheate worms, clams, snails, echinoderms and fish (both adult and juvenile) are found in this habitat. The commercially and recreationally important fish and shellfish species, pink shrimp (*Farfantepenaeus duorarum*), stone crabs (*Menippe mercenaria*), spiny lobster (*Panulirus argus*) and spotted seatrout (*Cynoscion nebulosus*) are important components of the fauna of seagrass meadows.

Oyster Bars

The American oyster, *Crassostrea virginica*, is a common component of the estuarine fauna from the Gulf of St. Lawrence down the Atlantic Coast, into the Gulf of Mexico and around to the Yucatan peninsula (Galtsoff 1964). The bar or bioherm formation is typical and provides a physical structure supporting dozens of resident species including polycheate worms, amphipods, crabs and small fish (Bahr 1981).

As a habitat component of Biscayne Bay, oysters were historically very common. Smith (1896) states "…There is a luxuriant growth of oysters in parts of Biscayne Bay." Meeder et al. (1997) report that "North Bay supported an active oyster fishery until the 1920's when Haulover Cut was constructed and reduced North Bay renewal time…"

In contrast Alleman et al. (1995) only mention in passing that "Historical freshwater inflows (both ground and surface water) were large and well distributed spatially and seasonally, which presumably supported a richer estuarine fish fauna than we find today…", and mentions that Smith (1896) "reported black drum (*Pogamias cromis*) as common near oyster beds in the bay and red drum (*Sciaenops occelatus*) abundant in all seasons. These estuarine fish are no longer common in Biscayne Bay…" presumably because of the lack of this habitat feature (both dynamic and static components, Browder and Moore 1981).

The Unit Management Plan for Oleta River State Park (FDEP, 2002) reports the existence of a live oyster reef (bioherm) at the mouth of the Oleta River. No further details are given.

Meeder et al. (1997) characterize three submerged plant communities along five transects located from Dinner Key to the Mowry Canal and notes that only fossil oyster bars were found "…buried by only a few centimeters to decimeters of sediment." No live oysters were reported observed. Meeder et al. (1997) also notes that "No extensive fossil oyster bars have been located…" in South Biscayne Bay.

Meeder et al. (1999), reports that no live oyster reefs, but nine historic reefs were found in a survey of 48 tidal creeks between the Coral Gables Canal and Mowry Canal, but that "oysters were seasonally abundant…" and "coon oysters (those that live on mangrove prop roots) were much more abundant." These may not be the American oyster, but are likely one of three other species of oysters that are found associated with mangroves; *Ostrea* (*Lopha) frons*, *Crassostrea rhizophorae* and *Isognomon alatus* (Britton and Morton 1989). Meeder (pers. comm.) has confirmed recent observations of submerged live American oysters in this same vicinity.

Healthy oyster bars are typically found in brackish water where salinities routinely drop below 15 psu. This provides protection from less euryhaline predators such as predatory gastropods and starfish. Changes in freshwater flows to Biscayne Bay (see above under "Mangrove Forests") have altered conditions that historically were more favorable to oyster reef formation and persistence.

Restoration of oyster reefs has been proposed as an indicator of successful management of freshwater flows to Biscayne Bay (Meeder 2001).

Hardbottom

Hardbottom refers to exposed rock or limestone where there are attached algae (*Halimeda* spp, *Penicillus* spp., *Rhipocephalus* spp., and *Udotea* spp.), sponges (*Hippospongia lachne*, *Spongia barbara*, *S. germinea*, *S. cheiris*), hard corals (*Porites* sp., *Solenastrea* sp. *Siderastrea*), fire coral (*Millepora* sp.) and/or soft corals (*Eunicea* spp., *Plexaurella dichotoma* and *Pseudopterogorgia* spp.) (Milano 1983).

Softbottom

Alleman et al. (1995) state that a benthic survey by Schroeder (1984) resulted in documentation of over 800 species of invertebrates. For softbottom habitats generally devoid of submerged aquatic vegetation and attached algae or invertebrates, the predominant organisms are epibenthic or infaunal invertebrates and some benthic fish like the toadfish, *Opsanus beta*. It is reported that Milano (1983) determined that 14% of Biscayne Bay was bare or softbottom habitat, supporting polycheate worms, molluscs (clams and snails), tunicates, nematodes, crabs, shrimp, amphipods and echinoderms, including sea cucumbers.

POTENTIAL INDICATOR SPECIES

The task of identifying individual species or suites of species that would serve as good indicators of ecosystem health is a challenging endeavor that must take into account a variety of inter-related factors, including:

- The existing spatial distribution and abundance of the organism;
- The salinity tolerance range of the species;
- The degree to which non-salinity water quality parameters could affect changes in the presence/absence and spatial distribution of the species;
- The extent to which changes in the species presence/absence over time could be determined to be based primarily on changes in salinity regime; and
- The extent to which impacts to the species that might result from changes in fresh water flows could result in enforcement actions by local, state and/or federal governmental agencies (i.e., impacts to listed species)..

Based on these criteria, a number of species and/or ecological communities have been identified as potential indicators for Biscayne Bay. Each species, or group of species is identified and described in the remainder of this section.

Micro-organisms

Several groups of micro-organisms have been analyzed for their potential utility as indicators of environmental health in Biscayne Bay. The groups that are analyzed in this sub-section include foraminiferans, phytoplankton and benthic diatoms.

Formaniferans

Foraminiferans (forams), tiny protozoans of the Order Foraminifera, are present in fairly large numbers on the surface of sediments in tidal waters.

They are chiefly marine rhizopods that typically have calcareous shells that are often perforated with minute holes through which protrude slender pseudopodia. Although many species are comparatively minute, some exceed 3-5 cm in total length when various spines and ridges are included. Some forams cement sand grains and shell fragments that are gathered from the surface of the sediments, others secrete calcium carbonate. These organisms are a major component of the limestone sediments in tidal areas. They consume unicellular algae, algal spores, bacteria, other micro-organisms such as copepods, ciliates and worms, and organic debris.

Fossil forams are particularly useful in identifying and interpreting historical sediment conditions, due to their overall widespread abundance and occurrence and their ‘convenient‘ size; sufficiently small to be recovered intact and an in large numbers, yet not so small that they cannot be easily examined, identified and counted.

Life spans vary from species to species and generally range from a period of a week or so to several months. Different species have differing sensitivities to certain water quality parameters, and salinity is a key factor in determining the presence / absence of some species.

Analyses of core samples taken at 23 sites located throughout Biscayne Bay during 1996 revealed the presence of 69 foram taxa (Ishman et. al., 1997). Two foram species (*Ammonia parkinsoniana tepida* and *Elphidium galvestonense mexicanum*) appear to have such similar water quality requirements that they often occur in close enough proximity to one another and have been characterized as constituting an *Ammonia-Elphidium* assemblage (Ishman et. al., 1997). These species presently exist in western areas of Biscayne Bay, and could serve as potential indicators of maintenance of desirable salinity regimes (S. Ishman, pers. comm.). Based on various characteristics, including their: a) life cycles, b) relatively narrow salinity tolerance range; c) high tolerance of non-salinity water quality parameters (e.g., elevated nutrients); d) relative abundance; and e) comparatively fast response time, the presence, absence and / or abundance of these species could be an excellent gauge of the extent to which reductions in freshwater flow (and the resulting changes in salinity) are causing harm or significant harm in Biscayne Bay.

On-going studies by Ishman have led to the identification of four benthic foraminiferan assemblages in surficial sediment samples collected in Biscayne Bay. One such assemblage, a “restricted environmental assemblage” is controlled by salinity and has been identified to occur in oligohaline to polyhaline conditions at locations where fresh water inflow is presently occurring.

A record of past ecosystem conditions can be reconstructed by analysis of sediment cores, and several such studies have been conducted in Biscayne Bay. Stone et. al. (2000) used analysis of sediment cores to reconstruct changes in conditions in the Featherbed Bank area of Biscayne Bay. Wingard et al. (2003a, b) have examined cores from Central, South-Central and Southern Biscayne for stratigraphic evidence of pollen, forams, ostracodes, mollusks, and combined this information with geochemical data as part of a paleoecological study of Biscayne Bay. Evidence suggests that over the last 500 years significant changes have occurred, including a general increase in the salinities in South Central Biscayne Bay, and more stable conditions over the last 100 years.

Phytoplankton

Phytoplankton are microscopic floating aquatic single-celled plants. They grow abundantly in oceans around the world and are the foundation of the oceanic food chain. Small fish, and some species of whales, eat them as food. Because phytoplankton depend upon certain conditions for growth, they are a good indicator of change in their environment. Even under ideal conditions an individual phytoplankton only lives for about a day or two. The largest phytoplankton include diatoms, coccolithophorids, and dinoflagellates. The smallest phytoplankton, the ultraphytoplankton (which includes picophytoplankton), include a single-cell planktonic form of the blue-green algae known as the cyanobacteria.

A significant amount of present research is being conducted on the phytoplankton that are associated with ‘red tide’, an increasingly frequent condition in which specific phytoplankton become so numerous that they become toxic to other marine life. In Biscayne Bay, the interest in phytoplankton has primarily been related to the blooms that are associated with discharges of nutrient-laden run-off from uplands. Although phytoplankton are vitally important as primary producers, due to a variety of factors, including their relatively short life cycles, and current-related transport, most phytoplankton would not serve as good indicators of the salinity regimes that are desired in the Biscayne Bay MFL project. A potential exception to this, however, are benthic diatoms, which are described below..

Diatoms

Diatoms are minute unicellular or colonial algae, organisms that are abundant in fresh water, estuarine and marine aquatic ecosystems from tropical areas to polar seas. Although sometimes epibenthic or epiphytic, most diatoms are planktonic. Benthic diatoms have been used as indicators of environmental change, and interpretation of data from sediment cores taken in northeastern Florida Bay have been used to reconstruct changing historical salinity regimes in that Bay (Huvane & Cooper (2000)). Diatoms are a constituent of periphyton, and as such, are being used as an indicator of environmental conditions in Everglades National Park. Wanless (1984) reported that in Biscayne Bay, living diatoms were generally most numerous in northern Biscayne Bay and that their abundance decreased toward the south.

Although phytoplanktonic diatoms are a valuable component at low levels of the food web, for a variety of reasons, including varying sensitivities to salinity and other water quality parameters, their typical existence as plankton, small size, difficulty in sampling and analyzing, diatoms do not appear to be suitable as indicators of estuarine conditions in Biscayne Bay.

Benthic diatoms, however, have been used to examine trends in salinity associated with the "white zone" (Ross et al. 2002, Gaiser and Wachnicka 2003) and may be useful for such situations.

Listed Species

Listed species are those individual species of flora and fauna that have been designated by the state of Florida as ‘endangered’, ‘threatened’ or ‘species of special concern’ and / or designated by the federal government as ‘endangered’ or ‘threatened. Review of information (FGC, 1997) and other information from the State of Florida (Chap 68, F.A.C), the U.S. Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS) and others, indicate that several species that are listed at the state and / or federal levels are known to inhabit the project area (Table 2). Although extremely low numbers and / or their vulnerability to other non-freshwater flow related conditions render most of these species inappropriate as indicators of estuarine health, the presence of some individuals of these species within the project area requires that specific consideration be given to ensure that reductions in fresh water do not result in situations that could be viewed as non-compliance with state and / or federal protected species regulations (e.g., Florida Wildlife Code, Federal Endangered Species Act, as amended). Narrative descriptions are provided for those species which could potentially be affected by reductions in freshwater.

Table 2
Marine and Estuarine Species that are State-listed and/or Federally-listed Species and which are known to occur in Biscayne Bay and/or Adjacent Areas

Common Name	Scientific Name	Designation FL	Federal	Potentially adversely affected by reductions in freshwater?	Comments
Fish					
Key Silverside	*Menidia conchorum*	T		No	Year-round resident in lower Keys, euryhaline Not known to occur in Biscayne Bay
Mangrove Rivulus	*Rivulus marmoratus*	SSC		No	Year-round resident, seems to prefer salinities of 20-35 ppt Distribution largely coincident with *Cardisoma guanhumi*
Key Blenny	*Starksia starki*	SSC		No	Not known from Biscayne Bay, but present on Looe Key, Monroe Co. Prefers coral reef habitat; marine salinities
Smalltooth Sawfish	*Pristis pectinata*		E	No	NMFS advises species largely absent from Biscayne Bay, & that preferred patchy seagrass habitat would not be affected
Reptiles					
American Alligator	*Alligator mississippiensis*	SSC	T(S/A)	No	Year-round resident, primarily in fresh water or low-salinity waters along west side of Biscayne Bay; habitat appears to somewhat overlap with *Crocodylus acutus*
Atlantic Loggerhead Turtle	*Caretta caretta*	T	T	No	Primarily summertime visitor, nesting on east-facing ocean beaches, prefers marine salinities
American Crocodile	*Crocodylus acutus*	E	E	Yes *	All size/ages seem to prefer intermediate (< 20 ppt), salinities, number are few, distributed from south boundary to Coral Gables area
Atlantic Green Turtle	*Chelonia mydas mydas*	E	E	No	Primarily summertime visitor, nesting on east-facing ocean beaches, prefers marine salinities
Leatherback Turtle	*Dermochelys coriacia*	E	E	No	Primarily pelagic, except during spring-summer nesting on east-facing ocean beaches, prefers marine salinities
Eastern Indigo Snake	*Drymarchon corais couperi*	E	E	No	Range may include mangrove wetlands west of shoreline, year-round resident, when present
Red Rat Snake (Lower Keys Population)	*Elaphe guttata guttata*	SSC		No	Not documented to occur north of lower Keys.
Atlantic Hawksbill Turtle	*Eretmochelys imbricata imbricata*	E	E	No	Infrequent visitor to Biscayne Bay, feeds primarily on sponges on reefs Prefers marine salinity regime
Florida Keys Mole Skink	*Eumeces egregious egregious*	SSC		No	Primarily inhabits sandy areas near the shoreline Northerly extent of range is Key Largo
Atlantic Ridley Turtle	*Lepidochelys kempi*	E	E	No	Migrant around Florida, may be an infrequent visitor to Biscayne Bay, prefers marine salinities

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Marine and Estuarine Species that are State-listed and/or Federally-listed Species and which are known to occur in Biscayne Bay and/or Adjacent Areas

Common Name	Scientific Name	Designation FL	Federal	Potentially adversely affected by reductions in freshwater?	Comments
Birds					
Roseate Spoonbill	*Ajaia ajaja*	SSC		Yes *	Uncommon year-round resident, foraging & nesting success appear to be partially dependant on estuarine salinity regimes occurring in suitable foraging habitats
Piping Plover	*Charadrius melodus*	T	T	No	Occasional passage migrant or winter resident, forages in intertidal zone, on sandspits, coastal inlets and mud flats
White-crowned Pigeon	*Columba leucocephala*	T		No	Uncommon year-round resident; primarily inhabits upland tropical hammocks, feeding on fruit-bearing species, including *Ficus* and *Metopium*.
Little Blue Heron	*Egretta caerulea*	SSC		No	Fairly common year-round resident; forages in shallow waters (fresh, marine and/or estuarine); No apparent salinity preferences
Reddish Egret	*Egretta rufescens*	SSC		No	Uncommon year-round resident; spring-summer nesting in coastal mangroves Appears to prefer mesohaline to hypersaline conditions
Snowy Egret	*Egretta thula*	SSC		No	Fairly common year-round resident; forages in shallow waters (fresh, marine and/or estuarine); No apparent salinity preferences
Tricolored Heron	*Egretta tricolor*	SSC		No	Fairly common year-round resident; forages in shallow waters (fresh, marine and/or estuarine); No apparent salinity preferences
White Ibis	*Eudocimus albus*	SSC		No	Fairly common year-round resident; forages in shallow waters (fresh, marine and/or estuarine); No apparent salinity preferences
Arctic Peregrine Falcon	*Falco peregrinus tundris*	E		No	Migrant/winter resident; opportunistic predator, primarily on other birds No apparent salinity preferences
American Oystercatcher	*Haemotopus palliatus*	SSC		No	Infrequent visitor, forages on benthic and benthonic organisms, relative absence may be related to lack of *Crassostrea virginica*
Bald Eagle	*Haliaetus leucocephalus*	T	T	No	Occasional sightings throughout the year; no documented nests within project area; primarily piscivorous, no salinity regime preference
Wood Stork	*Mycteria americana*	E	E	No	Uncommon winter resident, although year-round in nearby Everglades; forages primarily in shallow fresh or estuarine waters; Nesting not known in project area
Brown Pelican	*Pelecanus occidentalis*	SSC		No	Abundant to common year-round resident, but no nesting colonies within project area; Prefers estuarine/marine salinity regimes
Black Skimmer	*Rhynchops niger*	SSC		No	Rare to uncommon within project area; forages on small fish near surface, (e.g., *Menidia*, *Fundulus*, *Anchoa* and *Mugil*); prefers estuarine/marine salinity regimes
Least Tern	*Sterna antillarum*	T		No	Summertime breeding resident, feeds on small fish on surface; Nests on barren or sparsely-vegetated beaches & rooftops near estuarine/marine salinity regimes
Roseate Tern	*Sterna dougallii*	T	T	No	Rare winter visitor; feeds on small fish on surface. Prefers estuarine/marine salinity regimes

Table 2
Marine and Estuarine Species that are State-listed and/or Federally-listed Species and which are known to occur in Biscayne Bay and/or Adjacent Areas

Common Name	Scientific Name	Designation FL	Federal	Potentially adversely affected by reductions in freshwater?	Comments
Mammals					
Everglades mink	*Mustela vison mink*	T		No	Primary habitat is the shallow freshwater marshes of the Everglades and Big Cypress Swamp; unlikely to be present in tidally-affected areas of Biscayne Bay
Key Largo Woodrat	*Neotoma floridana smalli*	E	E	No	Habitat is dry tropical forest on northern Kay Largo, where it forages primarily in the forest canopy
Key Largo Cotton Mouse	*Peromyscus gossypinus allapaticola*	E	E	No	Habitat is primarily dry tropical forest on northern Kay Largo, but it has been documented to occur in Salicornia-dominated coastal strand
West Indian Manatee	*Trichechus manatus latirostris*	E	E	Yes *	Year-round resident, but more numerous during winter Seeks canal discharges during winter for warm &/or fresh water
Corals					
Pillar coral	*Dendrogyra cylindrus*	E		No	Present on coral reefs in eastern portions of project area, prefers marine salinity regime
Molluscs					
Florida Tree Snails	*Liguus fasciatus*	SSC		No	Inhabits upland hammocks, feeding primarily on epiphytic growths (i.e., lichens, fungi and algae on smooth-barked trees, including *Lysiloma* and *Ficus*.
Invertebrates					
Shaus' Swallowtail	*Papilio aristodemus*	E	E	No	Present in uplands (tropical hardwood hammocks and neighboring scrub area) within project area, host plants in Rutaceae
Miami Blue Butterfly	*Hemiargus thomasi bethunebakeri*	E		No	Present in openings and edges of tropical hardwood hammocks within project area, host plants include *Cardiospermum halicacabum*, possibly *Chiococca alba*, and various legumes
Marine Plants					
Johnson's Seagrass	*Halophila johnsonii*		T	Yes	Prefers less than marine salinities, South end of natural range appears to be near Virginia Key

American Crocodile

The American crocodile (*Crocodylus acutus*) is protected pursuant to the Florida Wildlife Code and the federal Endangered Species Act, as amended. Its designation at both levels is 'endangered'. An initial recovery plan for this species was developed in 1979. The plan was updated in 1994, and recovery actions are currently being implemented in accordance with the Multi-species Recovery Plan for South Florida (USFWS, 1999), which among other things, states that: "The American crocodile is a valuable indicator species of the health of South Florida's estuarine environments". Critical habitat has been designated for this species (Figure 10); the northern portion of which is included within the Biscayne Bay MFL project area.

Crocodiles are large, greenish-gray reptiles that reach lengths of approximately 3.8 m (11.4'). Males are somewhat larger than females, both of which can be distinguished from alligators by having a longer, narrower, more tapered snout.

Together with the American alligator (*Alligator mississippiensis)*, the American crocodile is one of two species of crocodilians endemic to the United States. Although their historic range may have extended up the east coast as far as Lake Worth Lagoon (Palm Beach County), up the west coast to the Tampa Bay area and south to Key West, crocodiles presently inhabit only coastal areas of extreme South Florida, being found primarily in mangrove communities in Monroe, Miami-Dade, Collier and Lee Counties. Their range also includes the Caribbean, Mexico, Central America and northern South America.

Hunting, habitat loss and fragmentation due to increased urbanization and agricultural lands uses have all contributed to the reduction in numbers of these large, reptilian carnivores (USFWS, 1999). Losses may also be attributable to vehicle-related mortality (particularly on U.S. 1 and Card Sound Road), and depredation of eggs or young, primarily by raccoons. At varying times and location, nest failures have also been attributed to both flooding and dessication (Mazzotti et. al., 1988, and Mazzotti 1989). Ogden (1978a) suggests that the disappearance of crocodiles from much of Florida Bay came about, "at least in part" because of increased mortality rates among salt-stressed juveniles.

The American crocodile is found primarily in mangrove swamps and low-energy mangrove-lined bays, creeks and inland swamps (Kushlan and Mazzotti, 1989). Nest areas typically include creek banks and other locations where sandy shorelines or raised marl creek banks are adjacent to deep water, particularly at locations that are protected from wind and wave action (USFWS, 1999). During the non-nesting season, crocodiles typically inhabit fresh and brackish water inland swamps, creeks, and bays (Kushlan and Mazzotti, 1989).

American crocodiles forage primarily from shortly before sunset to shortly after sunrise. Juveniles typically eat fish, crabs, snakes, and other small invertebrates. Adults eat fish, crabs, snakes, turtles, birds and small mammals (Ogden 1978b, Ross and Magnusson, 1989).

Field data collected from Florida Bay, Dunson (1982) documented that although American crocodile hatchlings are intolerant of 35 ppt water, his laboratory studies indicated that most small American crocodiles maintained body mass at salinities up to 17 ppt, and some even gained mass at 26 ppt. Kushlan (1988) suggests that hatchling crocodiles possess a number of behavioral adaptations for survival in hypertonic conditions, including consuming water-laden prey items, drinking freshwater from pools and lenses riding on top of salt water and avoidance of salt uptake. Also regarding salinity preferences and tolerances, USFWS (1999) states that:

"Water salinity affects habitat use and may be locally important, especially during periods of low rainfall. Although American crocodiles have salt glands that excrete excess salt and physiological mechanisms to reduce water loss...maintenance of an osmotic balance requires access to low salinity for juveniles. Hatchling crocodiles are particular susceptible to osmoregulatory stress and may need to have brackish to fresh water (4 ppt) available at least once per week to increase growth (Mazzotti et, al. 1986). Crocodiles larger than 200 g have sufficient mass to withstand osmoregulatory stress and are not typically believed to be affected by drought (Mazzotti and Dunson 1984). Freshwater needs of the crocodile are usually met with frequent rainfall, which results in a “lens” of fresh water on the surface for several days after rainfall (Mazzotti and Dunson 1984). Hatchling crocodiles are probably stressed and occasionally die during periods of low rainfall. Anthropogenic changes in the amount and timing of fresh water flow to South Florida may have resulted in shifts in the distribution of American crocodiles.”

Estimates of the population of crocodiles in South Florida suggest that from historical numbers of 1,000 to 2,000, numbers dropped to all-time lows during the 1960s and 1970s during which it is thought that there were between 100 and 400 non-hatchlings (USFWS 1999.), and that numbers have increased substantially since that time.

The most recent surveys for crocodiles in Biscayne Bay which are reflected in publications were performed by Mazzotti and Cherkiss (1998) pursuant to a contract with the SFWMD. Surveys were conducted from September 1996 through May 1998. During that period, a total of 132 crocodile observations were made. Sightings ranged from Chapman Field and the Coral Gables Waterway at the north to the U.S. 1 corridor and the Crocodile Lakes National Wildlife Refuge on Key Largo at the south. Figure 11 shows the locations and comparative numbers of crocodile sightings and captures as reported by Mazotti and Cherkiss (1998). Surveys did not include the cooling canal system at Florida Power and Light Company's Turkey Point Power Plant, an area long known for its population of crocodiles.

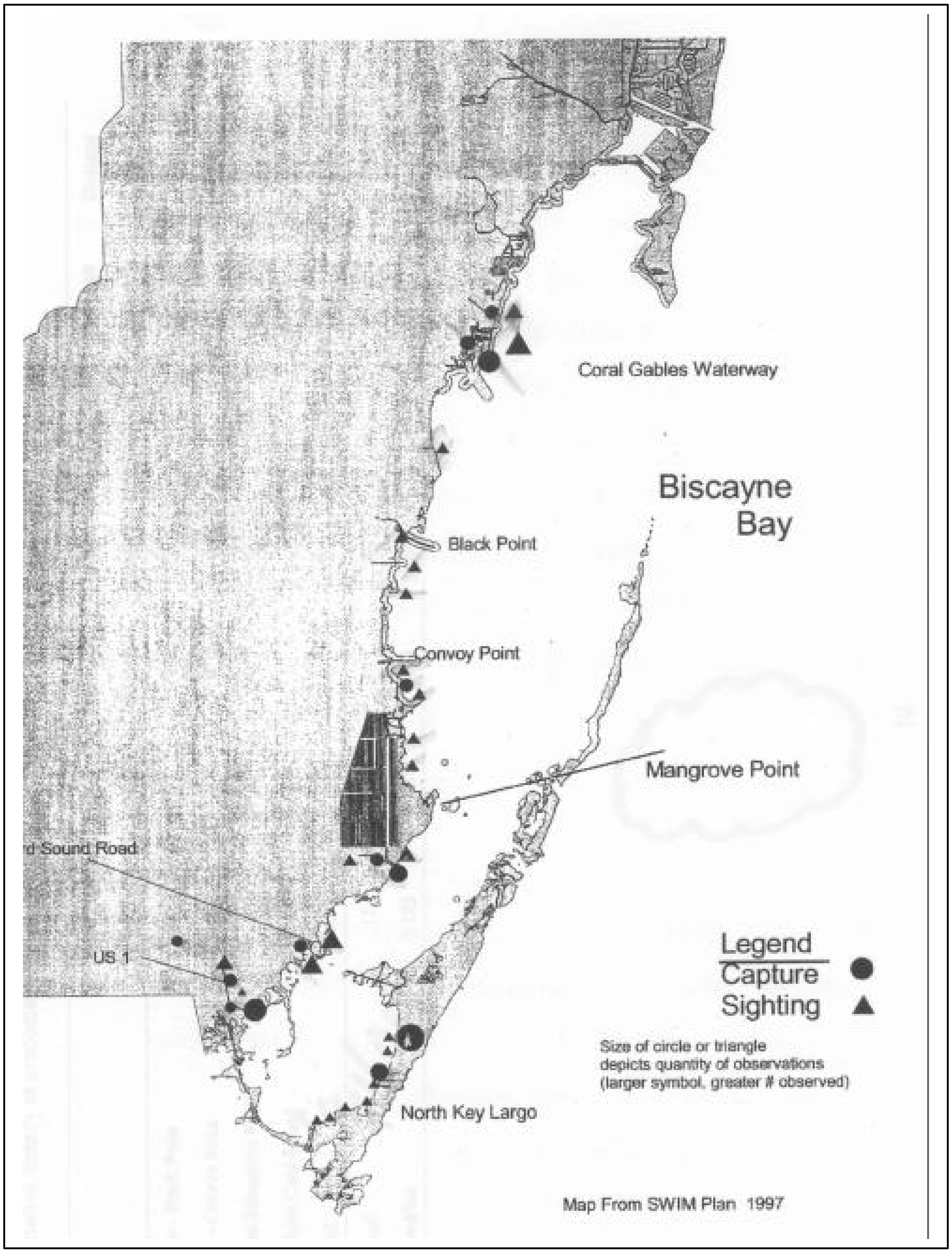
Limited water quality data were recorded at the locations of observations. Although salinities varied from 0 ppt to nearly 40 ppt, 45% of all non-hatchling crocodile observations were in water with salinity measurements of 0-5 ppt (Figure 12). In discussion of their findings, Mazzotti and Cherkiss (1998) state that: "Crocodiles benefit from restoration and maintenance of freshwater flows into the estuarine habitat. Location, timing, and amount of flow are important. For example, when possible freshwater flows should be directed through the remaining fringing mangrove swamp rather than simply discharged through canals. In general flow should peak at the end of the rainy season and continue discharging into the dry season. Freshwater flow should be adequate to maintain estuarine conditions (< 20 ppt salinity) into December in most years."

USFWS (1999) corroborates that "The timing and frequency of the freshwater hydroperiod substantially influences the health of the estuarine environment in South Florida and may be one of the most important large-scale factors influencing crocodile populations on the mainland".

Roseate Spoonbill

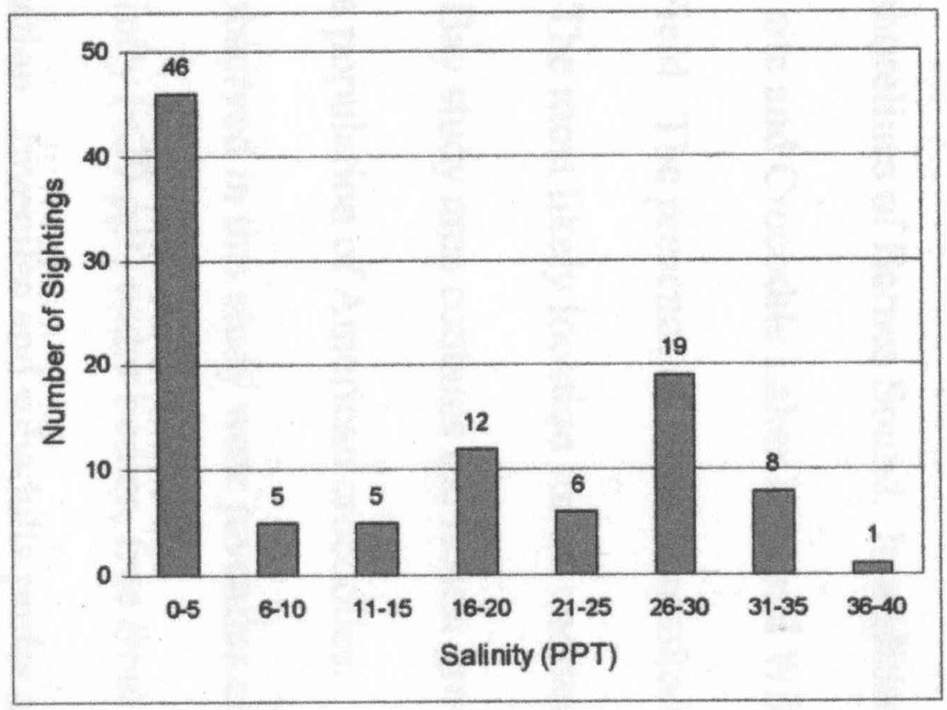
The Roseate Spoonbill (*Ajaia ajaja*), a brightly-colored, long-legged wading bird with a spatulate bill, is the only spoonbill native to the western hemisphere. It has been designated as a 'Species of Special Concern' by the State of Florida. Although it is protected pursuant to the federal Migratory Bird Treat Act, this species is not protected pursuant to the federal Endangered Species Act. No recovery plan has been developed and there is no designated critical habitat for this species.

Figure 11
Locations of Crocodile Sightings and Captures



Source: Mazotti and Cherkiss, 1998. Status and Distribution of the American Crocodile (*Crocodylus acutus*) in Biscayne Bay

Figure 12
Crocodile Sightings in Relation to Salinities



Source: Mazotti and Cherkiss, 1998. Status and Distribution of the American Crocodile (*Crocodylus acutus*) in Biscayne Bay

Accounts of historical populations suggest that the spoonbill population in the United States numbered in the thousands prior to the 1850s, after which a rapid decline occurred. This decline, which was attributed to the disturbance of colonies, plume hunting and collection of nestlings and adults for food and which occurred between 1850 and 1920, reduced the nationwide population to approximately 25 pairs (Allen 1942). By 1941, only one nesting colony (Bottle Key) was known to exist in Florida (Lorenz et. al., 2002). Populations began to rebound, however after protection mechanisms were enacted, particularly in coastal Texas and Louisiana, and estimates were that 2,200 to 2,700 nesting individuals existed in the 1970s.

Presently, although there are several widely-spaced individual nesting sites in other coastal areas in the southern half of peninsular Florida, the primary nesting areas for this species are in extreme south Florida. Ninety percent of spoonbill nesting in Florida has been on mangrove islands in Florida Bay in Everglades National Park, although a colony was recently documented to occur in coastal areas west of the mangrove shoreline in southern Biscayne Bay (Lorenz, pers. comm.). Lorenz et al. (2002) report that in recent years there have been more than 30 islands in Florida Bay with spoonbill nesting colonies. Cumulatively, the lack of terrestrial predators (primarily raccoons), minimal amount of human disturbance, lack of parasites and disease, and the presence and availability of prey items all likely contribute to the continued viability of individual nesting sites (Lorenz et. al., 2002).

Spoonbills forage in shallow marine, brackish and freshwater sites, including tidal ponds, and sloughs, mud flats, mangrove-dominated pools, freshwater sloughs and marshes and man-made impoundments (R. Bjork, 1996). Mangrove-dominated shorelines and the marine-estuarine transition zone have been documented as the primary foraging areas used by the spoonbills that nest in Florida Bay. The dwarf mangrove community that is present in areas where there is little soil accumulation overlaying a rock substrate appears to provide valuable foraging habitat for spoonbills.

Spoonbills forage in shallow by sweeping a partially-open bill back and forth in a semi-circular motion while slowly walking forward in search of small prey items. When the bill strikes a prey item, it immediately snaps shut; a process known as tactolocation. This unusual foraging strategy is successful only when water depths are less than 20 cm (Lorenz, 2000). Investigations regarding prey items (Allen, 1942, Dumas, 2000, Lorenz et. al., 2002) indicate that small fishes, including sheepshead minnows (*Cyprinodon variegatus*), sailfin mollies (*Poecilia latipinna*) are the primary prey items. Shrimp (*Palaemonetes* sp.) are also taken.

Annual wet season and dry season water level fluctuations that are typically present in south Florida are critical to the nesting success of many wading birds, including spoonbills. Their annual nesting cycle is timed around the decreasing water levels that are associated with the winter-spring dry season. Foraging by adults is most effective during this period, when the population of prey, which has increased during the wet season, becomes concentrated as surface waters diminish.

Although most spoonbills nest on islands in Florida Bay, they make daily flights to foraging areas to mainland wetlands north of Florida Bay. By conducting studies of flight distance from nesting sites during 1989-90, Lorenz, et. al. (2002), documented that the mean flight distance for spoonbills nesting in Florida Bay was 12.4 km $\pm$ 5.8 km (mean $\pm$ standard deviation), with approximately 83% of the flights being less than 16 km.

Recent studies by Lorenz (1999, 2000) in Florida Bay have revealed that comparatively higher, and more variable salinities in the same coastal wetlands has resulted in reduced prey biomass for foraging spoonbills. Additionally, long-term studies of spoonbill nesting territories indicates that spoonbills do respond to the destruction or degradation of their foraging grounds by relocating to other areas in closer proximity to suitable foraging areas. For these reasons, spoonbills appear to be an excellent indicator of ecosystem health for southern Biscayne Bay, as indicated by the maintenance of a nesting population adjacent to the Bay. Maintaining suitable foraging habitat for spoonbills may also contribute to the success of spoonbills and other bird species that nest outside the boundary of the project area

Additionally, because a variety of other vertebrate predators, including piscivorous fishes, reptiles and wading birds also depend on the same prey items, the continued presence of spoonbills will likely also indicate success for other species.

West Indian Manatee

West Indian manatees are large, herbivorous, air-breathing aquatic mammals that can be found within suitable habitat throughout much of peninsular Florida. They are protected pursuant to the Florida Wildlife Code and the federal Endangered Species Act, as amended. Their current designation at both levels is ‘endangered’, although the Florida Fish and Wildlife Conservation Commission is considering a ‘downlisting’ to threatened. An initial federal recovery plan for this species was developed in 1996, and the Multi-species Recovery Plan for South Florida (USFWS, 1999), contributed information pertinent to South Florida and Biscayne Bay. Critical habitat was designated for this species in the early 1970s as areas occupied by manatees 'which have those physical or biological features essential to the conservation of the manatee and / or which may require species management considerations". No specific locations, maps or other descriptions were provided to more specifically define critical habitat.

Miami-Dade County was one of 13 key counties that were required by the State of Florida to develop a county-specific Manatee Protection Plan (MPP). That Plan, DERM Technical Report 95-5 (DERM 1995), provides extensive information regarding manatees in Miami-Dade County, including sections on: habitat, manatee-human Interaction, local land development, education and awareness, governmental coordination and habitat protection. The MPP was approved by the State of Florida on December 21, 1995.

Manatees potentially inhabit all areas of Biscayne Bay. Depending on the design of any individual water control structure, manatees may also travel upstream of these structures. Although manatees may be present in the Bay during any month of the year, they are most numerous in Biscayne Bay during the winter months, a time in which manatees that have ranged to more northerly latitudes during other times of the year, return to south Florida as ambient water temperatures cool. Water temperatures lower than approximately 20^0C appear to increase manatee's susceptibility to cold-related stress and cold-induced mortality. In north and central Florida, manatees' winter-time distribution is primarily centered around reliable sources of warm water (e.g., power plant discharges, springs). Other manatees move south, where it is less likely that ambient water temperatures will drop below acceptable levels.

Manatees inhabit both freshwater and saltwater habitats, and the USFWS (1999) reports that: "Several factors contribute to the distribution of manatees in Florida. These factors are habitat-related and include proximity to warm water during cold weather, aquatic vegetation unavailability, proximity to channels of at least 2 m in depth, and location of fresh water sources." Natural or artificial sources of freshwater are sought by manatees, particularly those individuals that spend time in both estuarine and brackish water."

Manatees are opportunistic herbivores that feed on a variety of submerged, emergent and floating plants. Although their most well-known forage species are seagrasses, including turtle grass, and manatee grass they are also known to consume algae (Lewis et al. 1983). Although manatees unquestionably inhabit areas with marine salinities, and appear to survive equally well in fresh and salt waters, in areas of primarily marine salinities, manatees are well known for their desire to drink fresh water. They will drink water from hoses, and frequently travel upstream into rivers and canals, at least in part to reach freshwater areas.

Surveys and censuses of manatees have been performed annually for many years by local, state and/or federal agency personnel. These surveys have included aerial observations (typically fly-overs in fixed-wing aircraft immediately after the passage of cold fronts) and tracking of manatee movement by radio and/or satellite telemetry. The data, which were compiled for the period from 1989-94 reveals a number of specific area where there were repeated sightings (Figures 13a - c).

Based on the analyses of these data, the MPP identified 'preferred manatee habitats' as areas with dense vegetation for feeding, freshwater sources for drinking, and warm water refuges for warmth during the cold and further identified "Essential Manatee Habitat" as "any land or water area constituting elements necessary to the survival and recovery of the manatee population from endangered status which may require special management considerations and protective measures. The constituent elements include, but are not limited to: space for individual and population growth, and for normal behavior; available food sources with adequate water depth and quality; warm and fresh water sources; sites for breeding and rearing of offspring; and habitats protected from disturbances that are representative of the geographical and seasonal distribution of the species." It additionally identifies eight such Essential Manatee Habitat areas (Figures 14 a - d). Each of the six sub-regions that have been identified for the MFL project contains at least one of these Essential Manatee Habitat areas.

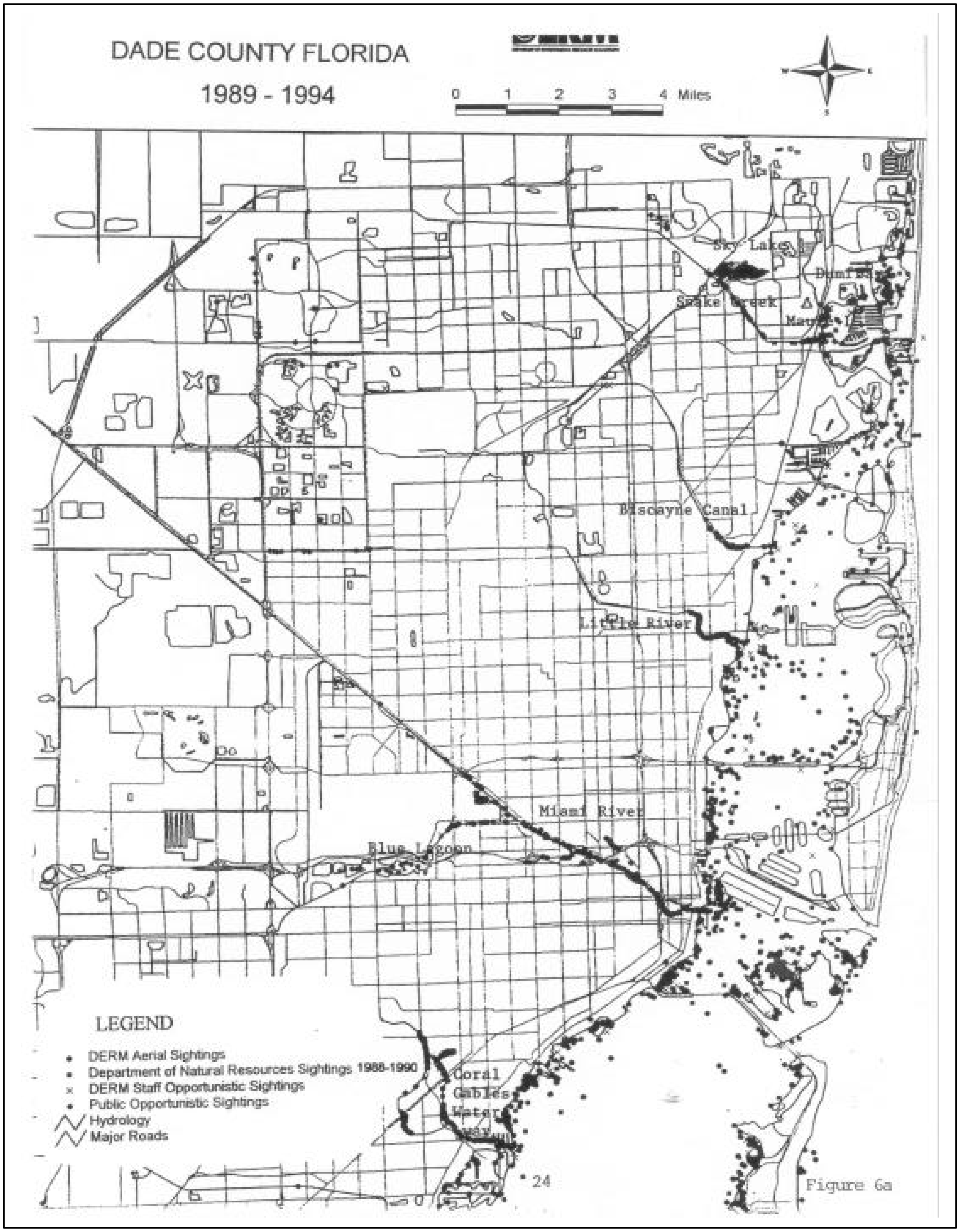
In general terms, the manatee habitat areas that could be adversely affected by reductions in the flows of freshwater include the following MPP designations; 1) Fresh Water Sources; 2) Warm Water Refuges and; 3; Other Aggregating Areas.

Fresh Water Sources

Regarding Fresh Water Sources, the MPP states that:

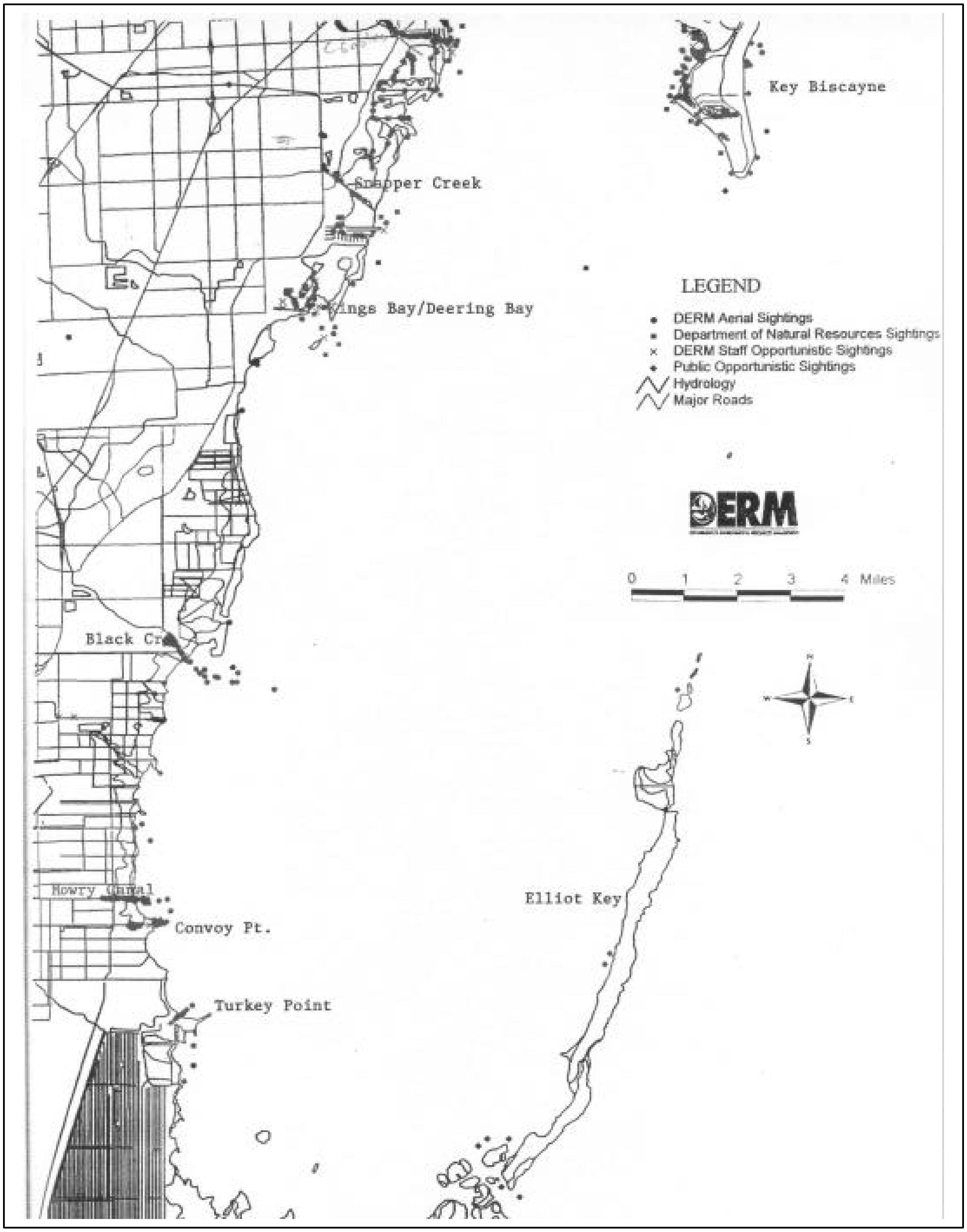
"Manatees utilize freshwater canal systems in Dade County, particularly during warm weather. They travel through open flood gates to access these areas. Manatees are observed as flood gates year-round, but aggregate at these locations in large numbers during cool weather. Those flood gates where manatees are most frequently

Figure 13 a
Manatee Sightings – Northern Biscayne Bay



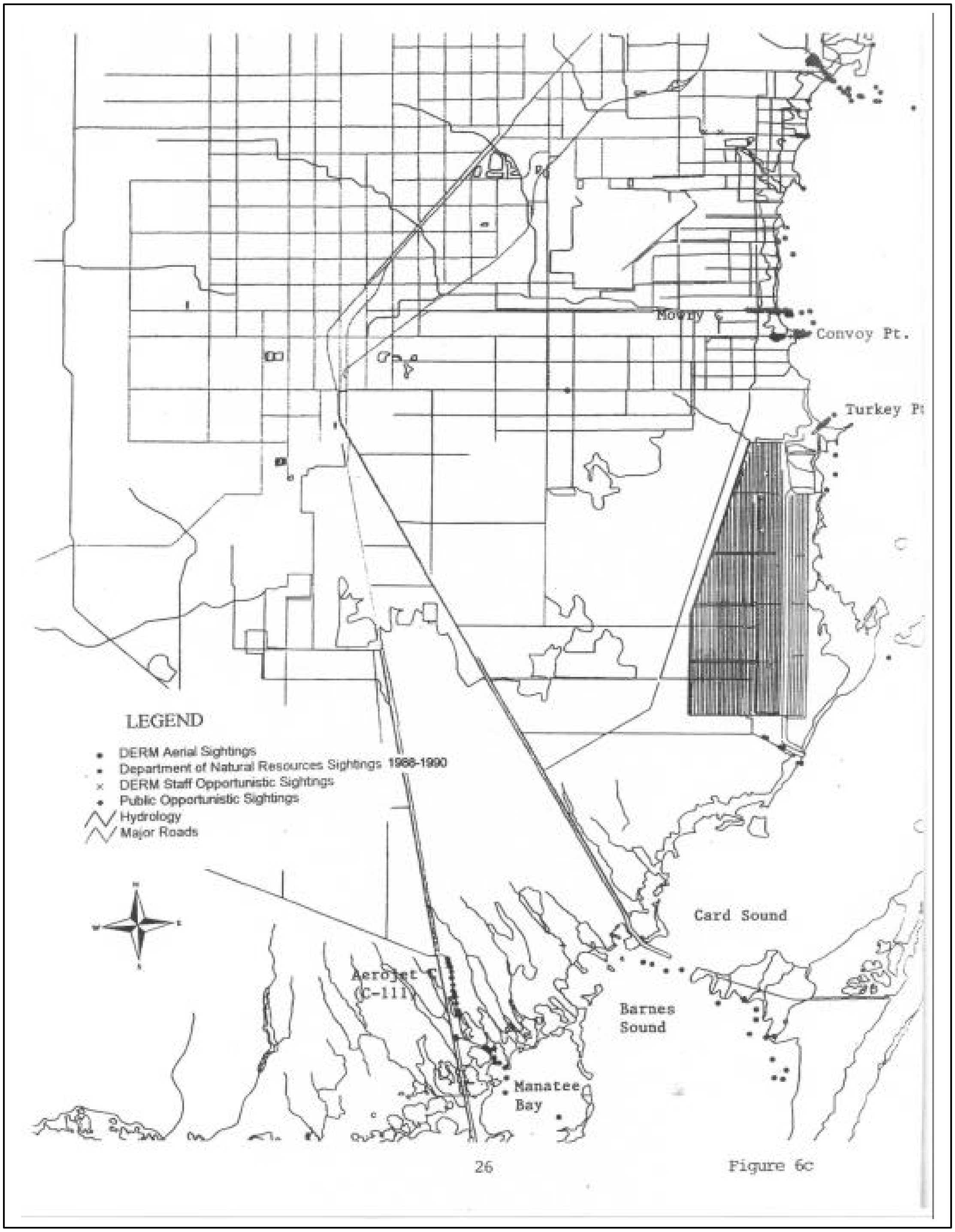
Source: Manatee Protection Plan. Miami-Dade Department of Environmental Resources Management

Figure 13 b
Manatee Sightings – Central Biscayne Bay



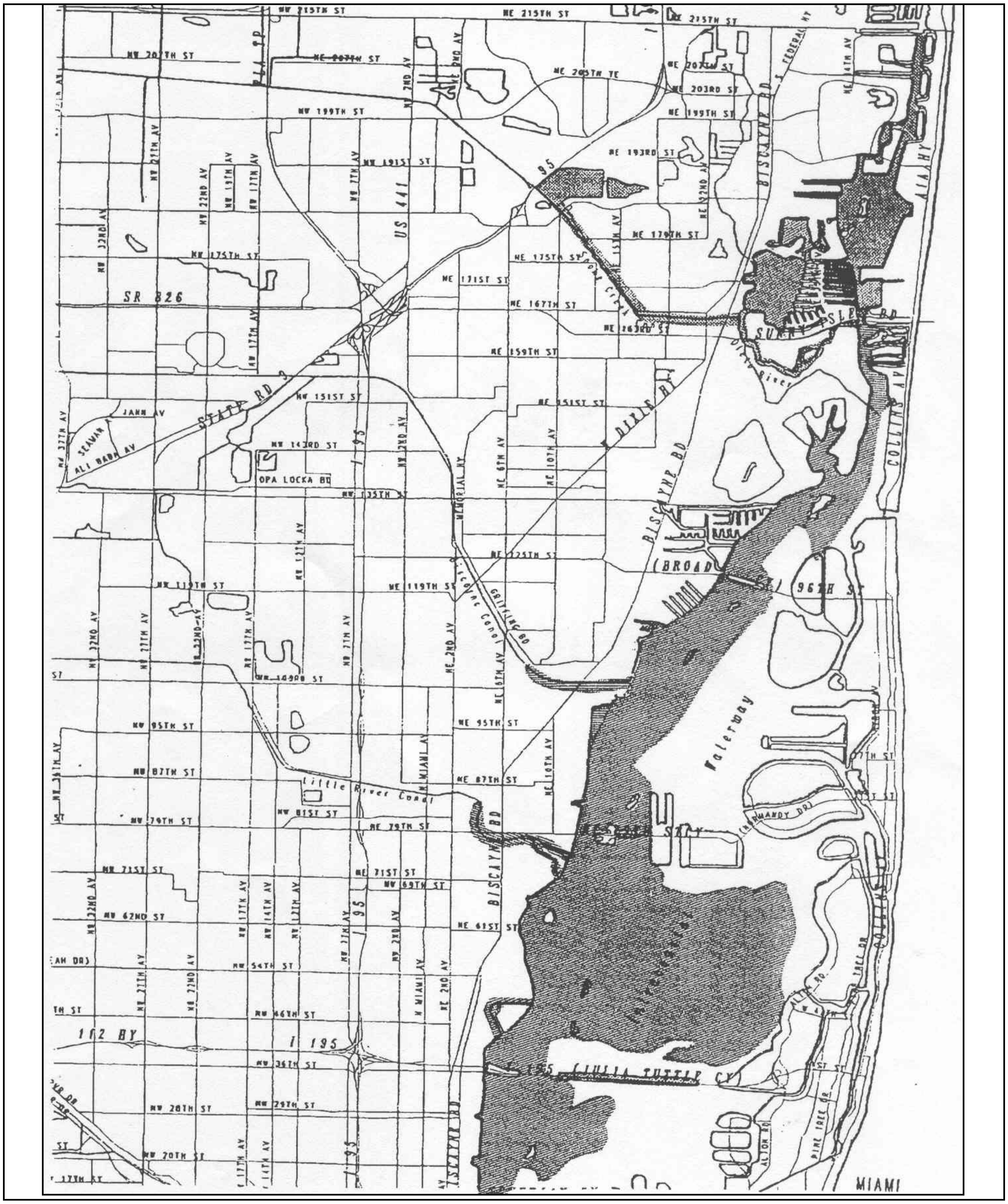
Source: Manatee Protection Plan. Miami-Dade Department of Environmental Resources Management

Figure 13 c
Manatee Sightings – Southern Biscayne Bay



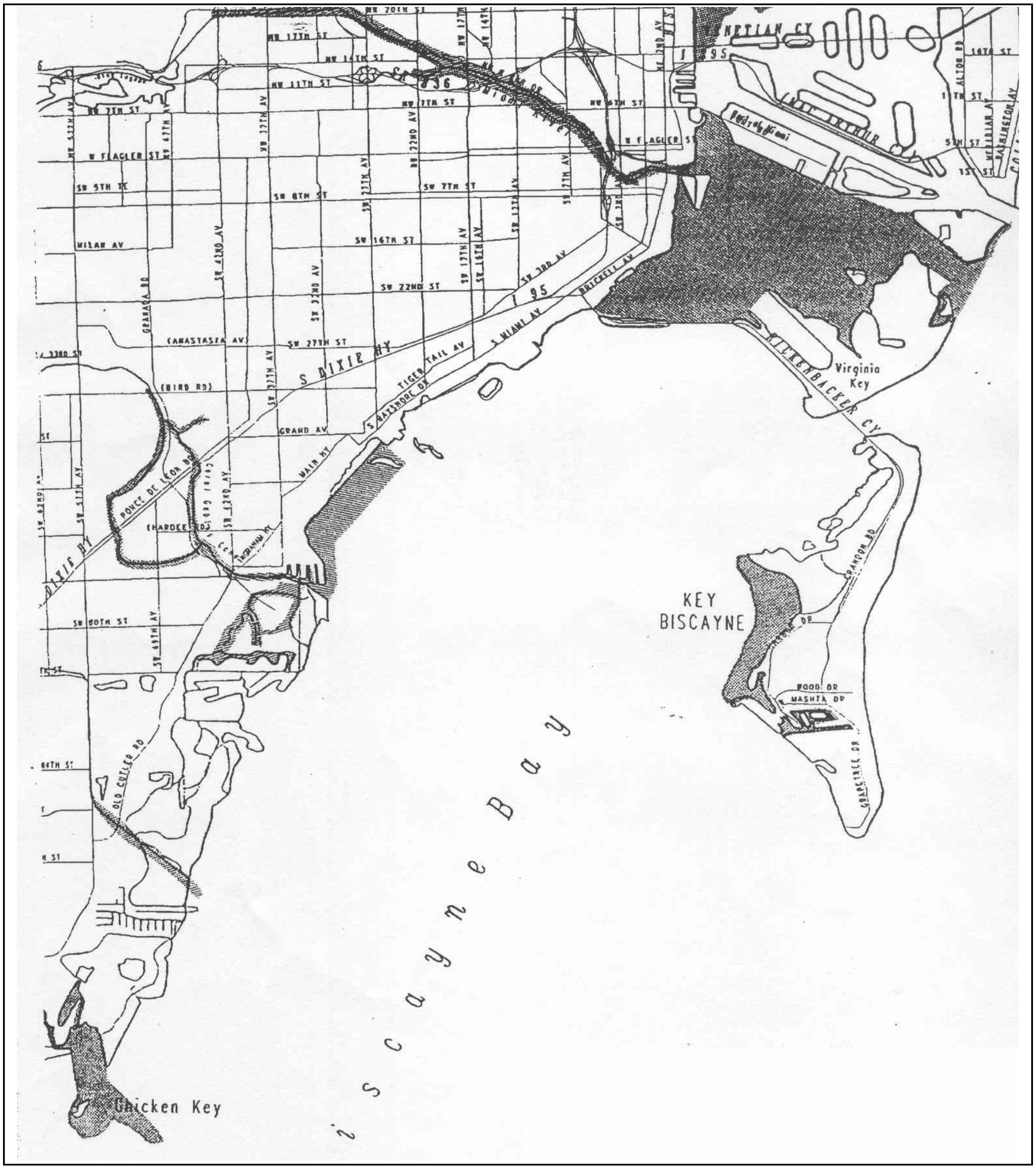
Source: Manatee Protection Plan. Miami-Dade Department of Environmental Resources Management

Figure 14 a – Essential Manatee Habitat Areas



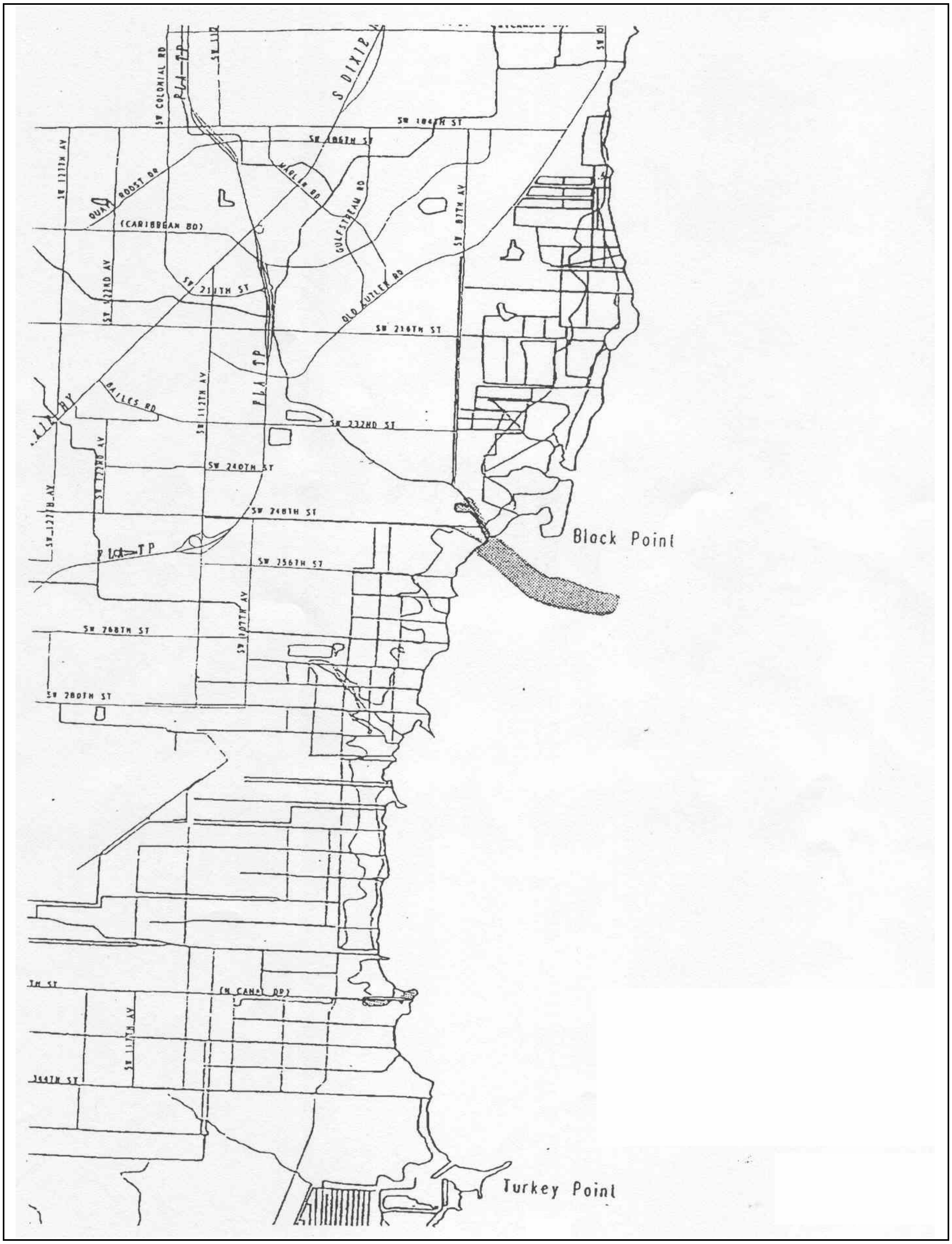
Source: Manatee Protection Plan. Miami-Dade Department of Environmental Resources Management

Figure 14 b – Essential Manatee Habitat Areas



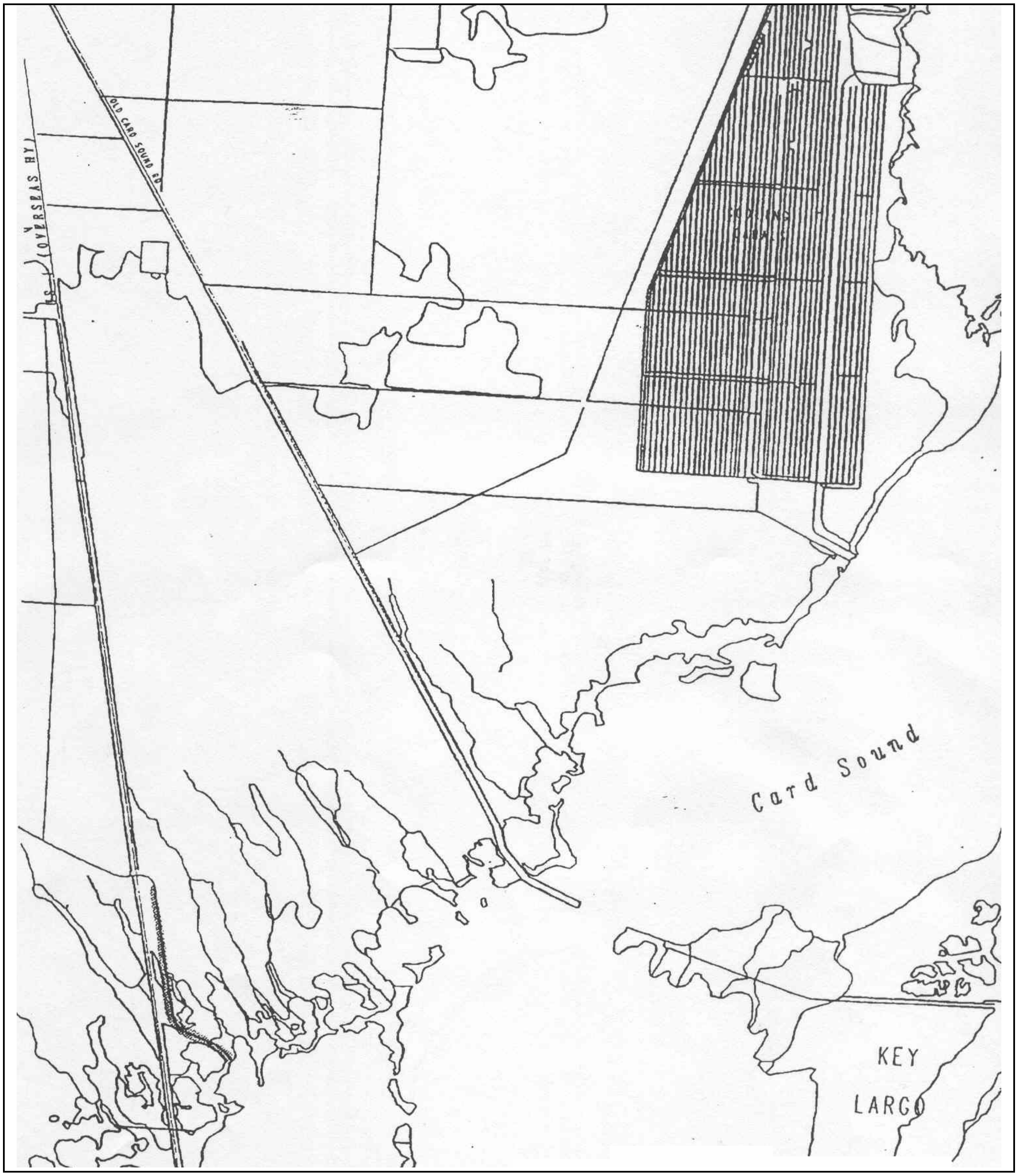
Source: Manatee Protection Plan. Miami-Dade Department of Environmental Resources Management

Figure 14 c – Essential Manatee Habitat Areas



Source: Manatee Protection Plan. Miami-Dade Department of Environmental Resources Management

Figure 14 d – Essential Manatee Habitat Areas



Source: Manatee Protection Plan. Miami-Dade Department of Environmental Resources Management

observed are located on Snake Creek, Biscayne Canal, Little River, Miami River, Tamiami Canal and Black Creek. Another popular manatee fresh water source is a stormwater outfall structure on a canal connected to Coral Gables Waterway. A daily pattern has been observed by manatee trackers in Dade County during cold weather months: many manatees leave Biscayne Bay in the morning and travel up rivers and canals to the fresh water source where they drink and rest, and will return to the Bay in the afternoon (Pers comm.., Kathryn Curtin, USFWS, 1990).

The portion of Little River immediately downstream of the salinity control structure is a consistent manatee gathering place during the winter months. Manatees drink freshwater water which leaks through the structure".

Warm Water Refuges

Regarding warm water refuges, it is well known that manatees are attracted to springs and the warm-water discharges from power plants during the winter, however, due to its sub-tropical location, ambient water temperatures in Biscayne Bay are thought to be warm enough for manatee use, "except during prolonged periods of cold temperatures" (DERM 1995). There are no springs in Miami-Dade County that are known to attract manatees. There are two power plants in Miami-Dade County, and both are located in coastal areas. The largest of these, the Florida Power and Light Company (FPL) Turkey Point Plant uses a cooling canal system that has no direct surface connection to Biscayne Bay, and therefore manatees are not attracted to this facility. FPL also maintains a power plant in the Cutler area. The Cutler Power Plant discharges thermally enhanced water into a tidal canal adjacent to Biscayne Bay. However, this facility is intermittently used, and is not a major aggregating site for manatees. FPL's Port Everglades Power Plant in Broward County does attract manatee in large numbers during the winter, and some of these manatees travel back and forth from the warm water discharge to foraging areas in Miami-Dade County.

Although there are no major sources of warm water in Miami-Dade County, aerial censuses have documented that manatees that are in County waters during prolonged periods of cold weather move upstream into rivers and canals and into deeper, protected waters that tend to stay slightly warmer than the shallow, exposed Bay (DERM 1995). Specific areas that are known to be used for this purpose are the Coral Gables Waterway, the upper Miami River and Little River.

Other Aggregation Areas

In addition to the known attractants of fresh water and warm water, localized conditions are known to attract manatees at several specific locations. Locations within the MFL project area include: 1) an extensive seagrass bed located on the northwest side of Virginia Key; and 2) a portion of the Black Creek marina.

Although it is not specifically designated as 'Aggregation Area', manatees have been documented to forage in the seagrass beds in South Dumfoundling Bay and between the Port of Miami and Rickenbacker Causeway. It is thought that the manatees that forage in these areas may be individuals that are attracted to the warm water discharges from the Port Everglades Power Plant (Broward County), and which move southward to these areas to feed.

Because manatees forage primarily on seagrasses, and because the presence, absence, distribution and density of individual seagrasses are somewhat dependant on salinity, manatees may potentially be affected by modifications to the delivery of fresh water into Biscayne Bay. However, because the likely effect of even a total cessation of freshwater inflows would be a shift in the species composition of seagrasses (replacement of manatee grass, shoalgrass and paddle grass with turtle grass) and not a significant overall reduction in seagrass biomass, reductions of inflows would not likely result in adverse impacts to manatee foraging habitat.

The MPP identifies a number of causes of manatee mortality and identifies corrective measures that are to be implemented to address these causes. Because flood gates, where manatees had gotten crushed when automatic sensors directed flood gates to close, were a major component of manatee mortality (46% during the period from 1974 through 1994) (DERM, 1995), direct attention was paid to re-designing the structures to reduce manatee mortality. Because collisions with vessels was the second highest known cause of death (27% during the period from 1974 through 1994), the County adopted a variety of zones where boat speeds were to be restricted. Vessel speed restriction zones are found in five of the six MFL-designated sub-regions of Biscayne Bay; there are no restriction zones in the Southern Bay sub-region. The location of these zones is shown on a variety of brochures (e.g., Boating and Angling Guide to Biscayne Bay) and distributed free to the public.

West Indian Manatees have been identified by USFWS (1999) as an indicator species for aquatic habitats, including seagrasses and mangroves in the South Florida ecosystem. Because seagrasses and mangrove habitats provide areas for foraging, calving, resting and mating, the presence, abundance and distribution of manatees are indicators of the health and vitality of these systems.

Johnson's Seagrass

Johnson's seagrass (*Halophila johnsonii*) is a small, rare aquatic plant that is known only to occur along the east and southeast coast of Florida from Brevard County to Biscayne Bay. It was designated as a threatened species in 1998 pursuant to the federal Endangered Species Act, as amended. It is not currently protected under State of Florida statutes, rules or regulations, although Section 581.185 F.S. 'provides for the automatic listing as a state endangered species of "all species determined to be endangered or threatened pursuant to the federal ESA of 1973" (NMFS 2002). A federal recovery plan for this species has been developed and was approved by the National Martine Fisheries Service, National Oceanic and Atmospheric Administration in 2002. Critical Habitat was designated for this species in ten distinct areas. The largest of these areas encompasses a significant portion of Biscayne Bay, and includes portions of the MFL Snake Creek / Oleta River, Northern Biscayne Bay and Miami Rover / Government Cut Sub-regions.

Johnson's seagrass is one of twelve species of *Halophila*, a genus that is distributed in warm-temperate and tropical waters worldwide (NMFS 2002). It is one of three species that is documented to occur in Biscayne Bay, and can be differentiated from the other species by having pairs of 2-5 cm long, linear leaves that extend upward from a rooted rhizome that is located just below the sediment surface. Johnson's seagrass somewhat resembles paddle grass, *Halophila decipiens*, with which it will occur (pers. observations) and was relatively recently recognized as a separate species. It is the first marine plant to be listed pursuant to the Endangered Species Act, and because it is a recent addition and because its Recovery Plan was very recently developed, information concerning the abundance and distribution of this species is very up-to-date.

Johnson's seagrass has been documented to occur only on the east coast of Florida, being found in coastal lagoons along approximately 200 km of coastline from approximately Sebastian Inlet (Brevard County) to Biscayne Bay, including areas of the Indian River Lagoon, Lake Worth Lagoon and Biscayne Bay. Based upon this limited range, Johnson's is thought to be the most spatially-restricted species of seagrass in the world (NMFS 2002). The largest known areas of Johnson's seagrass within this range are in the Indian River Lagoon and Lake Worth.

Within this range, Johnson's seagrass grows in a patchy, non-contiguous distribution in water depths from within the intertidal zone to maximum depths of approximately 3 m (Kenworthy, 1993; Virnstein et. al., 1997). Due to its presence in very shallow waters, and even being exposed at extreme low tides, it is thought to be tolerant of moderate desiccation and wide temperature ranges. Although it is reported to be more commonly found in monotyic patches, it may also be present with shoal grass and manatee grass.

Relatively little work has been done to identify the salinity, temperature and/or water quality preferences and tolerances of Johnson's seagrass. Research to date, however suggests that Johnson's seagrass survives in at least salinities from 15-43 ppt, and that its range may be greater (NMFS, 2002). It also grows in areas of varying water clarity, from comparatively turbid areas to clear-water areas near inlets, where currents are fast and strong.

In spite of its comparatively small size, studies indicate that Johnson's seagrass serves a food source for other organisms, as a refuge, habitat and nursery for wildlife species, assists in sediment stabilization and therefore reduces turbidity and erosion.

The federal recovery team identified five criteria on which to consider designation of critical habitat: 1) populations that have been documented to persist for 10 or more years; 2) persistent flowering populations; 3) the northern and southern limits of the species range; 4) unique genetic diversity; and 5) a documented high abundance compared to other areas in the species' range. Based on these criteria, ten areas, ranging in size from approximately 2 acres to 18, 757 acres have been designated as critical habitat for Johnson's seagrass. The largest of these, and the only one to occur within the MFL project area is the Biscayne Bay area, which accounts for 83% of the designated critical habitat for this species (Figure 8).

The recovery plan identifies a number of actions that are to be taken place in order to meet the recovery goal of delisting the species after assuring its persistence throughout its range. Although implementation of many of the identified actions will have no effect on MFL rule development, specific activities that are worth monitoring include:

Action #2: Initiate a range-wide monitoring program. Monitoring is to be performed to detect any changes in the southern distributional limits or range extensions, and specifically; "An important goal of the initial mapping would be to identify if any major distributional gaps presently exist in the southern part of the range." (NMFS 2002).

Action #3: Refine habitat requirements. Data are to be collected regarding various water quality parameters, including temperature, salinity, light intensity… to increase understanding of the conditions in which Johnson's seagrass survives.

Action #5: Determine and implement habitat management needs and techniques. The recovery team intends to work with FDEP and WMDs to develop water quality based targets for use in protecting seagrass populations. WMDs will develop Pollutant Load Reduction Goals (PLRGs) for SWIM waters. FDEP will use these PLRGs to determine Total Maximum Daily Loads (TMDLs) for waters that are on the State's list of impaired waters.

Oysters

This summary of American oyster biology related to salinity is formatted after that of Meeder et al. (2001) with additional review information from Galtsoff (1964), Castagna and Chanley (1973), Lough (1975) Bahr (1981) and Burrell (1986).

While live oysters have been collected across their range at temporary salinities ranging from 0 psu to 40 psu, the various life stages of the oyster each has different optimum requirements: Egg and sperm production does not occur below salinities of 7.5 psu, maximum survival of 2 day old larvae occurs at salinities of 19-30 psu, and 10 day larvae at 8-30.5 psu. Temperature is another important parameter and certain optimums are reported for various populations.

Larval development is optimum at 25-29 psu, and spat grow best at 15-26 psu. Best adult growth is in the same range, 14-30 psu. Moderate salinities of less than 15 psu for a significant period in the year may be beneficial through exclusion of less euryhaline predators and reduction in common disease organisms (Burrell 1986).

Oysters can close their shells and survive on stored reserves and apparently carry out anaerobic respiration to avoid death when external conditions are lethal, such as long periods of 0 psu salinities. Periods of closure can range up to

10 days. In his review of requirements for establishment and persistence of oysters as oyster bars, Meeder et al. (2001) notes that salinity and “steady food bearing water currents are essential.” Oysters are very specific suspension feeders, filtering seawater for phytoplankton. Evidence shows they can be very specific for certain phytoplankton groups or even species.

Oyster larvae settle from a planktonic life form onto many surfaces. Galtsoff (1964) describes these as “…rocks, gravel, cement, wood, shells of other mollusks, stems and leaves of marsh grass…tin cans, rubber boots,… tires, glass, tar paper…plastic…There is no evidence that the larvae are selective in finding a suitable place to set, provided the surface is not covered with slimy film, detritus or soft mud.” The latter two are however common features in certain areas along the west side of Biscayne Bay where historical oyster bar deposits are found.

Meeder et al. (2001) concluded that "a range of salinities of 5-20 psu…may be optimal for *C. virginica* in South Florida” and proposed a target salinity range for a tidal creek restoration project of 5-15 psu in the wet season and 10-19 psu in the dry season. The existing salinities in the area have a mean of 15 psu in the wet season and 25 psu in the dry season.

For this restoration project specific construction activities and freshwater flows were recommended along with the addition of several barge loads of shell to provide a base for a new oyster reef to overcome the problem of needing suitable settling substrate for oyster larvae (Meeder et al 2001, 2002).

Crustaceans

Crustaceans, which include lobsters, shrimp, crabs and barnacles are mostly aquatic arthropods that are categorized in the class Crustacea. Numerous species of crustaceans inhabit Biscayne Bay. Most are marine organisms that prefer typical marine salinities of ± 35 ppt, and are species whose presence, absence and/or abundance would not serve as good indicators of adverse impacts associated with reductions of inflow of fresh water. Many individual species tolerate wide variations in salinity. Several species, however which are present in Biscayne Bay for all or portions of their life cycles could potentially serve as indicators of desired salinity regimes. These include shrimp and crabs (Order Decapoda), as described hereafter. In addition to having life cycles that include estuarine waters (see Appendix C), several of these species (i.e., pink shrimp, blue crab and stone crab) are recognized as being “of major importance to commercial, sport or bait fisheries” (Idyll, 1966).

Shrimp

Shrimp found in Florida's coastal areas include members of the Penaeidae, which include pink shrimp (*Farfantepenaeus duorarum*), and brown shrimp (*Farfantepenaeus aztecus*) and members of the Palaemonidae, which include grass shrimp (*Palaemonetes pugio*). Of the several kinds of shrimp that are documented to occur in Biscayne Bay, pink shrimp are the most abundant (Cantillo, et. al., 2000). Grass shrimp, which are known to inhabit Biscayne Bay are well documented to be able to withstand wide ranges of salinity. Anderson (1985) reports that adult grass shrimp tolerate salinities of 2 to 36 ppt and their larva exist in salinities from 3-31 ppt. As a result of this broad euryhaline tolerance for salinity changes, and their lack of commercial fishery value when compared with pink shrimp, grass shrimp do not appear to be suitable for detailed consideration as a potential indicator species for MFL related analyses in Biscayne Bay.

Because pink shrimp, however have more restricted salinity tolerances, are more economically valuable and are a major food source for higher trophic level organisms, are a potential indicator species. Pink shrimp inhabit broad shallow continental shelf areas, shallow bays and estuaries. In Florida, pink shrimp nursery areas are found in estuaries and nearshore marine areas from Biscayne Bay, Florida Bay, the Ten Thousand Islands area and up the west coast to approximately the Tampa Bay area (Bielsa, et. al. 1983.).

The pink shrimp fishery is the most economically important of all the fisheries in Florida (Bielsa et. al. 1983). Records of pink shrimp landings, which are kept annually by the National Marine Fisheries Service , document that the millions of pounds of pink shrimp that are harvested annually in Florida waters are a valuable financial commodity.

Pink shrimp are also an important component of the aquatic food web, serving as food for a large variety of other organisms, including many fishes that are important either recreationally or commercially.

Estuaries and other coastal seagrass communities are important nursery grounds for pink shrimp during portions of their life cycle. Studies in Florida Bay and / or Biscayne Bay have documented that post-larvae pink shrimp settle in seagrass beds that are less than 1 m deep and that the highest densities of juveniles were found in seagrass communities 1-2 m deep on the western portion of Biscayne Bay (Diaz 2000).

Although details of the life cycle of pink shrimp in South Florida are still being learned, it is known that they emigrate from shallow, coastal nursery areas to deeper offshore waters in the last juvenile or early adult stage. They spawn throughout the year on the Tortugas shelf at water depths of 15-48 m (Bielsa et. al. 1983), although the peak in spawning activity generally is believed to coincide with maximum bottom-water temperatures (Munro et. al. 1968). Pelagic larvae go through several stages and are carried into the Florida Current from the Tortugas grounds by westerly and southwesterly currents where they settle into estuaries. Postlarvae become benthic and concentrate at locations where suitable habitat exists. Pink shrimp then spend from 2-6 months in nursery areas, where growth rate varies based on a variety of factors, including gender, water quality conditions, inclu ding temperature and salinity, and available food. They then emigrate back to offshore spawning areas.

Pink shrimp are omnivorous consumers, foraging primarily in seagrass communities, primarily at night. Studies of feeding habits that revealed that prey items include dinoflagellates, foraminiferans, nematodes, polychaetes, ostracods, copepods, mysids, isopods, amphipods, caridean shrimp and their eggs, molluscs, squid, annelids, other crustaceans, small fishes and plant material (Bielsa 1983).

In turn, pink shrimp are prey for a variety of other organisms, including fish, reptiles, aquatic mammals, including bottle-nose dolphins and birds. Fishes that prey on them include inshore species (e.g., common snook, spotted seatrout, and various snappers), reef species (e.g., groupers) and pelagic species (e.g., king mackerel). Wading birds, such as herons, egrets also forage for shrimp at locations where water depths are suitable.

(Bielsa et. al. 1983) provide an excellent summary of what is known about the salinity preferences of pink shrimp, as follows:

"Pink shrimp exhibit different degrees of preference to salinity at different stages of their life cycle. Hughes (1969) indicated that tidal transport of postlarvae may be initiated by increases in salinities of flood tides. Hildebrand (1955) reported that juveniles exhibited a preference for salinities of 20 ppt or more. As they grow, they move into deeper, saltier water, until finally they leave the bays and enter the open sea (Williams 1955). Gunter et. al. (1964) reported the greatest biomass of pink shrimp along the gulf coast was distributed "around the South Florida islands, where the salinities are oceanic." Tabb et. al. (1962) found postlarvae at salinities from 12 to 43 ppt, juveniles from 5 to 47 ppt and adults from 25 to 45 ppt in Florida Bay. Adult pink shrimp have been found on the Tortugas grounds at salinities from 36.2 to 37.7 ppt (Iversen and Idyll 1960).

Interactions between water temperature and salinity impose strict environmental restraints on shrimp populations. At low temperatures, all shrimp have difficultly adjusting to changes in salinity; survival rates are higher at moderate to high salinities under conditions of low water temperatures (Williams 1960)."

Maintaining desirable salinity regimes has been described as one of the critical factors for maintaining seagrass communities and habitat for pink shrimp. (Bielsa et. al. 1983) identify that "direct saltwater intrusion (or diversion of natural freshwater discharge), which causes unfavorable salinity regimes" is a leading cause of degradation of shrimp nursery habitats".

Browder et al. (1999) used two modeling approaches to explore the potential basis for variation in recruitment of pink shrimp from its Florida Bay nursery grounds to the Tortugas fishing grounds. The results indicate a strong relationship between density of juvenile shrimp and sea-surface temperatures. Three other variables (rainfall, water levels in Everglades National Park and mean wind speed) were also correlated with juvenile pink shrimp densities.

Although pink shrimp are vulnerable to a variety of diseases, none exerts an appreciable impact on the commercial pink shrimp fishery (Bielsa et. al. 1983). For these various reasons, the pink shrimp appears to be an excellent potential indicator species for maintaining desirable salinity regimes in those portions of Biscayne Bay where the shrimp fishery is currently thriving.

Crabs

There are three species of crabs (i.e., blue crab *Callinectes sapidus*, stone crab, *Menippe mercenaria* and horseshoe crab, *Limulus polyphemus*)) that are present in Biscayne Bay and which are potential indicators of desirable estuarine salinities. Information regarding the life cycles and salinity preferences for each of these species is provided below.

Blue Crab

The blue crab is a fairly abundant marine crustacean that inhabits coastal waters from Massachusetts Bay southward to the eastern coast of South America (Hill et. al. 1989.). They are the major commercial crab fishery in the U.S., representing approximately 50% of the total weight of all species of crabs harvested (Thompson 1984, NMFS 1986). A considerable amount of work regarding the life cycle and other aspects of blue crab biology has been conducted, with much of it centered on the economically important population that exists in Chesapeake Bay.

The blue crab appears to use areas of varying salinities at various times of their life cycle. Mating occurs primarily in relatively low-salinity waters in the upper areas of estuaries and lower portions of rivers (Pyle and Cronin, 1950; Darnell 1959; Williams 1965; Tagatz 1968). After mating, females migrate to high-salinity waters in lower estuaries sounds, and nearshore spawning areas (Churchill 1919; Darnell 1959; Fischler and Walberg 1962). Hill et. al. (1989) indicate that blue crab zoeae hatch in Chesapeake Bay Chincoteague Bay, Delaware Bay, and other estuaries, and then drift out to sea, where they fed and grow, after which they migrate vertically in the water column to reach flood and ebb tides which then transport them back into the bay area.

The blue crab is a major entity in estuarine food webs, both by consuming a variety of other plants and animals, and by serving as prey for a variety of commercially and/or recreationally important species of fish, birds and other animals.

Various studies reported by Hill et. al. (1989) have documented that the blue crab exists in waters of highly variable salinities, ranging from 0-34 ppt; that salinities of 22-28 ppt are needed for normal hatching of eggs and for normal development of zoeae; and that “specific salinity levels are not critical for post-larval crabs”. Laboratory studies reported by Guerin et. al. (1997) corroborate these data, which led to a conclusion that: “Salinity had no effect of growth rates of *C. sapidus* by any measure or weight or carapace width”.

Stone crab

The stone crab is a fairly abundant marine crustacean that inhabits coastal waters from approximately Cape Lookout, North Carolina southward throughout the Gulf of Mexico to the Yucatan, Mexico, the Bahamas, Cuba and Jamaica. (Lindberg 1984). It is a major commercial crab fishery in

Florida (Lindberg 1984). As a result of this economic value, a considerable amount of work regarding the life cycle and other aspects of stone crab biology.

The stone crab appears to use areas of fairly constant, nearly marine salinities throughout their life cycle. Mating and spawning has been documented to occur year-round in Biscayne Bay (Lindberg 1984), with spawning peaking during August and September. Development of the planktonic larvae to first crab stage usually takes 27-30 days, and larvae pass through five zoeal stages. Although field studies documenting larval growth may be lacking, culture-reared specimens were documented to have optimal growth rates and best survival at a temperature of 30^0C and “salinities in the range of 30 to 35 ppt” (Lindberg 1984).

The stone crab is a significant entity in both marine and estuarine food webs, both by using their powerful claws to catch and consume a variety of animals, and by serving as prey for a variety of fish, cephalopods, sea turtles and predatory gastropods.

Various studies reported by Lindberg (1984)) have documented that the stone crab is generally considered to be a euryhaline species. Ambient salinities at stone crab study sites have been documented to range from 16.3-32 ppt near Cedar Key (Bender 1971) and 29-38 ppt in Biscayne Bay (Cheung 1969).

Horseshoe crabs

The horseshoe crab is a fairly abundant marine arthropod that inhabits estuarine and marine waters from mid-coast Maine southward to the Gulf of Mexico. Horseshoe crab eggs have fairly recently been identified as a major food source for migrating shorebirds, and various research is currently being conducted to learn more about the habits and habitats of this unusual benthic creature. In Florida, the FWC’s Florida Marine Research Institute is currently conducting a survey to obtain records and ultimately develop a database of horseshoe crab mating/spawning areas. A query of their database revealed several reportings from Biscayne Bay, but the Bay does not appear to be a major stronghold for this species.

Horseshoe crabs typically inhabit estuaries and coastal areas where they spend nearly all of their lives under water. Adults emerge to lay eggs on sandy beaches, after which larvae eventually become planktonic. Mating and spawning has been documented to occur year-round in Florida, with spawning peaks apparently being coincident with tidal and / or climatic conditions that resulted in atypically high water levels (Ehrlinger 2002).

Various studies reported by Ehrlinger (2002) have documented that horseshoe crabs are very tolerant of widely variable salinities. Embryos have been shown to develop at salinities up to 40 ppt, and optimal salinity ranges are generally accepted to be 20-30 ppt, and laboratory tests have revealed that both embryos and larvae successfully developed, hatched and molted at salinities as high as 60 ppt (Ehrlinger (2002)).

Fish

Alleman et al. (1995) notes that 512 fish species have been reported from Biscayne Bay. Commercial fisheries catches, both by weight and value, were however dominated by bait shrimp (juvenile to adult *F. duoaram*) based upon data reported in 1984. Gray snapper (*Lutjanus griseus*), white mullet *(Mugil curema*), pilchard (scaled sardine), white grunt (*Haemulon plumieri*) and spotted seatrout were the five most abundant finfish harvested by recreational fisherman.

Creel survey data for Biscayne National Park (BNP) for the years 1976 to 1998 (29,940 interviews) is reported by Ault et al. (2001). One-hundred forty three of the 325 species of fish and invertebrates documented in that study were part of the recreational fishery. Again the dominant single species was an invertebrate, the spiny lobster (*Panulirus argus*), followed by grunts and snappers. The “highly prized gamefishes, such as bonefish, tarpon and snook” were hardly present in any of the samples. Even spotted seatrout, identified by Alleman et al. (1995) one of the top five fish species harvested in the Bay based upon data reported in 1984, was only a minor component of the creels sampled (565 fish in 30,000 interviews). Apparent harvest of this species by numbers and CPUE (catch per unit effort) peaked in the early 1980’s and has declined since. The 983 randomly located night time trawls (1996-2000) in BNP targeting pink shrimp yielded just 53 spotted seatrout (Ault et al. 2001).

Certainly sampling bias, both in which areas of BNP fisherman choose to fish in and for what species, and the lack of larger seine samples in inshore waters, skewed the samples to capture or document harvest of the “highly prized gamefishes” above, but not likely the presence of spotted seatrout, which should have shown up in nighttime shrimp trawls.

Similarly, a 14 month study with 224 samples, spotted seatrout comprised less than 0.02% of the total catch (Serafy et al. 1997). Ninety-six percent (96%) of all trout were captured north of Rickenbacker Causeway, and 68% came from just one of the eight sampled areas, the most northerly station at the mouth of the Biscayne Canal. Clearly spotted seatrout are not a common species in the sampling efforts described, or in the recreational creel. It can only be hypothesized that some as-yet-unidentified habitat factor is not appropriate, a particular food source is not available, or that the very intense shrimp trawling in what is identified by Ault et al. (1999) as the highest quality habitat for juvenile spotted seatrout (west side of Central and South-central Biscayne Bay) may be eliminating juvenile spotted seatrout as bycatch. Although Bortone (2003) has characterized spotted seatrout as a potentially ideal indicator species for monitoring estuaries, it does not appear it is a good indicator within Biscayne Bay for establishing MFL's.

Although sampling within mangrove lined tidal creeks has occurred in other portions of Florida (Lewis et al. 1985, Edwards 1991, Ley and McIvor 2002, Flannery et al. 2002), no known sampling of this type is known for Biscayne Bay. Serafy et al. (2003) visually sampled transects in mangrove prop root habitat in surveys parallel to the shore, similar to Ley and McIvor (2002) and found a similar group of fishes dominant. Part of the problem is likely the lack of any “natural” mangrove lined tidal creek, since most have been channelized, or denied historical levels of freshwater flow (Meeder et al 1999, 2001, 2002). Although there is much discussion about the potential nursery habitat role of mangroves, tidal marshes and tidal creeks within them, specific data is often lacking (Sheridan and Hays 2003). This is more likely a problem of sampling rather than any factual basis to reject the potential hypothesized role of coastal wetlands as nursery habitat for fish and decapods.

In summary, while there is an abundant fish community in Biscayne Bay, past modifications to freshwater flow have likely eliminated most if not all of the historical mangrove or tidal marsh lined tidal creeks with any kind of “natural” tidal and freshwater drainage hydrology. Thus use of these systems, and any potentially associated species as a biological indicator for freshwater inflow management, would be fraught with speculative outcomes, rather than predictable outcomes.

This is further supported by the work on Faunce et al. (2002) where visual sampling for gray snapper in an area protected from fishing, was compared to an area open to fishing. Differences in the size structure of the two observed populations were significant, with those observed in the closed area being two size classes larger. The fishery for gray snapper is characterized as “growth-overfished” in both this paper and in Ault et al. (1998). With the confounding error introduced by overexploitation, and the inherent difficulty in quantitatively sampling for fish, use of any fish species or community as an indicator for freshwater management in Biscayne Bay seems unwarranted until much more data is available about nearshore and tidal creek fish populations, and perhaps better management of these fisheries is introduced.

Seagrass

Fourqurean et al. (2003) have recently published the results of water quality sampling and seagrass occurrence by species and cover for 677 stations in Florida Bay sampled between March 1991 and March 2000. The sampling and correlations derived from the data were intended to attempt to construct "habitat requirements" models for the five species of seagrass encountered: turtle grass, manatee grass, shoal grass, paddle grass and wigeon grass. No stargrass was observed in the sampling, and Johnson's seagrass has never been observed south of Key Biscayne in Biscayne Bay, and therefore is not known to occur in Florida Bay. Eight seagrass community types, including no seagrass, were identified, and characterized as to the various sampled parameters.

For salinity, the results can be summarized as: "*Ruppia-Halodule* communities had the lowest and most variable salinity...while yearly mean salinity in the *H. decipiens*, *Syringodium filiforme*, and dense mixed-species beds was relatively high, with low variability. Intermediate yearly mean salinities and relatively high annual variability were found in the *Halodule wrightii*, dense *Thalassia*, and sparse *Thalassia* communities."

Thus all the seagrasses, and mixed seagrass communities exhibited some apparent habitat requirements for specific mean salinities, and could tolerate various ranges of variation. From the perspective of MFLs, the goal to manage shoal grass and overlying salinities to maximize production of shrimp in a polyhaline zone (18-30 psu) along the west shore of Central and South-Central Biscayne Bay would appear to be best accomplished by lowering mean annual salinity and increasing variability in salinity to reestablish a range of salinities to support a *Ruppia-Halodule* gradient into deeper water where *Thalassia* would likely predominate.

SALINITY TOLERANCES, PREFERRED HABITATS AND LIFE CYCLES OF POTENTIAL INDICATOR SPECIES OR SUITES OF SPECIES

As stated by Sklar and Browder (1998) "Although estuarine organisms are generally euryhaline, few occur throughout the entire range of salinities from full seawater strength to brackish. Rather, several communities of organisms occur within an estuary, each more abundantly within a relatively narrow part of the salinity spectra...As a result, shifts in isohalines cause major changes in community structure...Such shifts reduce or eliminate suitable living habitat by placing favorable salinities out of reach of animals that require bottom or shoreline habitat not found in the new location..."[see Appendix C].

The general life history of seven species found in Biscayne Bay are shown in Appendix C. These include the snook (Figure C-1), tarpon (C-2), redfish (C-3), spotted seatrout (C-4), gray snapper (C-5), pink shrimp (C-6) and spiny lobster (C-7). The figures are arrange roughly in order of true estuarine and low salinity dependency, with the snook, tarpon and redfish typical examples where spawning occurs in higher salinities, and the larvae seek lower salinity oligohaline habitat where they metamorphose into early juveniles and later leave these natal areas for higher salinity waters. This life cycle differs from that of the seatrout, shrimp and gray snapper where inshore movements of spawned larvae occur, but more often into muddy bottoms or shoreline vegetation with slightly higher salinities (mesohaline for redfish), or mangroves / seagrass meadows with mesohaline to polyhaline ranges of salinities (for gray snapper and shrimp). Finally, the spiny lobster exhibits use on inshore waters and macroalgae and sponge habitats as nursery areas with polyhaline to euhaline ranges of salinities and can be negatively impacted by too large of an input of freshwater to these areas.

The potential indicator species have been selected in part due to salinity tolerances. Tables 3a and 3b list common plants and animals found in Biscayne Bay, and their salinity preferences, both for juvenile and adult, if known. Habitat preference is also noted if known. As shown in the table, the vast majority of species have very broad tolerances for salinities as would be expected for species found under estuarine conditions. It is important to note that these are data typically reported for "salinity at time of capture" and not the optimum salinities for minimum physiological stress, or maximum productivity. For most of these species such detailed information is not available, limiting the usefulness of simple presence or absence of any species as an indicator for use in establishing and monitoring MFLs.

Table 3a

Salinity and Habitat Requirements for Potential Vegetative Indicator Species

Species	Salinity (ppt)	Substrate/habitat	Comments
Avicennia germinans Black mangrove	0-90	Soft mud or sand	Emergent woody species; long-lived; can excrete excess salt
Cladium jamaicense Sawgrass	0-5	Soft mud or sand	Herbaceous emergent; typically inhabits fw areas; is outcompeted in areas of high nutrients
Conocarpus erecta Buttonwood	0-50	Firm sand or muck	Emergent woody species; typically found at slightly higher elevations than red, black or white mangroves
Distichlis spicata Saltgrass	0-80	Firm sand or muck	Herbaceous emergent; quite tolerant of varying salinity regimes
Eleocharis cellulosa Spikerush	0-1	Firm sand or muck	Herbaceous emergent; within project area only in upstream (freshwater) areas
Halophila decipiens Paddle grass	20-40	Soft sand	Diminutive, submerged, herbaceous species; may be found in mixed beds with other seagrasses
Halophila englemanii Stargrass	20-40	Soft sand	Submerged, herbaceous species; relatively uncommon; may be with other seagrasses
Halophila johnsonii Johnson's seagrass	15-43	Soft sand or mud	Diminutive, submerged, herbaceous species; threat-ened species; distribution only north of Virginia Key
Halodule wrightii Shoal grass	6-40	Soft sand or mud	Submerged, herbaceous species; relatively abun-dant, may be found mixed with other seagrasses
Juncus roemerianus Black needlerush	0-35	Soft sand or mud	Emergent herbaceous species; within project area, found west of shoreline
Laguncularia racemosa White mangrove	0-50	Soft sand or mud	Emergent woody species; typically found at elevations higher than red and black mangroves
Rhizophora mangle Red mangrove	0-55	Soft sand or mud	Emergent woody species; typically found at elevations lower than black and white mangroves
Ruppia maritima Wigeon grass	0-390 **0-40**	Soft sand or mud	Submerged, herbaceous species; relatively rare in project area; only known in shallows near Black Pt.
Spartina spartinae Cordgrass	0-35	Soft sand or mud	Emergent herbaceous species; within project area, found west of shoreline
Syringodium filiforme Manatee grass	5-45	Soft sand or mud	Submerged, herbaceous species; fairly common in project area; best bed is in Northern sub-region
Thalassia testudinum Turtle grass	11-70	Soft sand or mud	Submerged, herbaceous species; fairly common throughout project area; is the primary seagrass in higher salinity areas

Table 3b

Salinity and Habitat Requirments of Potential Faunal Indicator Species

Species	Salinity (ppt) Juv.	Adult	Substrate &/or habitat	Comments
Invertebrates				
Callinectes sapidus Blue crab	5-28	0-34	Sand, salt marsh	Salt marsh habitat important nursery for juven-iles; adults in creeks, rivers and estuaries
Crassostrea virginica American oyster	7-39 **15-26**	0-42 **14-30**	Solid substrate	Although tolerant of varying temp, salinity and water quality conditions, preferred S% as noted
Farfantepenaeus duorarum Pink shrimp	5-47	25-45	Over seagrasses	Biscayne Bay population continually recruits from and returns to Tortugas grounds to the west; economically valuable species
Limulus polyphemus Horseshoe crab	10-15	5-34	Sand	Suitable shoreline profile appears to be more im-portant than salinity for successful reproduction
Menippe mercenaria Stone crab	> 20	6-40	Hardbottom juv-seagrass	Habitats variable; nearshore shallow-water grassflats, hardbottom with sponges, rubble…
Vertebrates				
Mammals				
Trichechus manatus W. Indian Manatee	0 - 35+		open water, seagrasses	Inhabit fresh water, estuaries & marine en-vironments. In Biscayne Bay, combination of warm water and fresh water in a predominately marine system causes aggregations
Turciops truncatus *Bottlenose Dolphin*	20- 35+		open water	Inhabits primarily marine environments, although also present in estuaries
Reptiles				
Crocodylus acutus American crocodile	0-40 pref < 20		shallow open water	Although tolerates wide salinity varioations, studies in BB documented approx. 45% of non-hatchling crocs were in s% of 1-5 ppt.
Malaclemys terrapin tequesta Diamondback terrapin	9-25		Estuarine waters	Prefers shallow, medium-salinity estuaries, where it feeds on sanils, crabs and other invertebrates
Birds				
Ajaia ajaja *Roseate Spoonbill*	0-40+		Sand	Feeds in waters of varying salinities; but requires abundant supply of salinity-dependant small fishes to nest successfully
Egretta caerulea Little Blue Heron	0-40+		Sand	Feeds in shallow waters of varying salinities; nests successfully in coastal and inland areas
Egretta rufescens Reddish Egret	0-40+		Sand	Feeds in waters of varying salinities; but requires abundant supply of salinity-dependant small fishes to nest successfully
Egretta thula Snowy Egret	0-40+		Sand	Feeds in shallow waters of varying salinities; nests successfully in coastal and inland areas

Table 3b

Salinity and Habitat Requirments of Potential Faunal Indicator Species

Species	Salinity (ppt) Juv.	Salinity (ppt) Adult	Substrate &/or habitat	Comments
Egretta tricolor Tri-colored Heron	0-40+		Sand	Feeds in shallow waters of varying salinities; nests successfully in coastal and inland areas
Eudocimus alba White Ibis	0-40+		Sand	Feeds on land & in waters of varying salinities; nests successfully in coastal and inland areas
Mycteria americana Wood Stork	0-40+		Sand	Feeds in shallow waters of varying salinities; nests successfully in coastal and inland areas
Pelicanus occidentalis Brown Pelican	0-40+		Open water	Feeds in open waters of varying salinities; nests primarily in coastal areas
Fish				
Bairdiella chrysoura Silver perch	5-25		Estuarine waters	Habitat generalist
Centropomus undecimalis Common Snook	0-25	5-37	Estuarine waters & tidal creeks	Shallow, low-salinity habitats preferred at early juvenile stages
Cynoscion nebulosus Spotted seatrout	1-25	5-37	Estuarine waters & seagrass	Prefers seagrass habitats, if present
Cypinodom variegatus Sheepshead killifish	0-37	0-160	Estuarine waters	Prefers very shallow estuarine waters (i.e., < 3 ft deep)
Eucinostomus gula Silver jenny	0-30		Estuarine waters	Habitat generalist
Floridichthys carpio Goldspotted killifish	0-30		Estuarine waters	Prefers very shallow estuarine waters (i.e., < 3 ft deep)
Fundulus confluentus Marsh killifish	0-30		Estuarine waters	Prefers very shallow estuarine waters (i.e., < 3 ft deep)
F. grandis Gulf killifish	0-30		Estuarine waters	Prefers very shallow estuarine waters (i.e., < 3 ft deep)
Haemulon sciurus Bluestriped grunt	14-37		Estuarine & marine waters	Prefers hardbottom and reef habitats
H. plumieri White grunt	14-37		Estuarine & marine waters	Prefers hardbottom and reef habitats
H. parra Sailors choice	14-37		Estuarine & marine waters	Prefers hardbottom and reef habitats
Lagodon rhomboides Pinfish	14-37		Estuarine & seagrasses	Prefers hardbottom and reef habitats
Lucania parva Rainwater killifish	0-30		Estuarine waters	Prefers very shallow estuarine waters (i.e., < 3 ft deep)

Table 3b

Salinity and Habitat Requirments of Potential Faunal Indicator Species

Species	Salinity (ppt) Juv.	Salinity (ppt) Adult	Substrate &/or habitat	Comments
Lutjanus griseus Grey snapper	10-40		Estuaries, marine waters, seagrasses & tidal creeks	Habitat for early juveniles includes tidal mangrove creeks
Myteroperca microlepis Gag grouper	10-37		Estuaries, marine waters, seagrasses	Early juveniles use seagrass beds, then migrate to offshore.
Megalops atlanticus Tarpon	1-10	10-37	Estuarine & marine waters	Obligate air-breather; early juveniles use shallow tidal ponds
Mugil spp Mullet	11-37		Estuarine & marine waters	Bottom feeder; shallow estuarine waters preferred by early juveniles
Opsanus beta Gulf toadfish	2-22		Estuarine & marine waters	Generalist; benthic feeder
Sphyraena barracuda Great barracuda	8-37	10-37	Estuarine & marine waters	Predatory, may carry dinoflagellate-based ciguatera poisoning when feeding on some tropical reefs

SECTION 5
POTENTIAL ALTERNATIVE APPROACHES FOR MFL DEVELOPMENT FOR BISCAYNE BAY

STATIC AND DYNAMIC HABITATS

Browder and Moore (1981) introduced the concept of dynamic and stationary or static habitats (Figure 15) to differentiate the two important components of estuarine habitat. Static habitat components are those more fixed in time and location. These are the classic habitats, such as mangrove forests and seagrass meadows, that are typically fixed in place. Only over very long time frames can they move. An example of this movement is the reports by Ross et al. (2000, 2002) of migration of the edge of the white zone landward due to salt water intrusion over a fifty year period.

The dynamic habitat component is typically a water quality parameter such as salinity or dissolved oxygen, or a water volume or level parameter. These are components that can change very quickly, often on a daily basis. The point that Browder and Moore (1981) initially made was that it is the overlap of specific dynamic and static habitat components produces the optimum productivity within a given ecosystem (Figure 15).

Figure 16 shows a typical estuarine stream ecosystem with an overlay of salinity zones as they might appear in a normal flow situation. Tidal flows and inputs of freshwater inputs are shown (diagram modified from Mitsch and Jorgenson 2004). Figure 17 shows a similar diagram for a hypothetical groundwater discharge into the Bay similar to that reported by Kohout and Kolipinski (1967). Figure 18 shows a typical static feature added to the figure (a seagrass meadow). Figure 19 shows how the interaction of the salinity regimes (dynamic component) and the location of the seagrass meadow (static component) produce some seagrasses within the euhaline and mesohaline zone, but the majority of the seagrass is within the polyhaline zone. Assuming that the ideal environment for a given species, or the maximum zone of production (or growth, survival, food web production for that species) is this type of habitat, the freshwater flows shown are optimum for creating habitat for that species. Conversely, if freshwater inputs are reduced the overlaps change, and less polyhaline seagrass meadow is available. Thus depending on what the Valued Ecosystem Component (VEC) may be for a given area, freshwater inputs can be designed (if they can be controlled) to optimize habitat for that VEC.

This concept of static and dynamic habitats can be used in a number of ways to evaluate the necessary freshwater needs of an estuary. As discussed below, these can include, Valued Ecosystem Components, as discussed in the previous Section

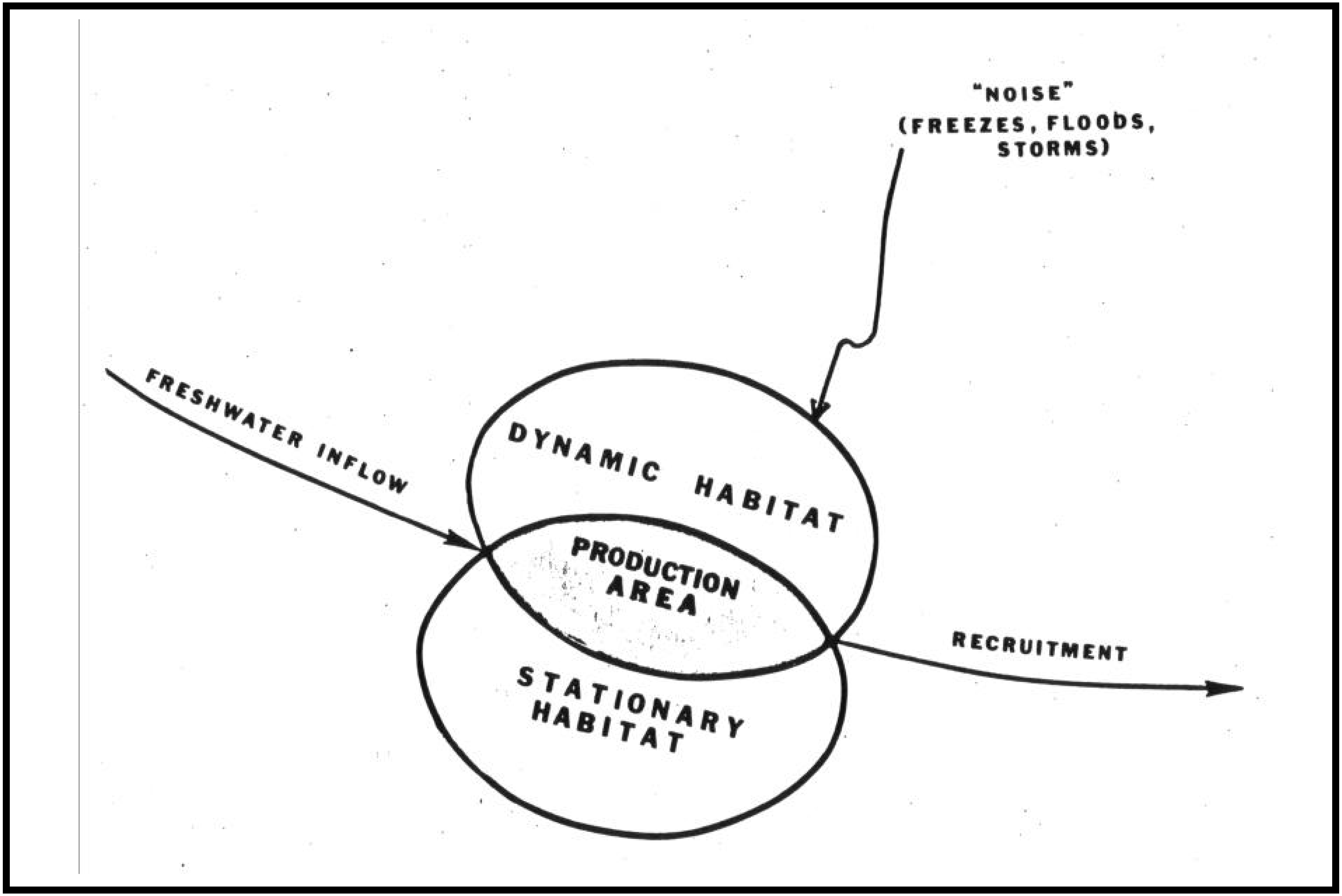


Figure 15
Stationary and dynamic habitat components,
from Browder and Moore (1981).

B F A

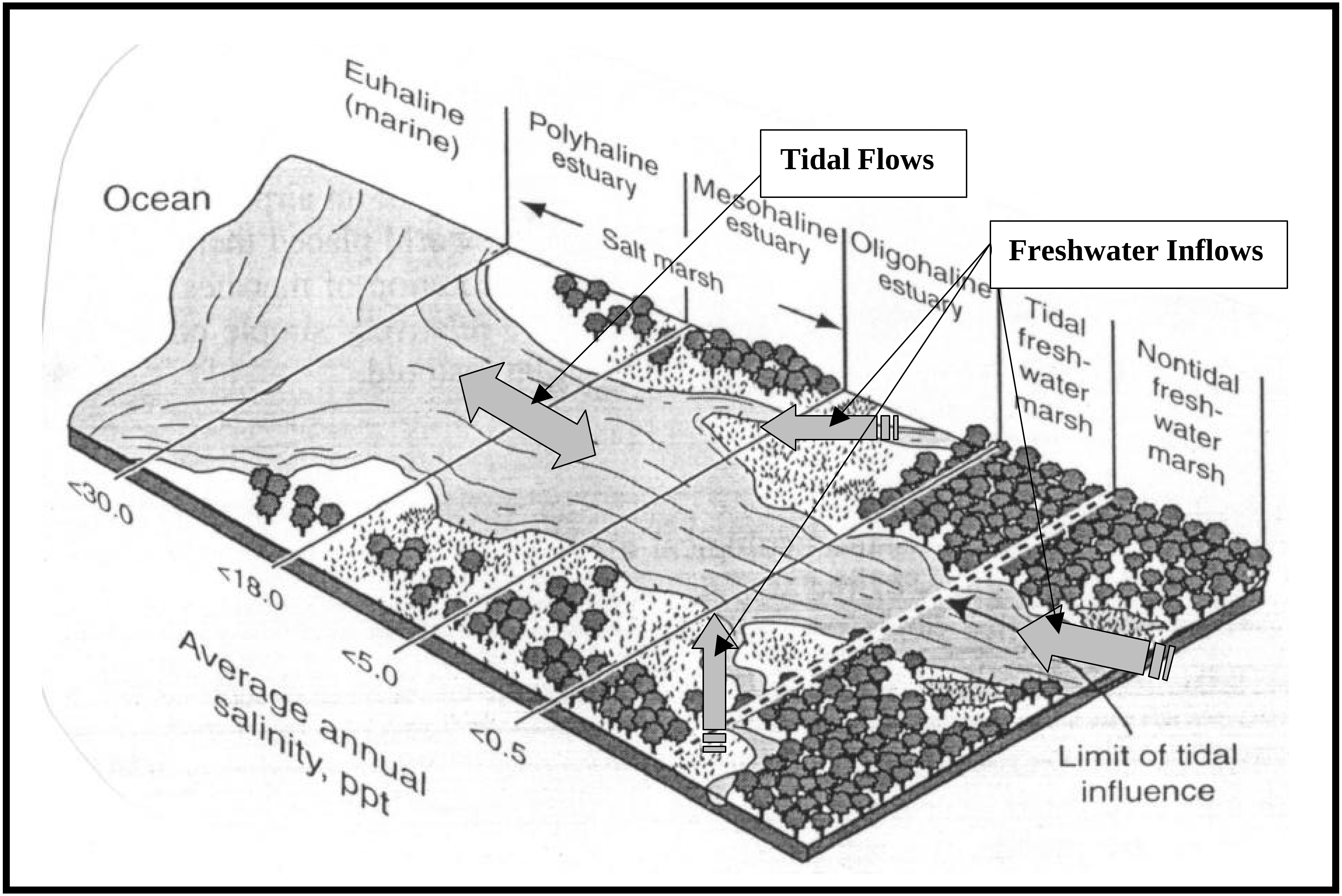


Figure 16
Graphic representation of the range of salinity zones overlaid on a typical tidal creek system entering a higher ocean habitat (modified from Mitsch and Jorgensen 2004).

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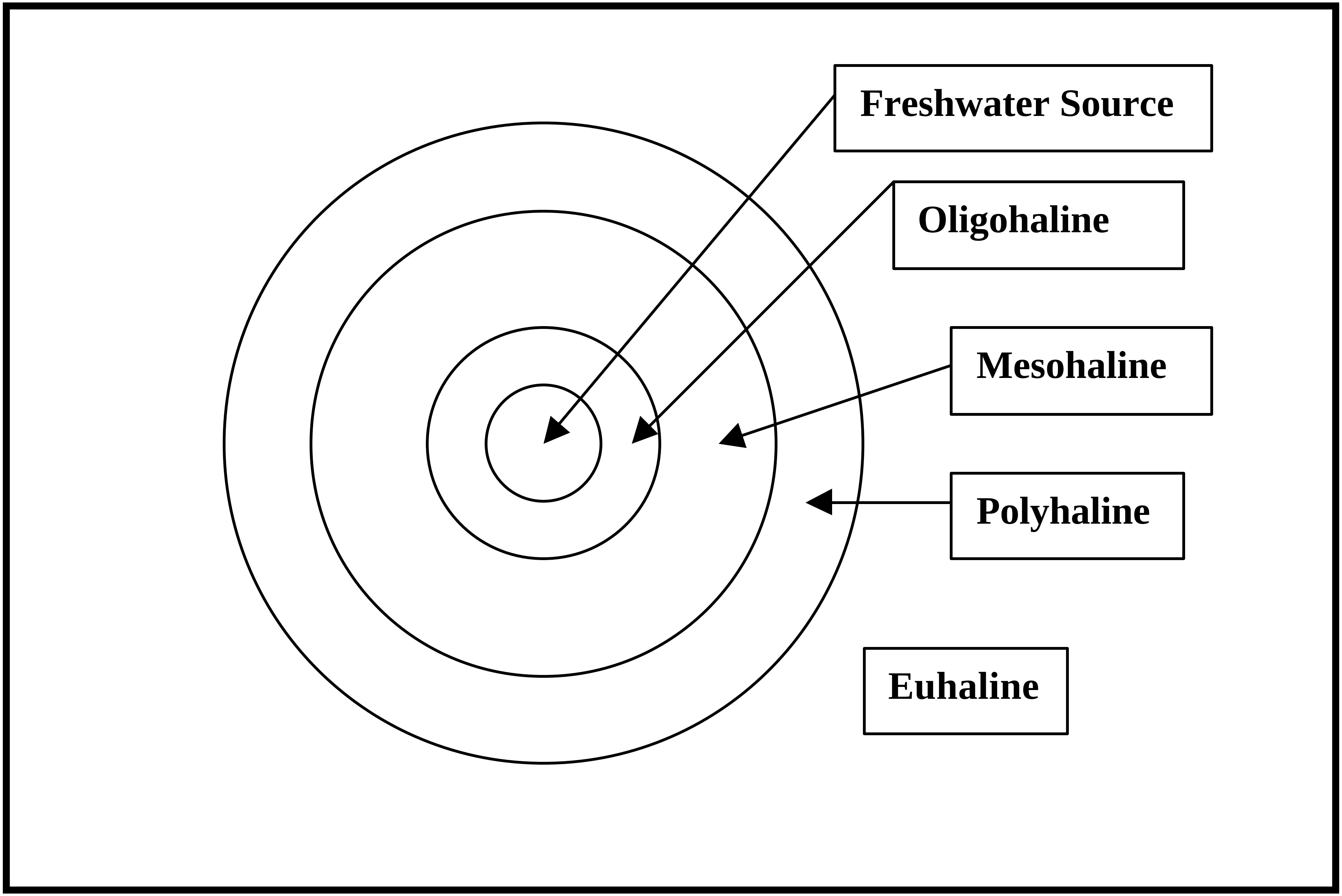

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Figure 17
Graphic representation of salinity zones around a submerged artesian well in a marine environment.

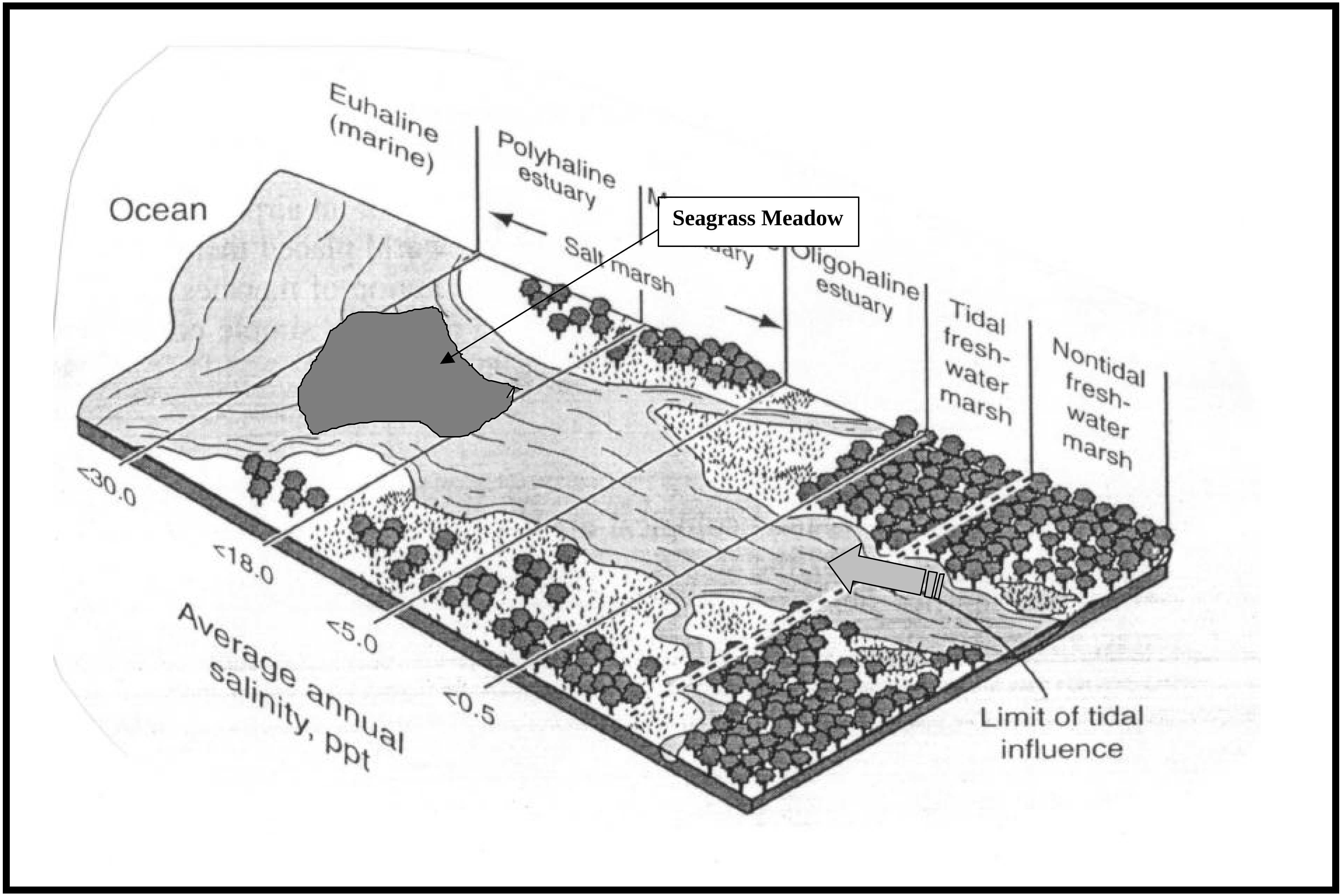

Figure 18
Graphic showing the location of a seagrass bed in the estuary.

B F A

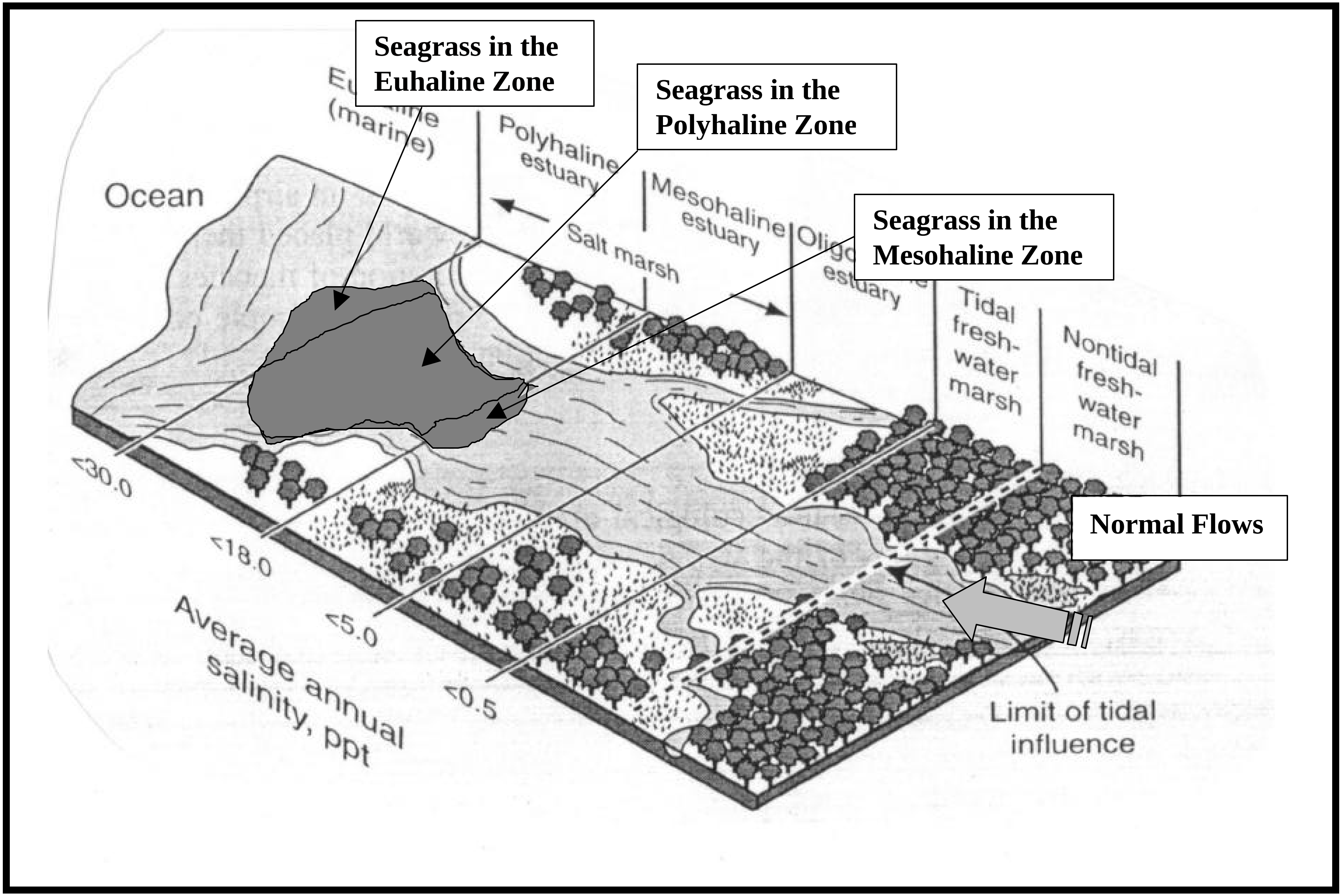

Figure 19
Graphic showing static habitat (seagrass meadow) with dynamic habitat (freshwater inflow) overlay and resulting seagrass/salinity zones under normal flow conditions.

B F A

4, indicator species, presence / absence / vitality of preferred habitats, ecological preservation, pre-development scenarios, requirements for preferred fish communities, community indices, food web support and soil characteristics.

Jackson et al. (2000) outlines a process to evaluate ecological indicators specifically of interest to the Office of Research and Development of the U.S.E.P.A. The outline lists 15 guidelines for indicator evaluation to structure presentation of alternatives for evaluation but does not describe a selection process. Some of the guidelines are however relevant to the process of Biscayne Bay MFL ecological indicator identification. These include relevance to identified assessment questions and ecological functions within the specific ecosystem under evaluation; logistics requirements and ultimately the costs for implementation; discriminatory ability among sites along a known gradient; ability to provide information to support a management decision or to quantify the success of past and future decisions.

Two presentations at the Estuarine Indicators Workshop (29-31 OCT 2003, Sanibel Island, Florida) were applicable to the question of how to evaluate various ecological indicators for final selection for the Biscayne Bay MFL.

The presentation by Bill Dunson (Dunson 2003) on choosing fish “bio-indicators” listed five characteristics of an ideal estuarine indicator:

1. Mix of taxonomic groups
2. Mix of tropic groups
3. Sensitivity to the abiotic parameter(s) of interest
4. Important to stakeholders
5. Existence of robust prior database on the bio-indicator(s)

Similarly, Louis Toth (Toth 2003) explained the process of prioritizing 140 potential indicators of success in the restoration of the Kissimmee River. Seven characteristics were evaluated:

1. Sensitivity to project effects
2. Reliability of response
3. Rapidity of response (for early warning and mid-course corrections)
4. Ease / economy of monitoring
5. Feedback to management (adaptive management)
6. Relevance to endpoint (sociopolitical evaluation and data availability)
7. Importance of endpoint (subjective evaluation of public opinion)

A scale of 1-5, with 1 being the highest rating (thus the lowest total value of a given rating meant the highest priority) was used. A combination of the Dunson and Toth methods were used in the analyses presented here.

Alternative approaches considered for the Biscayne Bay MFL development included:

- Valued ecosystem components
- Indicator species
- Presence / Absence / Vitality of Populations of Indicator Species
- Pre-development scenarios
- Ecological preservation at existing conditions
- Requirements for preferred fish communities
- Community index
- Food web support
- Soils

These nine approaches were then individually evaluated for each sub-region of the Bay for strengths, weaknesses, opportunities, threats, cost effective performance standards and speed of information return to managers for adaptive management decisions.

VALUED ECOSYSTEM COMPONENTS

SFWMD (2002d) defines valued ecosystem components (VEC's) as "…a species, community, or set of environmental conditions and associated biological communities that is considered to be critical for maintaining the integrity…" of a given estuarine ecosystem.

VEC's represent the full suite of plant and animal communities, individual species, substrate characteristics (hardbottom, softbottom), and water quality conditions (salinity zones, dissolved oxygen zones, etc.) that when taken together or individually are valued for aesthetics, commercial or recreational fisheries values, or heritage values. Once these are listed as they are in Section 6 above, the question is which of these, or components of each, may have higher or lower "values", and which are indeed sensitive to freshwater inputs to the estuary. Mangroves for example are VEC's for all the estuaries in the southern half of Florida, but are relatively insensitive to salinity changes over a very wide range since they are facultative halophytes not obligate halophytes. That is they can grow in totally fresh water, or survive in interstitial salinities as high as 55 psu for red mangroves and 90 psu for black mangroves. The American oyster, on the other hand is an obligate marine organism, but cannot persist in any numbers to form an oyster bar unless very specific salinity and bottom characteristics are present.

INDICATOR SPECIES

SFWMD (2002d) defines an indicator species as one where a change in abundance, distribution or condition can be related to flow or salinity. Criteria for selection may include commercial, recreational or aesthetic value, ecological importance, and whether it is a listed species or an endemic species.

Starting with the full suite of VEC's for Biscayne Bay, Table 4 was prepared and lists potential indicator species for minimum flows and levels, based upon their occurrence in Biscayne Bay, life history, review general estuarine literature and specific literature on Biscayne Bay, interviews and personal communications. Sources of information include Serafy et al (1997) who collected 95 taxa of fish from the Bay, Serafy et al (2003) who extended this work to mangrove fringed shorelines in the central, south-central and southern portions of the Bay, and Alleman (personal communication) who has prepared a draft table of species salinity relationships in the Bay that lists twelve species of fish, three invertebrates, wading birds as a group, and two species of seagrasses. Ault et al. (2001) reported via visual census or creel survey data, and collected a total of 325 species of fish and macroinvertebrates from 77 families within Biscayne National Park. Thorhaug et al (2001) lists two marine mammals, eight marine or estuarine reptiles, thirteen coastal birds, two fish, twenty-nine corals and ten marine plants as listed marine or estuarine species of concern in the Bay. Diatoms appear to be a sensitive indicator of both existing salinities and historic salinities (Ross et al., 2002, Gaiser and Wachnicka 2003) and are included as a group. Alleman et al. (1995) specifically cite the diamondback terrapin (*Malaclemys terrapin*), the mangrove water snake (*Nerodia fasciata compressicauda*), and the American crocodile (*Crocodylus acutus*) as important potential indicator species for freshwater inputs to the Bay.

From the information provided in this table it is apparent that not all the species considered occur throughout the entire Bay. For a species to be considered for use as an indicator species for a particular portion of the Bay, it must occur there, or have occurred there in the recent past and have some reasonable chance of returning in sufficient numbers to persist there if it is to be considered. Thus the American crocodile can be considered for portions of the Bay, but not all, since it is not reported for all parts of the Bay and is not likely to occur in some parts of the Bay except very rarely.

Table 4
Potential indicator species for freshwater minimum flows and levels establishment in Biscayne Bay.

Potential Indicator		**Sub-region**					
Scientific Name	Common Name	Snake Cr & Oleta R.	North	Miami River	Central	South Central	**S**
PLANTS (Microphytes – diatoms)							*** SSS
PLANTS (Macrophytes)							
Avicennia germinans	**Black mangrove**	* S			** S	* S	* S
Cladium jamaicense	**Sawgrass**						* S
Conocarpus erecta	**Buttonwood**						*
Distichilis spicata	**Saltgrass**						*
Eleocharis cellulosa	**Spikerush**						* SS
Halophila decipiens	**Paddle grass**			*			
Halophila englemanii	**Stargrass**						
Halophila johnsonii	**Johnson's seagrass**	*	*	*			
Halodule wrightii	**Shoal grass**		*	*	*	*	*
Juncus roemerianus	**Black needlerush**						*
Laguncularia racemosa	**White mangrove**	*			**	*	*
Rhizophora mangle	**Red mangrove**	* S			** S	* S	** S
Ruppia maritima	**Wigeon grass**				*	*	*SSS
Spartina spartinae	**Cordgrass**						
Syringodium filiforme	**Manatee grass**	*	*	*	*	*	*
Thalassia testudinum	**Turtle grass**			*	*	**	**
ANIMALS							
Invertebrates							
Callinectes sapidus	**Blue crab**						
Crassostrea virginica	**American oyster**	*			*		
Farfantepenaeus duorarum	**Pink shrimp**				***SSS	***SSS	
Limulus polyphemus	**Horseshoe crab**						
Menippe mercenaria	**Stone crab**						
Mixed spp of benthic macroinvertebrates, (epifauna & infauna)		*	*	*	**		*
Vertebrates							
Mammals							
Trichechus manatus	**W. Indian Manatee**			***			
Turciops truncatus	**Bottlenose Dolphin**						
Reptiles							
Crocodylus acutus					***** SSS**	***** SSS**	*** SSS

Table 4
Potential indicator species for freshwater minimum flows and levels establishment in Biscayne Bay.

Malaclemys terrapin tequesta	**Diamondback terrapin**				*	*	*
Birds							
Ajaia ajaja	**Roseate Spoonbill**	*			*	*	** SSS
Egretta caerulea	**Little Blue Heron**	*			*		
Egretta rufescens	**Reddish Egret**						
Egretta thula	**Snowy Egret**				*		
Egretta tricolor	**Tri-colored Heron**	*			*		
Eudocimus alba	**White Ibis**	*			*		
Mycteria americana	**Wood Stork**						
Pelicanus occidentalis	**Brown Pelican**	*	*				
Fish							
Bairdiella chrysoura	**Silver perch**	*		*			
Centropomus undecimalis	**Common Snook**	*	*	*	*		
Cynoscion nebulosus	**Spotted seatrout**	*	*	*	*		
Cypinodom variegatus	**Sheepshead killifish**		*				
Eucinostomus gula	**Silver jenny**	*	*	*	*		*
Floridichthys carpio	**Goldspotted killifish**		*				*
Fundulus confluentus	**Marsh killifish**		*				
F. grandis	**Gulf killifish**	*	*				
Haemulon sciurus	**Bluestriped grunt**	*	*	*	*		*
H. plumieri	**White grunt**	*	*	*	*		*
H. parra	**Sailors choice**	*	*	*	*		*
Lagodon rhomboides	**Pinfish**	*	*	*	*		*
Lucania parva	**Rainwater killifish**	*	*	*	*		*
Lutjanus griseus	**Grey snapper**	*	*	*	*		*
Myteroperca microlepis	**Gag grouper**	*		*			
Megalops atlanticus	**Tarpon**	*					
Mugil spp	**Mullet**	*		*			
Opsanus beta	**Gulf toadfish**	*	*	*	*		*
Sphyraena barracuda	Great barracuda		*				

Explanation - For each species, an indication is given as to whether that species is reported for a specific section of the Bay, and if present, how much life history and population information is available. * indicates present, but with little information. ** indicates present and some information and *** indicates present with a good set of local life history and population or map location data. If no * is present, it means we could find no record of the occurrence of this species in this part of the Bay. The existing data base in Biscayne Bay for freshwater sensitivity of a given species is reflected in the same way: S = some information, SS = good information, SSS = detailed information, no S = no information.

Appendix D Tables D-1 to D-6 take the analyses one step further by rating each of the potential indicator species for seven characteristics to determine usability as an indicator species. These seven categories were: presence / absence in the sub-region, sensitivity of applicable parameters (salinity), reliability of response, rapidity of response, ease and economy of monitoring, meaningful feedback to management and importance of endpoint. If a species was not reported to exist, or existed in too small a population to be usable as an indicator species, it received no further consideration. If it was present in suitable populations, it was rated for the remaining six categories. The scale for each rating was 0-5, with 0 indicating a poor response by this species for a given usability factor, 3 a medium response, and 5 an excellent response. Thus for species present in a sub-region, a maximum value of 30 could be achieved with these analyses. The highest rated species were highlighted in the tables and for each region were: the American oyster (Oleta), shoalgrass, manatee grass and spotted seatrout (Northern), forams and diatoms (Miami River), shoalgrass and pink shrimp (Central), shoalgrass, pink shrimp and spike rush (South-Central) and American crocodile and Roseate spoonbill (Southern).

PRESENCE/ABSENCE/VITALITY OF POPULATIONS OF INDICATOR SPECIES

From the analyses in Tables D-1 to D-6, it is apparent that while presence / absence data is available for a suite of indicator species, details on population sizes and vitality of those populations is generally lacking. Monitoring population sizes is difficult and expensive and has not been undertaken for any but the most easily visible and typically charismatic species, such as the manatee. For this reason, this approach to establishing MFLs did not rate high in the individual analyses by sub-region. (Appendix E Tables E-1 to E-6).

PRE-DEVELOPMENT SCENARIOS

When an estuary has a very low level of anthropogenic impacts, establishment of MFLs may look at the pre-development conditions for the estuary and watershed and determine if it is possible to restore some or all of the pre-development estuarine functions. Given the level of development in all the watersheds in Florida, this is not a common approach. Mattson (2002), however, describes the approach to the management of freshwater flows in the Suwannee River estuary and characterizes the approach as a "natural flow regime principle" which assumes that an altered hydrologic regime (i.e., the MFL) "...is still near-natural in terms of magnitude, frequency, duration and timing of freshwater inflows..." This approach is not likely to work in Biscayne Bay due to the extreme modifications to historical flows (Bellmund et al., 1999, Browder and Wanless 2001, Wanless and Browder 2001, Browder et al. 2001, Serafy et al. 2001).

ECOLOGICAL PRESERVATION

Under circumstances where some anthropogenic alterations to the watershed and estuary have occurred, but the extent of change has not caused significant harm, it is possible to manage freshwater inflows by carefully establishing the existing abiotic and biotic conditions for VEC's and indicator species, and plan for preserving those indicators in population sizes similar to that which currently exists by designing a percent-of-flow withdrawal plan. This is similar to what is currently underway for the Alafia, Little Manatee and Manatee Rivers that flow to Tampa Bay (Flannery et al. 2002) where commercial and recreationally important fish species, and their food sources and habitats, are targets for preservation. Again, the significant modifications to the watershed and the estuary of Biscayne Bay, and the resulting changes in VECs and indicator species, do not appear to show promise for successful use of this method (Serafy et al 2001).

REQUIREMENTS FOR PREFERRED FISH COMMUNITIES

Valued fish communities in Biscayne Bay include the snapper-grunt complex that is most often caught by recreational fisherman, and the “highly prized gamefishes, such as bonefish, tarpon and snook” (Ault et al. 2001). This former group of fish is currently over-fished in the Bay, and the latter group is rarely caught, as is the spotted seatrout which was historically a popular gamefish, but is now almost non-existent in fisherman's creels. The redfish is simply non-existent, and nine years of stocking efforts have failed to bring it back (Serafy et al. 2001).

All of this points to extreme pressure on existing fish populations, and the reduction or disappearance of some of the historically prized gamefish likely due to reductions in both the static and dynamic estuarine fish nursery habitat essential to most of these species (Lewis et al. 1985). Thus these types of habitats need to be restored in Biscayne Bay, following plans similar to those prepared by Meeder et al. (2001, 2002). Restoration of tidal creeks and their appropriate tidal flows was a popular recommendation among interviewees for this project but is not the subject of this particular effort, but that of CERP, RECOVER, and the Biscayne Bay Coastal Wetlands project.

COMMUNITY INDEX

Various indices, usually combining abundance, density and uniqueness of species composition to create a mathematical formula to describe the "health" or biotic index of an ecosystem have been proposed (see review in Engle 2000). The biotic index necessarily integrates multiparameter effects on a particular suite of species.

Graves et al. (2003) (Estuarine Indicators Workshop, Sanibel) presented the results of their study of the macrobenthos and water quality along two transects extending seaward from the shoreline at C-103 and C-2 into Biscayne Bay. The results were indicative of multi-parameter affects, with changes in the inshore macrobenthos at the C-103 site, as compared to the C-3 site in spite of very similar canal discharge rates and presumed salinities. The cause of the differences was determined to be a ten-fold increase in nitrate nitrogen in the discharge water from the canal at C-103. The point being, that trying to use a mixed suite of macrobenthos as an indicator of salinity differences or changes would not be a good idea, at least in this area of Biscayne Bay. Use of a biotic index to manage freshwater flows into Biscayne Bay, therefore, does not appear to be useful at this time.

FOOD WEB SUPPORT

Carbon and nutrient flows can be measured and modeled for estuarine ecosystems. If a particular source of carbon or nutrients can be linked to the health of the estuary, or support of a particular VEC or indicator species, and also tied to freshwater flows, it might be useful to manage freshwater flows. For Biscayne Bay, however, the level of modeling is at the conceptual stage (Lirman et al. 2002, Browder et al. 2003) and genuinely identifying where food web support for Biscayne Bay is controlled by freshwater inflows is still only at the conceptual stage except for the work of Lorenz (1999, 2000) and Lorenz et al. (2002) for the food web of Southern Biscayne Bay. Thus this approach does not appear useful at this time for any of the sub-areas except this one.

SOIL CHARACTERISTICS)

Soil conditions have been used by the St. John River Water Management District as the primary indicator for establishing Minimum Flows and Levels rules for many water bodies that are located within their region. Soils that are inundated and/or saturated for long periods of time develop various characteristics that are so predictable and measurable that their presence and/or absence is used as an indicator in identifying wetland boundaries. Because soils are comparatively slow to respond to changes in water levels, soil conditions are used for wetland delineation primarily when there have been changes in vegetative cover or hydrology.

In the context of MFL rule-making, soils have been used as indicators primarily in fresh water lakes and ponds, where changes in soil characteristics at a specific location could be an indication that levels have decreased to the extent that the existing floral and faunal communities would be subject to harm. The use of soils as an indicator in estuarine habitats would only be potentially useful in the transition zone between open-water areas and uplands. Within this gradient, measurements of soil salinity and/or depths to water during the dry season could be helpful in ensuring that reduced levels and flows do not cause harm to existing biota. Because the majority of the wetland/upland transition zone along the shoreline within the Biscayne Bay project area has been replaced with seawalls and bulkheads, the use of soil conditions as an indicator of estuarine conditions would be potentially useful only along the southern portions of the Bay. Even in these regions, the measurements would need to be taken in areas west of the mangrove shoreline. Some of these areas are already being considered for restoration through the Biscayne Bay Coastal Wetlands project.

The major potential drawback to using soils as an MFL indicator is the comparatively slow response time; by the time there are actual measurable changes in soil characteristics, the harm to previously-existing flora and fauna will have already occurred.

EVALUATION OF ALTERNATIVE APPROACHES

These nine approaches have been individually evaluated by sub-region of the Bay for strengths, weaknesses, opportunities, threats, speed of information return to managers for adaptive management decisions, and cost effectiveness of potential performance standards. Tables D-1 to D-6 list the nine alternatives considered for use for each of the six sub-regions, with values established on a scale of 0-5 by best-professional-judgment by the BFA Team combined with knowledge derived from the reviewed literature, and comments by interviewees to the principal scientists. The six values were then added together for a final score. The minimum score could therefore be 0, and the maximum 30. Table 5 lists the results of all of the analyses and shows that for each sub-region the following approaches had the highest ratings: indicator species (Oleta and Northern, Score 22 for both), community index (Miami River, Score 20), VECs and indicator species tied for Central Biscayne Bay (Scores 22), VECs (South Central, Score 22) and food web support (Southern, Score 26).

Table 5

Comparison of Different MFL Approaches for Each Sub-region

POTENTIAL APPROACHES	Sub-Region					
	Oleta River Snake Creek	Northern Biscayne Bay	Miami River Gov't Cut	Central Biscayne Bay	South-Central Biscayne Bay	Southern Biscayne Bay
Valued Ecosystem Component(s)	18	18	16	22	22	16
Indicator Species	22	22	15	22	21	16
Presence/Absence/Vitality of Preferred Habitats	17	17	17	12	12	13
Ecological Preservation	14	14	8	15	15	15
Pre-development Scenario	6	6	5	5	5	5
Requirement for preferred fish communities	14	15	11	10	10	10
Community Index	12	12	20	12	12	12
Food Web Support	12	12	5	12	12	26
Soil Characteristics	12	12	6	12	12	12

Shaded bocks indicate the recommended approach for each sub-region, based on it receiving the highest ranking.
It is important to note that these values represent a composite of multiple factors (see Appendix E).

SECTION 6
RECOMMENDATION OF PREFERRED APPROACHES

The recommended approach to establishing minimum flows and levels for Biscayne Bay is to utilize a different approach for each of the six sub-regions of the Bay. Biscayne Bay is a large heterogeneous ecosystem that has undergone major anthropogenic changes in the last 100 years. Thus each of the sub-regions has unique characteristics that demand unique treatment regarding necessary freshwater flows to either maintain existing conditions, or restore some semblance of historical conditions to allow for a particular ecological function to exist at some level satisfactory to water managers, citizens and scientists.

Appendix E Tables E-1 to E-6 list the various alternatives considered for use for each of the six sub-regions, with values established on a scale of 0-5 for by best-professional-judgment by the two principal scientists writing this report: Greg Braun and Roy R. "Robin" Lewis III, combined with knowledge derived from the reviewed literature, and comments by interviewees to the principal scientists.

Each potential approach was rated on a scale of 0-5, and the six values were then added together for a final score. The minimum score could therefore be 0, and the maximum 30. Each of these final totaled values is listed in summary in Table 5. The highest scores are highlighted. For one region, Central Biscayne Bay, two possible approaches are tied with the same score, 22. Since the valued ecosystem components and the chosen indicator species are the same for this region, this does not impact the choice of approach.

Table 6 is modified from Table 5 to now include a subjective rating by the principal scientists of the currently existing strength of scientific data support for a particular recommended approach. On a rating scale of 0-5, 0 is pure conjecture with no data support, 3 is moderate data support, and 5 is very strong data support. For most of the recommended approaches, the current scientific data base to support a specific quantitative MFL is low to moderate. As noted by Browder et al. (2001), "(D)evelopment of the information and modeling tools necessary to link water management, salinity envelopes, and biological performance measures is still in their early stages with respect to Biscayne Bay...thus far it has not been possible to translate changes in freshwater flow into terms meaningful to the Bay ecosystem in more than a general sense."

The highest rated approaches, strength of scientific data support for that approach and recommended contingency plan for each region are listed below.

Table 6

Comparison of the Relative Strength of Scientific Support for the Different MFL Approaches for Each Sub-region

POTENTIAL APPROACHES	Sub-Region					
	Oleta River Snake Creek	Northern Biscayne Bay	Miami River Gov't Cut	Central Biscayne Bay	South-Central Biscayne Bay	Southern Biscayne Bay
Valued Ecosystem Component(s)	18	18	16	22	22	16
Indicator Species	22	22	15	22	21	16
Presence/Absence/Vitality of Preferred Habitats	17	17	17	12	12	13
Ecological Preservation	14	14	8	15	15	15
Pre-development Scenario	6	6	5	5	5	5
Requirement for preferred fish communities	14	15	11	10	10	10
Community Index	12	12	20	12	12	12
Food Web Support	12	12	5	12	12	26
Soil Characteristics	12	12	6	12	12	12
Relative Strength of Scientific Support (0-5)	2	3	2	2	2	4

Shaded bocks indicate the recommended approach for each sub-region, based on it receiving the highest ranking.
It is important to note that these values represent a composite of multiple factors (see Appendix E).

OLETA RIVER/SNAKE CREEK

The recommended approach rated highest at 22 with a range of values from 6-22. The approach is the **Indicator Species** approach, with the indicator species being the American oyster, West Indian manatee and Johnson's seagrass (Table E-1).

The scientific data to support for using this approach is rated 2 on a scale of 0 to 5, where 0 is pure conjecture with no data support, 3 is moderate data support, and 5 is very strong data support (Table 6).

While we know oysters are present (FDEP 2002), there is no definitive mapping of the existing oyster resources in this area, and the health of the oysters is unknown. Therefore it is not possible to say it maintaining the existing water flows and levels will protect this resource. We know manatees use this area (DERM 1995)**,** but whether the existing water flows are optimum or sub-optimum for manatee protection is unknown. We know Johnson's seagrass is present in the park (FDEP 2002)**,** but this species is only described in the Johnson's seagrass recovery plan as being euryhaline and found in a salinity range of 15-43 psu, "…but has been observed growing perennially near the mouths of freshwater discharge canals…" (page 1.2-3 in NMFS 2002). Again, whether flows are optimum or not in this area is unknown.

Given these uncertainties, the recommended contingency option is to maintain all the existing flows through wetlands and into the Bay in this area until additional scientific information on the specific freshwater flows and levels for these, or additional species occurring in this location, are scientifically documented.

NORTHERN BISCAYNE BAY

The recommended approach rated highest at 22 with a range of values from 6-22. The approach is the **Indicator Species** approach, with the indicator species being the spotted seatrout and manatee grass (Table E-2).

The scientific information data support for this option is rated as a 3 on a scale of 0-5 (Table 6).

The moderate level of information available is reflected in the reported capture of 96% of all seatrout from one study (Serafy et al. 1997) north of Rickenbacker Causeway, and 68% in this portion of the Bay. Bellmund et al. (1999)(page 7) confirm the use of this species with the statement that "…In North Biscayne Bay sea trout spawning is believed to be linked to the presence of stable low salinity areas which are available seasonally…"

The dominant species within seagrass beds in this area is manatee grass. This species also appears to grow best in stable salinity fluctuation areas, but data to support the existing freshwater flows as being protective of these seagrass beds is lacking. Fourqueran (pers. comm..) feels its tolerance of lower light levels than other species of seagrass may be the cause of its persistence and perhaps competitive advantage at this location, rather than a tolerance of lower salinities than other seagrass species.

Given these uncertainties, the recommended contingency option is to maintain all the existing flows into this sub-area of the Bay until additional scientific information on the specific freshwater flows and levels for these, or additional species occurring in this location, are scientifically documented.

MIAMI RIVER/GOVERNMENT CUT

The recommended approach rated highest at 20 with a range of values from 5-20. The approach is the **Community Index** approach, intended to utilize a biodiversity index similar to that developed by Berkely and Campos (1984) for the Bay (Table E-3)

The scientific information data support for this option is rated as a 2 on a scale of 0-5 (Table 6).

We have been able to find very little specific information on indicator species for this area of the Bay. Alleman (pers. comm.) notes that this part of the bay was reported by Serafy et al. (1997) to have the highest fish species diversity of all the sampled stations. The Miami River is known to have highly polluted bottom sediments that are now the subject of a maintenance dredging project**,** but the existing water flows likely maintain a complete gradient from freshwater in its upper reaches, to euhaline at the entrance to the port. This range of salinities overlaps a wide variety of bottom communities, and may be the reason for such a high diversity of fish and possibly also invertebrates.

Given these uncertainties, the recommended contingency option is to maintain all the existing flows into this sub-area of the Bay until additional scientific information on the specific freshwater flows and levels for these, or additional species occurring in this location, are scientifically documented.

CENTRAL BISCAYNE BAY

The recommended approach rated highest at 22 with a range of values from 5-22. Both the **Indicator Species** approach and the **Valued Ecosystem Component** approach scored the same (Table E-4). The **Indicator Species** approach was judged the better of the two by the principal scientists, and the species chosen were being the pink shrimp and shoalgrass. Benthic infaunal and epifaunal invertebrate communities were not chosen as good indicators due to the multiparameter responses that are not directly connected with salinity changes in this sub-area of the Bay (Graves et al. 2003).

The scientific information data support for this option is rated as a 2 on a scale of 0-5 (Table 6).

This level of uncertainty is supported by the following quotes from the proposal (currently funded) for the "Biscayne Bay Coastal Biological Community Performance Measures Project" (Browder 2001): "…major water management initiatives will influence the quantity, timing and quality of freshwater inflow to Biscayne Bay…" however "…Biscayne Bay is handicapped by lack of information about conditions and communities in the western nearshore Bay…The benthic animal community, consisting of small forage fish, juvenile game fish, and invertebrates such as pink shrimp…blue crab…gray snapper…are linked to nearshore environments, but their relationships with freshwater inflow have received little investigative attention in Biscayne Bay." The data for the first year of this sampling are expected to be available in nine months, and a second year of sampling is proposed.

The study plan for the above reference study (Robblee et al. 2001) stated that the dominant vegetation type(s) for the sampling areas will be measured and reported along with the invertebrate and fish collected. Water quality data will be collected using hydrolabs. Although Fourqueran et al. (2003) characterized shoalgrass as a species more characteristic of variable salinities, no simultaneous fauna data was gathered. Therefore, the data from this ongoing study should provide a more definitive answer to the question about what salinity over what habitat type results in a greater catch of specific species. Until that is known, it is very difficult to define species/salinity/habitat relationships for this sub-area of the Bay.

Given these uncertainties, the recommended contingency option is to maintain all the existing flows into this sub-area of the Bay until such time as additional scientific information on the specific freshwater flows and levels for the above mentioned suite of species, or additional species occurring in this location, are scientifically documented, a revised and more scientifically based freshwater flow plan can be studied.

SOUTH-CENTRAL BISCAYNE BAY

The recommended approach rated highest at 22 with a range of values from 5-22. The approach is the **Valued Ecosystem Component** approach, with the VEC a sustainable pink shrimp harvest (Table E-5).

The scientific information data support for this option is rated as a 2 on a scale of 0-5 (Table 6).

South Central Biscayne Bay shares many of the same characteristics as Central Biscayne Bay except that all of this area is within Biscayne National Park, it has less dense seagrass area, and more hardbottom mixed with seagrass. Robblee et al. (2001) note that the work of Diaz (2001) indicates that pink shrimp abundance north of Black Point is greater than that found south of Black Point possibly indicating some major difference in seagrass and / or salinity regimes in the two areas. The discussion above about the Biscayne Bay Coastal Biological Community Performance Measures Project and associated narratives applies here as well as sampling is taking place in both areas.

Given the similar uncertainties found in Central Biscayne Bay, the recommended contingency option is similar, to maintain all the existing flows into this sub-area of the Bay until such time that additional scientific information on the specific freshwater flows and levels for the above mentioned suite of species, or additional species occurring in this location, are scientifically documented, and a revised and more scientifically based freshwater plan can be studied.

SOUTHERN BISCAYNE BAY

The recommended approach rated highest at 26 with a range of values from 5-26 (Table E-6). The approach is the **Food Web Support** approach, with the intent that the forage fish food base for both the Roseate spoonbill (and several other wading bird species) and the American crocodile would be the target reference point.

The scientific information data support for this option is rated as a 4 on a scale of 0-5 (Table 6).

This high rating is based upon the detailed studies reported in Lorenz et al. (2002) and Mazzotti and Cherkiss (1998). Unlike the other areas of the Bay, the problems of historic freshwater input modifications to this area have been looked at in more detail related to the C-111 canal which enters the most southerly portion of this area at Manatee Bay (Bellmund et al. 1999). Lorenz (pers. comm.) has recently been made aware of significant Roseate spoonbill use of the wetlands west of Turkey Point and is of the professional opinion that restoring freshwater flows to this area could have significant positive benefits to the Roseate spoonbill, associated wading bird species, and the American crocodile. This is due to a similar biological response described in Bellmund et al. (1999), Lorenz (1999), Lorenz (2000) and Lorenz et al. (2002). This response is an increase in the small demersal fish (i.e., *Cyprinodon variegatus* and *Poecilia latipinna*) and benthic epifaunal shrimp of the genus *Palaemonetes* "…found in virtually every analysis of spoonbill diet…" as a result of lower salinities, and reduced variation in overall salinities within brackish marsh and scrub mangrove habitat typical of the landward zone behind a narrow fringe of mangroves. These same food items are also important for subadult crocodiles (USFWS 1999) which also respond favorably to reduced salinity stress. Bellmund et al. (1999) referred to the response as the production of "high fish biomass" (p. 9). Lorenz et al. (2002) stated that "…the biomass of the prey base is impacted by hydrographic conditions: specifically, fish production is related to the salinity regime such that increased freshwater flow is correlated with increased prey-base fish stock…" (p. 601).

It is likely that the current conditions in this sub-area of the Bay result in some reduction to this "prey-base fish stock", and to increased salinities impacting survival of juvenile American crocodiles. Until these potential impacts can be better quantified, the contingency alternative should be to maintain the existing fresh water flows.

SECTION 7
INFORMATION DEFICIENCIES AND NEEDS

In conducting the literature search, interviewing experts and analyzing the information that is available concerning historical and existing conditions in Biscayne Bay, the project team has identified a number of areas in which additional information would be extremely valuable in developing and/or refining MFL rules and thresholds. In many cases, such as analysis of oyster populations, surveys and/or mapping has been done only in portions of the Bay. Having and analyzing the results of a bay-wide mapping effort of this estuarine-dependant species would be extremely valuable in understanding existing salinity regimes and in identifying conditions that could prevent significant harm. A preliminary list of data needs includes:

1) Actual locations of oyster bars and seagrass in and around Oleta River Park need to be confirmed and mapped.

2) Current and historical water quality data needs to be synthesized to determine what the seasonal salinity regimes are, particularly in the western inshore (and canal) areas of Central, South-Central and Southern Bay. If data are lacking, a water quality sampling program needs to be instituted. Probably ten year minimum sampling on a monthly basis at a network of 25 stations.

3) For the same locations above, detailed maps of live and fossil or recent historical American oyster and other oyster species, and seagrass (from D. Mir-Gonzalez study), and fresh and saltwater wetlands need to be mapped very accurately. Results from research presently being conducted (e.g., FIU graduate student D. Mir-Gonzalez) should be obtained and analyzed, and any adjustments/modifications to the MFL process that may be warranted should be considered.

4) The role of salinity/habitat interactions and population data for spotted seatrout in Biscayne Bay needs clarification.

5) The reason for the lack of spotted seatrout in Central and South-Central Bay needs to be determined, and potential bait shrimp bycatch impacts, and roller-frame trawl impacts to habitat, need to be elucidated to avoid blaming lack of freshwater as the culprit for absence of this species.

6) Means of moderating pulses of freshwater via canals need to be developed to better utilize the existing freshwater supplies to nourish existing, restored or created wetlands along the western shoreline.

7) The most up-to-date information on Roseate spoonbill nesting and foraging in conjunction with other wading birds in the Turkey Point area needs further clarification to confirm this species can be used as an indicator in South-Central to Southern Biscayne Bay.

8) The data collection efforts by the Roblee/Browder team needs to be extended to overlap both wet and dry years in order to have data that encompasses the entire range of possible seasonal salinity regimes for MFL establishment or modification in the future.

9) The forage fish prey base in both the "white zone" and in the mangroves and brackish marshes along the western shore of the Bay needs further sampling in relation to salinity/habitat interactions and food web interactions.

10) Additional research and/or monitoring should be performed to help understand the extent to which fresh water and/or warm water are attractants for manatees at locations of surface flow into Biscayne Bay.

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United States Environmental Protection Agency, United States Army Corps of Engineers and Metro-Dade Department of Environmental Resources Management. 1994. Technical Summary Document for the Advance Identification of Possible Future Disposal Sites and Areas Generally Suitable for Disposal of Dredged or Fill Material in Wetlands Adjacent to Southwest Biscayne Bay, Dade County, Florida. 128 pp.

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APPENDIX A

TASK 2 REPORT
LITERATURE AND DATA REVIEW

BIBLIOGRAPHY DATABASE IN SUPPORT OF LITERATURE AND DATA REVIEW – TASK 2

FOR THE PROJECT

FRESHWATER FLOW AND ECOLOGICAL RELATIONSHIPS IN BISCAYNE BAY

BY

BARNES FERLAND AND ASSOCIATES, INC.

AND SUBCONSULTANTS

APPLIED TECHNOLOGY MANAGEMENT, INC.
LEWIS ENVIRONMENTAL SERVICES, INC.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT
WEST PALM BEACH, FLORIDA

OCTOBER, 2003

INTRODUCTION

This literature review and bibliography database are part of the overall scope of the project titled, *Freshwater Flow and Ecological Relationships in Biscayne Bay* and is presented in fulfillment of the requirements of the Task 2 – Literature Search and Data Review and detailed in Contract No. C-15967-WO04-06. The bibliography is a result of a literature survey and represents the readily identifiable body of knowledge concerning freshwater flow and ecological relationships with respect to establishing Minimum Flows and Levels (MFLs) in Biscayne Bay. These references will likely support some portion of the final report and recommendations. A bibliography database was prepared in Microsoft Access 2000 software that allows a search of the documents through various listings and tables. The following describes the information sources used and the bibliographic database contents.

REFERENCE SOURCES

Numerous information sources were used to develop this database including various libraries and Internet web-based information. A list of key words was developed for selecting bibliographic entries and is included as Table 1.

University Library Sources

The libraries at the University of Miami and the University of Florida were used for source material. The University of Miami Rosenstiel School of Marine and Atmospheric Sciences maintains an online annotated bibliography of Biscayne Bay related materials. An online search of this database was conducted. The University of Florida Marston Science Library provided access to the entire state library system as well as a number of proprietary literature databases such as Cambridge Scientific Abstracts and Web of Science. The University of Florida journal collection also allowed hard copies of most citations to be made.

A particularly large number of relevant citations were found in the journal *Estuaries*, published by the Estuarine Research Federation (ERF). This journal was called *Chesapeake Science* prior to 1978. A CD obtained through the ERF was used to search all past issues of *Estuaries* and *Chesapeake Science* from 1960 through 1999. Hard copies of the journal for the years 2000 through the current 2003 issue were reviewed at the library. The December 2002 *Esturaries* was dedicated to the subjects of minimum flow with a dedicated issue titled *Freshwater Inflow: Science, Policy, Management* and provided a number of relevant citations that summarize the MFL programs and methods at several of the Florida Water Management Districts.

Internet Sources

A primary method of research has been use of the Internet web-based information to screen for titles, preferably with abstracts, and then follow up by obtaining printed copies of those references that appear most relevant. The *key word* search feature is useful to identify relevant titles from each agency/entity web site. The web sites listed below were useful in identifying references related to this project:

www.leg.state.fl.us/statutes
Establishing minimum flows and levels (MFLs) is mandated by state water policy (Section 373.042 F.S.). The MFL designate the minimum hydrologic/hydraulic conditions that must be maintained to prevent significant harm to the ecology or water resources of the area resulting from permitted withdrawals. The MFL state statue can be obtained from this web site.

www.sfwmd.gov; www.sjrwmd.com; www.swfwmd.state.fl.us
Technical reports, published by each Water Management District, can be identified from their web sites and printed copies can be downloaded or ordered online and sent by mail. The SFWMD, SWFWMD, SRWMD, and SJRWMD websites were searched for publications regarding their ongoing MFL programs. Several reports/documents were obtained regarding their MFL efforts. Several related project descriptions are also provided on their websites. Citations are also included from interviews with the District MFL staff.

www.fws.gov
The U.S. Fish and Wildlife Service (FWS) provided a number of the species profiles that are included in the literature review. These species profiles include detailed discussions of life history stages and salinity tolerances. Species profiles in the literature review results include those for spotted seatrout, American oyster, pink shrimp, and the blue crab. Also obtained through the FWS were habitat suitability index (HIS) models for these species.

www.epa.gov
The U.S. Environmental Protection has numerous publications, which printed copies can be ordered online and sent by mail. The Surf Your Watershed site (www.cfpub.epa.gov/surf/) provides general information and links that describe water related issues in the vicinity of Biscayne Bay.

www.usgs.gov
The USGS "on-line catalog" was used to search references using several key word combinations. Copies of some reports can be downloaded but most still have to be obtained by mail. The publication database is limited largely to in-house reports, but does contain some outside papers by USGS authors. Related ongoing USGS project descriptions are also described. Online water levels, quality and flow data can also be downloaded.

www.discoverbiscaynebay.org
This is a very useful web-site for specific information that provides an understanding of the various issues on Biscayne Bay. This website has been developed to improve communication among those involved in improving Biscayne Bay. It serves as a central clearinghouse to collect information on Biscayne Bay protection, restoration, and enhancement efforts, and make it accessible electronically. The site map shows information categories, which include maps, news articles, over 150 publications and links to agencies and special projects.

BIBLIOGRAPHY DATABASE

This database lists documents that may be used to prepare the final project report and also lists documents that may not specifically be used in preparing the final report, but which contain information of related interest. This version of the database contains 299 total bibliographic entries considered to have *some direct relevance* to the project. References, suggested during the interviews with experts (Task 3), are included in the database as well as those provided by District Staff. It is anticipated that a few additional entries or adjustments to the database may occur throughout this project, as new references are discovered or acquired. The final version of this bibliography database will be delivered with the final report.

A list of key words was developed for selecting bibliographic entries and is included as Table 1. These keywords were grouped into topic categories and can be used to query the database. Many of the entries are associated with more than one code and therefore can be cross-referenced to more than one subject area.

The references contained in this MS Access database can be queried to generate the following reports:

- A listing of 86 Biscayne Bay specific references;
- A listing of 99 references that are considered most relevant;

- Topic Category 1 - Animal Species (146 references);
- Topic Category 2 - Aquatic Plants and Habitats (98 references);
- Topic Category 3 - Ecological Indicators (45 references);
- Topic Category 4 - Impact Approach (70 references);
- Topic Category 5 - Water Quality Data (89 references);
- Topic Category 6 - Hydrologic Data (40 references);
- An alphabetical listing by author of all 299 references;

Appendix A includes a report that lists all 299 references alphabetically by author. Each bibliographic entry contains the author name(s), date, title of publication, publication, publisher, and check boxes for topic categories.

TABLE 1 – BISCAYNE BAY KEY WORDS

minimum flows and levels	estuarine invertebrates	habitat
salinity effects	estuarine indicators	habitat requirements
salinity ranges	estuarine hydrologic	habitat suitability
salinity requirements	alterations	hypersaline
salinity sensitivity	estuarine nursery habitat	target species
salinity tolerance	estuarine organisms	valued ecosystem
salinity preference	estuarine stratification	component
seagrasses	estuarine refugia	fish osmoregulation
submerged aquatic	fisheries	fish osmotic regulation
vegetation	fishery resources	grass shrimp
isohaline	fish nursery habitat	seatrout
oligohaline habitat	adaptability	gray snapper
mesohaline habitat	American oyster	mangrove snapper
oligohaline wetlands	American crocodile	mullet
mesohaline wetlands	benthos/benthic	snook
ecology	benthic communities	red drum
ecological communities	benthic structure	black drum
ecological significance	epibenthic community	tarpon
epiphytes	Biscayne Bay	blue crab
estuary	brackish	eastern oyster
estuarine dependent	forage fish	shoal grass
estuarine fish	killifish	manatee grass
estuarine fisheries	freshwater requirements	Halophila
estuarine reptiles	life history	manatee
estuarine criteria	indicator species	

ATTACHMENT A

BIBLIOGRAPHY DATABASE
ALPHABETICAL LISTING BY AUTHOR

SFWMD Biscayne Bay MFL Literature Review

Complete Alphabetical Listing by Author

Author: Abraham, B.J. **Date:** 1985

Title: Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (mid-Atlantic): Mummichog and Striped killifish

Publication:

Publisher: USFWS

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Adams, J.B. et al **Date:** 2002

Title: A method to assess the freshwater inflow requirements of estuaries and application to the Mtata Estuary, Sout Africa

Publication: Estuaries 25(6B): 1382-1393

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Alber, M. **Date:** 2002

Title: A conceptual model of estuarine freshwater inflow management

Publication: Estuaries 25(68):1246-1261

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Complete Alphabetical Listing by Author

Author: Alleman, R. **Date:** 1991

Title: A synopsis of the water quality and monitoring program in Biscayne Bay, Florida

Publication: The light requirements of seagrasses: results and recommendations of a workshop (Kenworthy, W., W. Judson, and D.E. Haunert, eds.)

Publisher:

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Alleman, R. **Date:** 2003

Title: Biscayne Bay coastal wetlands performance measures

Publication: SFWMD: Version 7/31/03

Publisher: SFWMD

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Alleman, R. **Date:** 2003

Title: Graphics related to the Biscayne Bay TABS - MDS Model

Publication: SFWMD

Publisher: SFWMD

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Complete Alphabetical Listing by Author

Author: Alleman, R. **Date:** 1995

Title: Update, surface water improvement and management plan for Biscayne Bay

Publication: Biscayne Bay SWIM Planning Document

Publisher: SFWMD

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☑

Author: Alleman, R. **Date:** 1995

Title: Update, surface water improvement and management plan for Biscayne Bay

Publication: Biscayne Bay SWIM Technical Appendix

Publisher: SFWMD

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☑

Author: Alleman, R., T. Stone, and S. Dignard **Date:** 2003

Title: Analysis of beneficial surface freshwater flows into Biscayne Bay (draft)

Publication: SFWMD

Publisher: SFWMD

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☑

Complete Alphabetical Listing by Author

Author: Anderson, G. **Date:** 1985

Title: Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Gulf of Mexico): Grass shrimp

Publication: U.S. FWS Biological Report 82

Publisher: USFWS

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Araujo, F.G., W.P. Williams, and R.G. Bailey **Date:** 2000

Title: Fish assemblages as indicators of water quality in the Middle Thames Estuary, England (1980-1989)

Publication: Estuaries 23(3):305-317

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Ault, J., S. Smith, G. Meester, J. Luo and J. Bohnsack. **Date:** 2001

Title: Site characterization for Biscayne National Park: Assessment of fisheries resources and habitats

Publication: NOAA Technical Memorandum NMFS-SEFSC-468

Publisher: NOAA

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Complete Alphabetical Listing by Author

Author: Ault, J., S. Smith, G. Meester, J. Luo and J. Bohnsack. **Date:** 2001

Title: Site characterization for Biscayne National Park: Assessment of fisheries resources and habitats.

Publication: NOAA Technical Memorandum NMFS-SEFSC-468.

Publisher: NOAA

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Ault, J.A., G.A. Diaz, S.G. Smith, J. Luo, J. A.Serafy **Date:** 1999

Title: An efficient sampling survey design to esitmate pink shrimp population abundance in Biscayne Bay, Florida

Publication: North American Journal of fisheries Management 19:696-712

Publisher:

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Ault, J.S., J. Luo, S.G. Smith, J.E. Serafy, R. Humston, and G.A. Diaz **Date:** 1998

Title: A spatial dynamic multistock production model

Publication: Canadian Journal of Fisheries and Aquatic Sciences

Publisher:

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Complete Alphabetical Listing by Author

Author: Austin, H., D.S. Haven, and M.S. Moustafa **Date:** 1993

Title: The relationship between trends in a condition index of the American oyster, Crassostrea virginica, and environmental parameters in three Virginia estuaries

Publication: Estuaries 16(2): 362-374

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Baker, P., D. Bergquist, and S. Baker **Date:** Unknown

Title: Oyster reef assessment in the Suwannee River Estuary: Final Report

Publication:

Publisher: Department of Fisheries and Aquatic Sciences, Univ. Florida

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Bancroft, G.T. et al **Date:** 1994

Title: Relationships among wading bird foraging patterns, colony locations, and hydrology in the Everglades

Publication: Everglades: The Ecosystem and Its Restoration

Publisher: St. Lucie Press

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Complete Alphabetical Listing by Author

Author: Banks, M.A., G.J. Holt, and J.M. Wakeman **Date:** 1991

Title: Age-linked changes in salinity tolerance of larval spotted seatrout (Cynoscion nebulosus, Cuvier)

Publication: Journal of Fish Biology 39: 505-514

Publisher: The Fisheries Society of the British Isles

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Beare, A. and J.B. Zedler **Date:** 1987

Title: Cattail invasion and persistence in a coastal salt marsh: the role of salinity reduction

Publication: Estuaries 10(2) 165-170

Publisher:

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Beck, M.W. et al **Date:** 2003

Title: The role of nearshore ecosystems as fish and shellfish nurseries

Publication: Issues in Ecology Number 11

Publisher: The Ecological Society of America

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Bedient, P. et al **Date:** 1999

Title: Report of the scientific peer review panel on the data, theories, and methodologies supporting the minimum flows and levels rule for the northern Tampa Bay area, Florida

Publication: SWFWMD

Publisher: SWFWMD

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species ☐ **Aquatic Plants/Habitat** ☐ **Ecological Indicators** ☐

Impact Approach ☐ **Water Quality Data** ☐ **Hydrologic Data** ☐

Author: Bellmund, S. , J. Browder, and S. Alspach **Date:** 1999

Title: Issue paper in freshwater flows to Biscayne Bay

Publication:

Publisher:

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species ☐ **Aquatic Plants/Habitat** ☐ **Ecological Indicators** ☐

Impact Approach ☐ **Water Quality Data** ☐ **Hydrologic Data** ☐

Author: Berkeley, S **Date:** 1984

Title: Fisheries assessment of Biscayne Bay

Publication: Final report

Publisher:

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species ☑ **Aquatic Plants/Habitat** ☐ **Ecological Indicators** ☐

Impact Approach ☐ **Water Quality Data** ☐ **Hydrologic Data** ☐

Complete Alphabetical Listing by Author

Author: Berkeley, S. and W. Campos **Date:** 1984

Title: Fisheries assessment of Biscayne Bay

Publication: Final draft

Publisher: Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Berkeley, S., D. Pybas, and W. Campos **Date:** 1985

Title: Bait shrimp fishery of Biscayne Bay

Publication: Florida Sea Grant Program, Technical Paper 40

Publisher: Florida Sea Grant College Program, Gainesville, FL

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Bert, T.M., J. Dodrill, G.E. Davis, and J. Tilmont **Date:** 1983

Title: The population dynamics of the stone crab (Menippe mercenaria) in Everglades and Biscayne National parks

Publication: Florida Scientist 43

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Bielsa, L.M., W.H. Murdich, and R.F. Labinsky **Date:** 1983

Title: Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (South Florida): Pink shrimp

Publication: U.S. FWS Biological Report 82

Publisher: USFWS

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Birnak, B.I. **Date:** 1974

Title: An examination of the influence of freshwater canal discharges on salinity in selected Southeastern Florida estuaries

Publication: NTIS # PB-231 610

Publisher: National Technical Information Service

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☑

Author: Bishop, T.D. and C.T. Hackney **Date:** 1987

Title: A comparative study of the mollusc communities of two oligohaline intertidal marshes: spatial and temporal distribution of abundance and biomass

Publication: Estuaries 10(2): 141-152

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Black, D.W. **Date:** 1994

Title: Protecting the water quality of Biscayne Bay

Publication: Florida Scientist 57(1): 51-52

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Bornman, T.G., J.B. Adams, and G.C. Bate **Date:** 2002

Title: Freshwater requirements of a semi-arid supratidal and floodplain salt marsh

Publication: Estuaries 25(6B): 1394-1405

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Bortone, S.A, and J.L. Williams **Date:** 1986

Title: Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (South Florida): Gray, Land, Mutton, and Yellowtail snappers

Publication: U.S. FWS Biological Report 82

Publisher: USFWS

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Bortone, S.A. Ed. **Date:** 2003

Title: Biology of the spotted seatrout

Publication: CRC Marine Biology Series

Publisher: CRC Press

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Bortone, Steven A. **Date:** 2003

Title: Spotted seatrout as a potential indicator of estuarine conditions

Publication: ? Chapter 16 297-300

Publisher: CRC Press LLC

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Brook, I.M. **Date:** 1982

Title: The effect of freshwater canal discharge on the stability of two seagrass benthic communities in Biscayne National Park, Florida

Publication: Oceanol. Acta 1982: 63-72

Publisher: SCOR/IABO/UNESCO

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Complete Alphabetical Listing by Author

Author: Browder, J. , Z. Zein-Eldin, M. Criales, M. Robblee, S. Wong, T. Jackson and D. Johnson **Date:** In press

Title: Dynamics of pink shrimp (Farfantepenaeus duorarum) recruitment potential in relation to salinity and temperature in Florida Bay. Estuaries

Publication:

Publisher:

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Browder, J., R. Alleman, P. Ortner, and S. Markley **Date:** 2003

Title: Biscayne Bay conceptual ecological model

Publication: TBD

Publisher:

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Browder, J., V.R. Restrepo, J.K. Rice, M.B. Robblee, and Z. Zein-Eldin **Date:** 1999

Title: Environmental influences on potential recruitment of pink shrimp, Farfantepenaeus duorarum, from Florida Bay nursery grounds.

Publication: Estuaries 22:484-499

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Browder, J.A. **Date:** 1981

Title: A new approach to determining the quantitative relationship between fishery production and the flow of fresh water to estuaries

Publication: Proceedings of the National Symposium on Freshwater Inflow to Estuaries

Publisher: USFWS

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Browder, J.A. **Date:** 1994

Title: Watershed management and the importance of freshwater flow to estuaries

Publication: Proceedings, Tampa Bay Area Scientific Information Symposium 2: 7-22

Publisher: TEXT, Tampa

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Browder, J.A. and J. Tashiro, E. Coleman-Duffle, A. Rosenthal, and J.D. Wang **Date:** 1989

Title: Documenting estuarine impacts of freshwater flow alterations and evaluating proposed remedies

Publication: Proceedings of the International Wetland Symposium: 300-312

Publisher: Association of Wetland Managers, Inc.

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☑

Complete Alphabetical Listing by Author

Author: Browder, J.A. et al **Date:** 1997

Title: Chapter 15: Success criteria based on a fishery species, Pink shrimp

Publication: Ecologic and precursor success criteria for south Florida ecosystem restoration

Publisher: South Florida Ecosystem Restoration Task Force

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Browder, J.A., et al. **Date:** 2002

Title: Dynamics of pink shrimp (Farfantepenaeus duorarum) recruitment potential in relation to salinity and temperature in Florida Bay.

Publication: Estuaries

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Browder, J.A., F.H. Sklar **Date:** 1998

Title: Coastal environmental impacts brought about by alterations to freshwater flow in the Gulf of Mexico

Publication: Environmental Management 22:547-562

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Browder, J.A., J. Tahsiro, E Coleman-Duffie, A. Rosenthal **Date:** 1989

Title: Documenting estuarine impacts of freshwater flow alterations and evaluating proposed remedies

Publication: Wetlands and River Corridor Management Proceedings of the International Wetlands Symposium

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Brown, G. **Date:** 2001

Title: Physics based numerical hydrodynamic and salinity model of Biscayne Bay, FL

Publication: Proceedings of the 16th Biennial Conference of the Estuarine Research Federation

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Brown-Peterson, N.J., M.S. Peterson, D.L. Nieland, M.D. Murphy, R.G. Taylor, & J.R. Warren **Date:** 2002

Title: Reproductive biology of female spotted seatrout, Cynoscion nebulosus, in the Gulf of Mexico: differences among estuaries?

Publication: Environmental Biology of Fishes 63: 405-415

Publisher: Klower Academic Publishers

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Bulger, A.J., B.P. Hayden, M.E. Monaco, D.M. Nelson, M.G. McCormick-Ray **Date:** 1993

Title: Biologically-based estuarine salinity zones derived from multivariate analysis

Publication: Estuaries 16:311-322

Publisher:

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Bulger, A.J., B.P. Hayden, M.G. McCormick-Ray, M.E. Monaco, and D.M. Nelson **Date:** 1990

Title: A proposed estuarine classification: analysis of species salinity ranges

Publication: ELMR Report No. 5

Publisher: NOS/NOAA

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Burrel, V.G. **Date:** 1986

Title: Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (South Atlantic): American oyster

Publication: U.S. FWS Biological Report 82

Publisher: USFWS

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Complete Alphabetical Listing by Author

Author: Byrne, D.M. **Date:** 1978

Title: Life history of the spottin killifish, Fundulus luciae (Pisces: Cyprinodontidae) in Fox Creek Marsh, Virginia

Publication: Estuaries 1(4): 211-227

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Campbell, H.W. **Date:** 1972

Title: Ecological or physiological interpretations of crocodilian nesting habits

Publication: Nature 238: 404-405

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Chamberlain, R.H. and P.H. Doering **Date:** 1998

Title: Freshwater inflow to the Caloosahatchee Estuary and the resource-based method for evaluation

Publication: Charlotte Harbor Technical Report No. 98-02

Publisher: Charlotte Harbor National Estuary Program

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Chamberlain, R.H. and P.H. Doering **Date:** Unknown

Title: Preliminary estimate of optimum freshwater inflow to the Caloosahatchee Estuary: A resource-based approacl

Publication: Preliminary estimate of optimum freshwater inflow to the Caloosahatchee Estuary: A resource-based approacl

Publisher: SFWMD

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Chervinski, J. **Date:** 1984

Title: Salinity tolerance of young catfish, Clarias lazera (Burchell)

Publication: J. Fish Biol. 25: 147-149

Publisher: The Fisheries Society of the British Isles

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Chervinski, J. **Date:** Unknown

Title: Salinity tolerance of young gilthead sea bream

Publication:

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Complete Alphabetical Listing by Author

Author: Christiansen, J.D., M.E. Monaco, and T.A. lowery **Date:** 1997

Title: An index to assess the sensitivity of Gulf of Mexico species to changes in estuarine salinity regimes

Publication: Gulf Research Reports Vol.9 Nol. 4:219-229

Publisher:

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Clark, R.D., W. Morrison, J.D. Christensen, M.E. Monaco and M.S. Coyne **Date:** Unknown

Title: Modeling the distribution and abundance of spotted seatrout: integration of ecology and GIS technology to support management needs

Publication:

Publisher: NOAA/NOC/NCCOS/CCMA Biogeography Program

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Coen, L.D. and M.W. Luckenbach **Date:** 2000

Title: Developing success criteria and goals for evaluating oyster reef restoration: ecological function or resource exploitation?

Publication: Ecological Engineering 15: 323-343

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Coen, L.D., M.W. Luckenbach, and D.L. Breitburg **Date:** 1999

Title: The role of oyster reefs as essential fish habitat: a review of current knowledge and some new perspectives

Publication: Fish habitat: essential fish habitat and rehabilitation pp. 438-454

Publisher: American Fisheries Society

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Cofer-Shabica, S.V., J.D. Wang **Date:** 1989

Title: The effects of freshwater canal discharges on salinities in Biscayne National Park

Publication: Coastal Zone 89 Proeceedings of the Sixth Symposium on Caostal and Ocean Management 2738 -2753

Publisher: ASCE

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☑

Author: Collins, M.R. **Date:** 1985

Title: Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Florida) - Striped mullet

Publication: U.S. FWS Biological Report 82

Publisher: USFWS

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Committee on a Systems Assessment of Marine Environmental Monitoring, National Research Council **Date:** 1990

Title: Chapter 4: Designing and Implementing Monitoring Programs

Publication: Managing Troubled Waters: The Role of Marine Environmental Monitoring

Publisher: National Academy of Sciences

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Comp, G. and W. Seaman **Date:** 1985

Title: Estuarine habitat and fishery resources of Florida. In: Florida Aquatic Habitat and Fishery Resources

Publication: Florida Chapter, American Fisheries Society, Kissimmee, FL

Publisher:

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Costello, T.J., D.M. Allen **Date:** 1966

Title: Migrations and geographic distribution of pink shrimp, Pinaeus duorarum, of the Tortugas and Sanibel Grounds, Florida

Publication: Fishery Bulletin 65:449-459

Publisher:

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Countryman, R.A. and M.T. Stewart **Date:** 1997

Title: Geophysical delineation of the position of the saltwater interface in the Lower Suwannee River Basin

Publication: Final Contract Report for SRWMD and USGS

Publisher: Geology Department, University of South Florida

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Crisp, D.J. **Date:** 1967

Title: Chemical factors inducing settlement in Crassostrea virginica

Publication: J. Anim. Ecol 36: 329-335

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Cropper, W.P., D. Lirman, S.C. Tosini, D. DiResta, J. Luo and J. Wang **Date:** 2001

Title: Population dynamics of a commercial sponge in Biscayne Bay, Florida

Publication: Estuarine, Coastal and Shelf Science 53:13-23

Publisher: Academic Press

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Complete Alphabetical Listing by Author

Author: Cummins, K. **Date:** Unknown

Title: Chapter 14: South Florida success criteria estuarine and inland fish populations and communities

Publication: Ecologic and precursor success criteria for south Florida ecosystem restoration

Publisher: South Florida Ecosystem Restoration Task Force

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Dame, R. **Date:** 1996

Title: Ecology of marine bivalves: an ecosystem approach

Publication: CRC Marine Biology Series

Publisher: CRC

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Dame, R.F., J.D. Spurrier, R.G. Zingmark **Date:** 1992

Title: In situ metabolism of an oyster reef

Publication: Journal Experimental Marine Biology and Ecology 171: 251-258

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Darst, M.R., H.M. Light, and L.J. Lewis **Date:** 2002

Title: Ground-cover vegetation in wetland forests of the Lower Suwannee River floodplain, Florida, and potential impacts of flow reductions

Publication: Water Resources Investigations Report 02-4027

Publisher: USGS

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Davenport, J. **Date:** 1982

Title: Environmental stimulation experiments on marine and estuarine animals

Publication: Adv. Mar. Biol. 19: 133-256

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Davis, G.E. **Date:** Unknown

Title: National Park Service spiny lobster fishery research in Florida a progress report

Publication:

Publisher: National Park Service

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: De Sylva, D **Date:** 1970

Title: Ecology and distribution of postlarval fishes of southern Biscayne Bay, Florida

Publication: Progress report to the U.S.E.P.A. Water Quality Office. Contract FWQA 18050 DIU, covering the period 1 June 1969 - 30 September 1970

Publisher: Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: De Sylva, D **Date:** 1969

Title: Sport fisheries

Publication: In: Voss, G., F. Bayer, C. Robins, M. Gomon and E. LaRoe (eds.), The marine ecology of the Biscayne National Monument, Miami

Publisher: Rosenstiel School of Marine and Atmospheric Sciences, University of Miami. Miami, FL

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: De Vries, M.C., R.B. Forward, and W.F. Hettler **Date:** 1995

Title: Behavioral response of larval Atlantic menhaden Brevoortia tyrannus (Latrobe) and spot Leiosomus xanthurus (Lacepede) to rates of salinity change

Publication: Journal of Experimental Marine Biology and Ecology 185: 93-108

Publisher: Elsevier Science Ltd.

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: DeAngelis, D.L., W.F. Loftus, J.C. Trexler, and R.E. Ulanowicz **Date:** 1997

Title: Modeling fish dynamics and effects of stress in a hydrologically pulsed ecosystem

Publication: Journal of Aquatic Ecosystem Stress and Recovery 6: 1-13

Publisher: Kluwer Academic Publishers

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Defeo, O. **Date:** Unknown

Title: Testing hypotheses on recruitment, growth, and mortality in exploited bivalves: an experimental prospective

Publication: Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management: 257-264

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Defeo, O., A. de Alva **Date:** 1995

Title: Effects of human activites on lon-term trends in snady beach populations: the wedge clam Donax hanleyanus in Uruguay

Publication: Marine Ecology Progress Series 123: 73-83

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Dennis, G.D., K.J. Sulak **Date:** 2001

Title: Mangrove prop-root habitat as essential fish habitat in northeastern Florida Bay

Publication: Florida Bay Science Conference Presentation, April 2001

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: deSylva, D.P. **Date:** 1976

Title: Fishes of Biscayne Bay, Florida

Publication: pp. 181-202 in A.L. Thorhaug, A.S. Volker, eds., Biscayne Bay - Past, Present, Future (University of Miami Sea Grant Special Publication 5)

Publisher: University of Miami

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Diaz, G. **Date:** 2001

Title: Population dynamics and assessment of pink shrimp (Farfantepenaeus duorarum) in subtropical nursery grounds

Publication: Ph.D. Dissertation

Publisher: University of Miami

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Diaz, G.A. **Date:** Unknown

Title: Spatial and temporal patterns of pink shrimp post-larval settlement in Biscayne Bay

Publication: Presentation

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species ☑ **Aquatic Plants/Habitat** ☐ **Ecological Indicators** ☑

Impact Approach ☐ **Water Quality Data** ☐ **Hydrologic Data** ☐

Author: Diaz, G.A., S.G. Smith, J.E. Searfy, and J.S. Ault **Date:** 2001

Title: Allometry of the growth of pink shrimp Farfantepenaeus duorarum in a subtropical bay

Publication: Transactions of the American Fisheries Society 130:328-335

Publisher: American Fisheries Society

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species ☐ **Aquatic Plants/Habitat** ☑ **Ecological Indicators** ☐

Impact Approach ☐ **Water Quality Data** ☑ **Hydrologic Data** ☐

Author: Doering, P.H., R.H. Chamberlain, and D.E. Haunert **Date:** 2002

Title: Using submerged aquatic egetation to establish minimum and maximum freshwater inflows to the Caloosahatchee Estuary, Florida

Publication: Estuaries 25(6B): 1343-1354

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species ☐ **Aquatic Plants/Habitat** ☐ **Ecological Indicators** ☐

Impact Approach ☐ **Water Quality Data** ☑ **Hydrologic Data** ☐

Author: Drouin, G. and J.H. Himmelman **Date:** 1985

Title: Impact of tidal salinity fluctuations on echinoderm and mollusc populations

Publication: Can. J. Zool. 63: 1377-1387

Publisher: NRC Canada

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Dunson, W.A. **Date:** 1982

Title: Salinity relations of crocodiles in Florida Bay

Publication: Copeia 2:374-385

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Edwards, C.E. **Date:** 1980

Title: Giant shrimp in Biscayne Bay

Publication: Of Sea and Shore

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Edwards, R.E. **Date:** 1991

Title: Nursery habitats of important early-juvenile fishes in the Manatee River Estuary System of Tampa Bay

Publication: Proceedings, Tampa Bay Area Scientific Information Symposium 2: 237-251

Publisher: TEXT, Tampa

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Egler, F. **Date:** 1950

Title: Southeast saline Everglades vegetation

Publication: Florida and Its Management

Publisher: American Museum of Natural History

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Ehrhardt, N.M. and C.M. Legault **Date:** 1999

Title: Pink shrimp, Farfantepenaeusduorarum, recruitment variability as an indicator of Florida Bay dynamics

Publication: Estuaries 22(2B): 471-483

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Ellis, T.M. **Date:** 1981

Title: Tolerance of sea water by the American crocodile, Crocodylus acutus

Publication: J. Herpetol. 15(2): 187-192

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Engel, D.W., W.F. Hetter, L. Coston-Clements, D.E. Hoss **Date:** 1987

Title: The effect of abrupt salinity changes on the osmoregulatory abilities of the Atlantic Menhaden Brevoortia tyrannus

Publication: Comparative Biochemisrty and Physiology 86A: 723-727

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Environmental Consulting & Technology, Inc. **Date:** 2003

Title: Environmental Evaluations for the Development of Minimum Flows and Levels for the St. Johns River Near Deland at State Road 44, Volusia County

Publication: Prepared for St. Johns River Water Management District, Palatka, Florida

Publisher: Prepared by ECT, Gainesville, Florida, ECT No. 020157-0100

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☑	**Hydrologic Data**	☑

Complete Alphabetical Listing by Author

Author: EPA **Date:** 2000

Title: Chapter 1: Introduction: Bioassessment and Biocriteria Technical Guidance

Publication: Estuarine and Coastal Marine Waters: Bioassessment and Biocriteria Technical Guidance

Publisher: EPA

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Estevez, E. **Date:** 2002

Title: Review and assessment of biotic variables and analytical methods used in estuarine inflow studies

Publication: Estuaries 25(6B): 1291-1303

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Estevez, E.D. **Date:** 2000

Title: A review and application of literature concerning freshwater flow management in riverine estuaries

Publication: Mote Marine Laboratory Technical Report 680

Publisher: SFWMD

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☑	**Hydrologic Data**	☑

Author: Estevez, E.D. and J. Sprinkel **Date:** 1999

Title: Dispersion and abundance of submerged aquatic vegetation in the tital Suwannee River, Florida in relation to flow, salinity, and related variables

Publication:

Publisher: Mote Marine Laboratory

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species ☐ **Aquatic Plants/Habitat** ☐ **Ecological Indicators** ☐

Impact Approach ☑ **Water Quality Data** ☐ **Hydrologic Data** ☐

Author: Estevez, E.D. and J. Sprinkel **Date:** 2000

Title: Dispersion and abundance of wood habitat of the Santa Fe and Lower Suwannee River Systems in relation to flow and flow-related variables

Publication:

Publisher: Mote Marine Laboratory

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species ☐ **Aquatic Plants/Habitat** ☐ **Ecological Indicators** ☐

Impact Approach ☑ **Water Quality Data** ☐ **Hydrologic Data** ☐

Author: Estevez, E.D., R.E. Edwards, D.M. Hayward **Date:** 1991

Title: An ecological overview of Tampa Bay's tidal rivers

Publication: Proceedings, Tampa Bay Area Scientific Information Symposium 2: 237-251

Publisher: TEXT, Tampa

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species ☐ **Aquatic Plants/Habitat** ☐ **Ecological Indicators** ☐

Impact Approach ☐ **Water Quality Data** ☑ **Hydrologic Data** ☑

Author: Fatt, J.C. and J.D. Wang **Date:** 1987

Title: Canal discharge impacts on Biscayne Bay salinities, Biscayne National Park

Publication: National Park Service Research/Resources Management Report SER-89

Publisher: National Park Service

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Flannery, M.S., E.B. Peebles, and R.T. Montgomery **Date:** 2002

Title: A percent-of-flow approach for managing reductions of freshwater inflows from unimpounded rivers to southwest Florida estuaries

Publication: Estuaries 25(6B): 1318-1332

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Florida Department of Natural Resources **Date:** 1991

Title: Biscayne Bay- Card Sound aquatic preserve management plan.

Publication: Cabinet draft

Publisher: Florida Department of Natural Resources, Tallahassee, FL

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Fonseca, M.S., W.J. Kensworthy, and G.W.Thayer **Date:** 1992

Title: Seagrass beds: nursery for coastal species

Publication: Stemming the Tide of Coastal Fish Habitat Loss Marine Recreational Fisheries 14 Proceedings of A Symposium on Conservation of Coastal Fish Habitat 141-146

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Foster, Ann M., T.J. Smith III **Date:** 2001

Title: Changes in the mangrove/marsh ecotones of the Florida Everglades

Publication: Sixteenth Biennial Conference of the Estuarine Research Federation USGS Poster

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Frisbie, C.M. **Date:** 1961

Title: Young black drum, Pogonias cromis, in tidal fresh and brackish waters, especially in the Chesapeake and Delaware Bay areas.

Publication: Chesapeake Science 2(1-2): 94-100

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Frithsen, J.B., A.F. Holland **Date:** Unknown

Title: Benthic communities as indicators of ecosystem condition

Publication:

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Frusher, S.D., R.L. Giddins, and T.J. Smith III **Date:** 1994

Title: Distribution and abundance of grapsid crabs (Grapsidae) in a mangrove estuary: effects of sediment characteristics, salinity tolerances, and osmoregulatory ability

Publication: Estuaries 17(3): 647-654

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Gaby, R., M.P. McMahon, F.J. Mazotti, W.N. Gillies and J.R. Wilcox **Date:** 1985

Title: Ecology of a population of Crocodylus acutus at a power plant site in Florida

Publication: J.Herpetol. 19(2): 189-198

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Gaumet, F., G. Boeuf, J.P. Truchot, and G. Nonnott **Date:** 1994

Title: Effects of environmental water salinity on blood acid-base status in juvenile turbot (Scophthalmus maximus L.)

Publication: Comp. Biochem. Physiol. 109A: 985-994

Publisher: Elsevier Science Ltd.

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Gleason, P.J. ed. **Date:** 1984

Title: Environments of South Florida present and past II

Publication:

Publisher: Miami Geological Society

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Godcharles, M.F. and M.D. Murphy **Date:** 1986

Title: Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Florida) - King mackerel and Spanish mackerel

Publication: U.S. FWS Biological Report 82

Publisher: USFWS

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Golder Associates, Inc. **Date:** 2000

Title: Report on mapping low-salinity submerged aquatic vegetation beds in the lower Suwannee River

Publication:

Publisher: Golder Associates, Inc.

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Good, J.C. and J.M. Jacobs **Date:** 2001

Title: Ecologically sustainable watershed management using annualized flow duration curves

Publication: Proceedings of the World Water & Environmental Congress 9ASCE) May 20-24, 2001, Orlando, FL

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Gore, J.A., C. Dahm, and C. Klimas **Date:** 2002

Title: A review of "Upper Peace River: an analysis of minimum flows and levels"

Publication:

Publisher: SFWMD

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Greer, A.E. **Date:** 1975

Title: Clutch size in crocodilians

Publication: J. Herpetol. 9(3): 319-322

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Guerin, J.L. and W.B. Stickle **Date:** 1997

Title: A comparative study of two sympatric species within the genus Callinectes: osmoregulation, long-term acclimation to salinity and the effects of salinity on growth and moulting

Publication: Journal of Experimental Marine Biology and Ecology, 218: 165-168

Publisher: Elsevier Science

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Guerin, J.L. and W.B. Stickle **Date:** 1997

Title: Effect of salinity on survival and bioenergetics of juvenile lesser blue crabs, Callinectes similis

Publication: Marine Biology 129: 63-69

Publisher: Springer-Verlag

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Gunderson, L.H. **Date:** 1994

Title: Vegetation of the Everglades: determinants of community composition

Publication: Everglades: The Ecosystem and Its Restoration

Publisher: St. Lucie Press

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Hackney, C.T. **Date:** 2000

Title: Restoration of coastal habitats: expectation and reality

Publication: Ecological Engineering 15: 165-170

Publisher: Elsevier

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Halley, R.B **Date:** 2001

Title: Productivity measurements of benthic communities in Biscayne National Park as an indicator of ecosystem health

Publication: USGS Open File Report 01-091

Publisher: USGS St. Petersburg

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Handeland, S.O., T. Jarvi, A. Ferno, and S.O. Stefansson **Date:** 1996

Title: Osmotic stress, antipredator behaviour, and mortality of Atlantic salmon (Salmo salar) smolts

Publication: Can. J. Fish. Aquat. Sci. 53: 2673-2680

Publisher: NRC Canada

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Haney, D.C. **Date:** 1999

Title: Osmoregulation in the sheepshead minnow, Cyprinodon variegatus: Influence of a fluctating salinity regime

Publication: Estuaries 22(4): 1071-1077

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Harding, J.M. and R. Mann **Date:** 1999

Title: Fish species richness in relation to restored oyster reefs, Piankatank River, Virginia

Publication: Bulletin of Marine Science 65: 289-300

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Harding, J.M. and R. Mann **Date:** 2001

Title: Temporal variation and patchiness of zooplankton around a restored oyster reef

Publication: Estuaries 24(3): 453-466

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Harlem, P **Date:** 1979

Title: Aerial photographic interpretation of the historical changes in northern Biscayne Bay, Florida: 1925-1976

Publication: University of Miami: Sea Grant Technical Bulletin No. 40

Publisher: University of Miami

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Harper, D., J. Bohnsack and B. Lockwood **Date:** 2000

Title: Recreational fisheries in Biscayne National Park, Florida, 1976-1991

Publication: Marine Fisheries Review. 62(1), 2000

Publisher: Marine Fisheries

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Complete Alphabetical Listing by Author

Author: Hartman, D. **Date:** 1979

Title: Ecology and behavior of the manatee (Trichechus manatus) in Florida

Publication: Dept. of Conservation, Cornell Univ., NY. Special Pub. No. 5

Publisher: The American Society of Mammologists

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Harwell, M.A. **Date:** 1997

Title: Ecosystem management of South Florida

Publication: Unknown

Publisher: Unknown

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Hill, J. and C.E. Cichra **Date:** 2002

Title: Minimum flows and levels criteria development

Publication: The Effects of Water Levels on Fish populations

Publisher: University of Florida, Institute of Food and Agricultural Sciences

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Hill, J., D.L. Fowler, and M.J. Van Den Avyle **Date:** 1989

Title: Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (mid-Atlantic): blue crab

Publication: U.S. FWS Biological Report 82

Publisher: USFWS

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Holm Jr., G.O. and C.E. Sasser **Date:** 2001

Title: Differential salinity response between two Mississippi River subdeltas: implications for change in plant composition

Publication: Estuaries 24(1): 78-89

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Hopkins, S.H. **Date:** 1973

Title: Annotated bibliography on effects of salinity and salinity changes on life in coastal waters

Publication: U.S. ACOE Waterways Experiment Station

Publisher: Texas A&M University

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Houde, E.D. **Date:** Unknown

Title: Survey of the literature relating to sport and commercial fishes of South Florida

Publication:

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Houde, E.D. and J.D.A. Lovdal **Date:** 1985

Title: Patterns of variability in icthyoplankton occurrence and abundance in Biscayne Bay, Florida

Publication: Estuarine Coastal and Shelf Science (20): 79-103

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Huey, Raymond B. **Date:** 1991

Title: Physiological consequences of habitat selection

Publication: The American Naturalist 137: 91 -115

Publisher: University of Chicago

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Hughes, J.E., L.A. Deegan, M.J. Weaver, and J.E. Costa **Date:** 2002

Title: Regional application of an index of estuarine biotic integrity based on fish communities

Publication: Estuaries 25(2): 250-263

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Idyll, C.P. **Date:** Unknown

Title: Economically important marine organisms in Biscayne Bay

Publication:

Publisher: University of Miami

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Idyll, C.P. **Date:** Unknown

Title: Economically important organisms in Biscayne Bay

Publication:

Publisher: University of Miami

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Irlandi, E., B. Orlando, S. Macia, P. Biber, T. Jones, L. Kaufman, D. Lirman, and E.T. Patterson **Date:** 2002

Title: The influence of freshwater runoff on biomass, morphometrics, and production of Thalassia testudinum

Publication: Aquatic Botany 7: 67-78

Publisher: Elsevier Science

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Irlandi, E., B. Orlando, S. macia, P. Biber, T. Jones, L. Kaufman, D. Lirman, and E.T. Patterson **Date:** 2002

Title: The influence of freshwater runoff on biomass, morphometrics, and production of Thalassia testudinum

Publication: Aquatic Botany 72(1): 67-78

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Irlandi, E., S. Macia, J. Serafy **Date:** 1997

Title: Salinity reduction from freshwater canal discharge: effects on mortality and feeding of an urchin (Lytechinus variegatus) and a gastropod (Lithopoma techtum)

Publication: Bulletin of Marine Science 61 869-879

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Complete Alphabetical Listing by Author

Author: Ishman, S **Date:** 1997

Title: Ecosystem history in south Florida: Biscayne Bay sediment core descriptions

Publication: U.S. Geological Survey. USGS open file report 97

Publisher: USGS

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Ishman, S.E., I. Graham, and J. D'Ambrosio **Date:** 1997

Title: Modern benthic foraminifer distributions in Biscayne Bay: Analogs for historical reconstructions

Publication: USGS Report 97-34

Publisher: USGS

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Ishman, S.E., T.M. Cronin, G.L. Brewster-Wingard, D.A. Willard, and D.J. Verardo **Date:** 1998

Title: A record of ecosystem change, Manatee Bay, Barnes Sound, Florida.

Publication: Journal of Coastal Research. (SI)26:125-138

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Jackson, L.E., J.C. Kurtz, and W.S. Fisher **Date:** 2000

Title: Evaluation guidelines for ecological indicators

Publication: EPA ORD

Publisher: EPA

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Jacob, W.F. and M.. Taylor **Date:** 1983

Title: The time course of seawater acclimation in Fundulus heteroclitus L.

Publication: Journal of Experimental Zoology 228: 33-39

Publisher: Alan R. Liss, Inc.

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Jeffrey, D.W., B. Madden, B.Rafferty, R. Dwyer, and J.G. Wilson **Date:** Unknown

Title: Indicator organisms as a guide to estuarine management

Publication:

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Johnson, D.R., and W. Seaman **Date:** 1986

Title: Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Florida) - spotted seatrout

Publication: USFWS Biol. Rep. 82(11.43)

Publisher: USFWS

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Jory, D.E. and E.S. Iversen **Date:** 1989

Title: Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Florida) - Black, Red, and Nassau Groupers

Publication: U.S. FWS Biological Report 82

Publisher: USFWS

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Joseph, E.B. and V.P. Saksena **Date:** 1966

Title: Determination of salinity tolerances in mummichog (Fundulus heteroclitus) larvae obtained from hormone-induced spawning

Publication: Chesapeake Science 7(4): 193-197

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Kennedy, V.S. **Date:** 1991

Title: Habitat requirements for Chesapeake Bay living resources: eastern oyster.

Publication: Habitat requirements for Chesapeake Bay living resources

Publisher: Chesapeake Research Consortium, Inc.

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Kimmerer, W.J. **Date:** 2002

Title: Physical, biological, and management responses to variable freshwater flow into the San Francisco Estuary

Publication: Estuaries 25(6B): 1275-1290

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Klaoudatos, S.D. and A.J. Conides **Date:** 1996

Title: Growth, food conversion, maintenance and long-term survival of gilthead sea bream, Spatus auratus L., juveniles after abrupt transfer to low salinity

Publication: Aquaculture Research 27: 765-774

Publisher: Blackwell Science Ltd.

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Kohout, F.A. **Date:** 1987

Title: Aquifer-estuary fresh-salt water balance

Publication: Groundwater Problems in coastal areas

Publisher: Unesco

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Kohout, F.A. **Date:** 1967

Title: Relation of seaward and landward flow of groundwater to the salinity of Biscayne Bay, (Florida)

Publication: Masters Thesis, Univ. of Miami

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Kohout, F.A. and M.C. Kolipinski **Date:** 1967

Title: Biological zonation related to groundwater discharge along the shore of Biscayne Bay, Miami, Florida

Publication: Estuaries

Publisher: American Association for the Advancement of Science

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Konstantinov, A.S. and V.V. Martynova **Date:** 1993

Title: Effect of salinity fluctuations on energetics of juvenile fish

Publication: Journal of Icthyology 33: 1-8

Publisher: Scripta Technica, Inc.

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Kostecki, P.T. **Date:** 1984

Title: Habitat suitability index models: spotted seatrout

Publication: USFWS

Publisher: USFWS

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Kucera, C.J., C.K. Faul, and G.J. Holt **Date:** 2002

Title: The effect of parental acclimation to spawning salinity on the survival of larval Cynoscion nebulosus

Publication: Journal of Fish Biology 61(3): 726-738

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Kucera, C.J., C.K. Faul, and G.J. Holt **Date:** 2002

Title: The effect of spawning salinity on eggs of spotted seatrout (Cynoscion nebulosus, Cuvier) from two bays with historically different salinity regimes

Publication: Journal of Experimental Marine Biology and Ecology 272(2): 147-158

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Kumlu, M. and D.A. Jones **Date:** 1995

Title: Salinity tolerance of hatchery-reared postlarvae of Penaeus indicus H. Milne Edwards originating from India

Publication: Aquaculture 130: 287-296

Publisher: Elsevier Science B.V.

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Kushlan, J.A. **Date:** 1988

Title: Profiles - conservation and management of the American Crocodile

Publication: Environmental Management 12:777-790

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Kushlan, J.A. and D.A. White **Date:** 1977

Title: Nesting wading bird populations in southern Florida

Publication: Florida Scientist 40: 65-72

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Kushlan, J.A. and F. Mazzotti **Date:** 1989

Title: Population biology of the American crocodile

Publication: J. Herpetol. 23(1): 7-21

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Kushlan, J.A., F.J. Mazzotti **Date:** 1989

Title: Historic and present distribution of the American crocodile in florida

Publication: Journal of Herpetology 23: 1-7

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Langevin, C.D. **Date:** 2000

Title: Simulation of ground-water discharge to Biscayne Bay, southeastern Florida

Publication: USGS Water Resources Investigation Report 00-4251

Publisher: USGS

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Lankford, T.E., and T.E. Targett **Date:** 1994

Title: Suitability of estuarine nursery zones for juvenile weakfish (Cynoscion regalis)

Publication: Marine Biology 119: 611-620

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Lasserre, P. and J.L. Gallis **Date:** 1975

Title: Osmoregulation and differential penetration of two grey mullets, Chelon labrosus (Risso) and Liza ramada (Risso) in estuarine fish ponds

Publication: Aquaculture 5:323-344

Publisher: Elsevier Scientific

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Leak, J.C. and E.D. Houde **Date:** 1987

Title: Cohort growth and survival of bay anchovy Anchoa mitchilli larvae in Biscayne Bay, Florida

Publication: Marine Ecology Progress Series 36:109-122

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Lee, T.N. and C. Booth **Date:** Unknown

Title: Exchange processes in shallow estuaries

Publication: Quarterly Journal of the Florida Academy of Sciences

Publisher: Florida Academy of Sciences

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Lehman, P.W. **Date:** 2000

Title: Phytoplankton biomass, cell diameter, and species composition in the low salinity zone of northern San Francisco Bay Estuary

Publication: Estuaries 23(2): 216-230

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Lehnert, R.L. and D.M. Allen **Date:** 2002

Title: Nekton use of subtidal oyster shell habitat in a southeastern U.S. estuary

Publication: Estuaries 25(5): 1015-1024

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Lenihan, H.S., F. Micheli, S.W. Shelton, and C.H. Peterson **Date:** 1999

Title: The influence of multiple environmental stressors on susceptibility to parasites: an experimental determination with oysters

Publication: Limnology and Oceanography 44: 910-924

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Light, H.M., M.R. Darst, L.J. Lewis, and D.A. Howell **Date:** 2002

Title: Hydrology, vegetation, and soils of riverine and tidal floodplain forests of the lower Suwannee River, Florida, and potential impacts of flow reductions

Publication: USGS Professional Paper 1656A

Publisher: USGS

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Lindall, W.N. **Date:** 1974

Title: Alterations of estuaries of South Florida: a threat to its fish resources

Publication: Operculum

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Lindberg, W.J. and M.J. Marshall **Date:** 1984

Title: Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (South Florida): Stone Crab

Publication: U.S. FWS Biological Report 82

Publisher: USFWS

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Lindeman, K.C., R. Pugliese, G.T. Waugh, and J.S. Ault **Date:** 2000

Title: Developmental patterns within a multispecies reef fishery: management applications for essential fish habitats and protected areas

Publication: Bulletin of Marine Science 66: 929-956

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Lirman, D. and W.P. Cropper, Jr. **Date:** 2003

Title: The influence of salinity on seagrass growth, survivorship, and distribution within Biscayne Bay, Florida: Field, experimental, and modeling studies

Publication: Estuaries 26(1): 131-141

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Lirman, D., B. Orlando, S. Macia, D. Manzello, L. Kaufman, P. Biber and T. Jones **Date:** 2003

Title: Coral communities of Biscayne Bay, Florida and adjacent offshore areas: diversity, abundance, distribution, and environmental correlates

Publication: Aquatic Conservation: Marine and Freshwater Ecosystems 13:121-135

Publisher: Wiley InterScience

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Lirman, D., E.A. Irlandi, and W.P. Cropper **Date:** 2002

Title: A conceptual model of Biscayne Bay

Publication: http://www.rsmaas.miami.edu/groups/cmea/bbay

Publisher: University of Miami

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Complete Alphabetical Listing by Author

Author: Llanso, R.J. et al **Date:** 2002

Title: An estuarine benthic index of biotic integrity for the mid-Atlantic region of the United States. I. Classification of assemblages and habitat definition

Publication: Estuaries 25(6A): 1219-1230

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Llanso, R.J. et al **Date:** 2002

Title: An estuarine benthic index of biotic integrity for the mid-Atlantic region of the United States. II. Index Development

Publication: Estuaries 25(6A): 1231-1242

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Lonereragan, N.R., I.C. Potter, R.C.J. Lenanton, and N. Caputi **Date:** 1986

Title: Spatial and seasonal differences in the fish fauna in the shallows of a large Australian estuary

Publication: Marine Biology 92: 575-586

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Long, E.R., M.J. Hameedi, G.M. Sloane, and L.B. Read **Date:** 2002

Title: Chemical contamination, toxicity, and benthic community indices in sediments of the lower Miami River and adjoining portions of Biscayne Bay, Florida

Publication: Estuaries 25(4A): 622-637

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Lorenz, J.J., et al **Date:** 2002

Title: Nesting patterns of Roseate spoonbills in Florida Bay 1935-1999: Implications of landscape scale anthropogenic impacts

Publication: The Everglades, Florida Bay, and Coral Reefs of the Florida Keys: An Ecosystem Sourcebook

Publisher: CRC Press

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Lough, R.G. **Date:** 1975

Title: A reevaluation of the combined effects of temperature and salinity on survival and growth of bivalve larvae using response surface techniques

Publication: Fishery Bulletin 73: 86-94

Publisher:

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Low, R.A **Date:** 1973

Title: Shoreline grassbed fishes in Biscayne Bay, Florida, with notes on the availability of clupeid fishes

Publication: Masters Thesis, Univ. of Miami

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Luckenbach, M.W., R. Mann and J.A. Wesson **Date:** 1999

Title: Oyster reef habitat restoration. A synopsis and synthesis of approaches

Publication: Virginia Institute of Marine Science Press

Publisher: VIMS

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Luo, J., J.E. Serafy **Date:** 2002

Title: Data quality control, time series analysis and statistical modeling of salinity and canal discharges in Biscayne National Park

Publication: Final Report to Biscayne National Park 1-26

Publisher:

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Markley, S. and G. Milano **Date:** 1985

Title: A summary report on its physical and biological characteristics

Publication: Miami-Dade County Department of Environmental Resources Management

Publisher: Miami-Dade County

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Martinez-Palacios, C.A., L.G. Ross, and M. Rosado-Vallado **Date:** 1990

Title: The effects of salinity on the survival and growth of juvenile Cichlasoma urophthalmus

Publication: Aquaculture 91: 65-75

Publisher: Elsevier Science B.V.

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Mattson, R.A. **Date:** 2002

Title: A resource-based framework for establishing freshwater inflow requirements for the Suwannee River Estuary

Publication: Estuaries 25(6B): 1333-1342

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Complete Alphabetical Listing by Author

Author: Mattson, R.A. and J. Krummrich **Date:** 1995

Title: Determination of salinity distributions in the Upper Suannee River Estuary

Publication: Final Report

Publisher: Florida Game and Freshwater Fish Commission and SRWMD

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Mazzotti, F **Date:** 1983

Title: The ecology of Crocodylus acutus in Florida; A thesis in ecology. Ph.D. dissertation

Publication: Pennsylvania State University, University Park, PA

Publisher: Pennsylvania State University

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Mazzotti, F.J. and M.S. Cherkiss **Date:** 1998

Title: Status and distribution of the American crocodile (Crocodylus acutus) in Biscayne Bay

Publication: SFWMD Poject Report

Publisher: Everglades Research and Education Center, Univ. Florida

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Mazzotti, F.J., B. Bohnsack, M.P. McMahon, and J.R. Wilcox **Date:** 1986

Title: Field and laboratory observations on the effects of high temperature and salinity on hatchling Crocodylus acutus

Publication: Herpetologica 42(2): 191-196

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: McAdory, R. **Date:** 2001

Title: Large synoptic tide, velocity, salinity, and weather data set for use in modeling Biscayne Bay, FL

Publication: Proceedings of the 16th Biennial Conference of the Estuarine Research Federation

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: McGeer, J.C., L. Baranyi, and G.K. Iwama **Date:** 1991

Title: Physiological responses to challenge tests in six stocks of Coho Salmon (Oncorhynchus kisutch)

Publication: Can. J. Fish. Aquat. Sci. 48: 1761-1771

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: McIvor, C.C., J.A. Ley, and R.D. Bjork **Date:** 1994

Title: Changes in freshwater inflow from the Everglades to Florida Bay including effects on biota and biotic processes: a review

Publication: Everglades: The Ecosystem and Its Restoration

Publisher: St. Lucie Press

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: McMichael, R. and TS. Tsou **Date:** 2000

Title: Analysis of fisheries data in association with the development of minimum flows and levels for the Lower Suwannee River/Estuary

Publication:

Publisher: Florida Fish and Wildlife Conservation Commission

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Meeder, J., M. Ross, and P. Ruiz **Date:** 1999

Title: Characterization of historic Biscayne Bay watersheds

Publication: First Quarterly Report to Florida Center for Environmental Studies

Publisher:

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Meeder, J., P. Harlem, and A. Renshaw **Date:** 2001

Title: Historic creek watershed study; Final Results: Year 1

Publication:

Publisher:

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Meeder, J., P. Harlem, and A. Renshaw **Date:** 2002

Title: Restoration of the Black Creek coastal wetlands and adjacent nearshore estuarine zone of Biscayne Bay

Publication:

Publisher:

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Meyer, D.L. and E.C. Townsend **Date:** 2000

Title: Faunal utilization of created intertidal eastern oyster (Crassostrea virginica) reefs in the southeastern United States

Publication: Estuaries 23: 33-45

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Miami-Dade County Department of Environmental Resources Management **Date:** 1995

Title: Dade County Manatee Protection Plan

Publication:

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Miami-Dade County Department of Environmental Resources Management **Date:** 1994

Title: Technical summary document for the advanced identification of possible future disposal sites and areas generally unsuitable for disposal of dredged or fill material in wetlands adjacent to southwest Biscayne Bay, Dade County, Florida

Publication:

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Milano, G **Date:** 1983

Title: Bottom communities of Biscayne Bay

Publication: Miami-Dade County Department of Environmental Resources Management, Miami, FL.

Publisher: Miami-Dade County

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Moler, P. and C. Abercrombie **Date:** 1992

Title: Growth and survival of Crocodylus acutus in South Florida, USA

Publication: Crocodiles. Proceedings of the 11th Working Meeting of the Crocodile Specialist Group

Publisher: IUCN

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Monaco, M.E. and J.D. Christensen **Date:** 1997

Title: Coupling species distributions and habitat

Publication: Changing Oceans and Changing Fisheries: Environmental Data for Fisheries Research and Management

Publisher: NMFS

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Monaco, M.E., T.A. Lowery, and R.L. Emmett **Date:** 1992

Title: Assemblages of U.S. west coast estuaries based on the distribution of fishes

Publication: Journal of Biogeography 19: 251-267

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Montague, C.L. and J. Ley **Date:** 1993

Title: A possible effect of salinity fluctuation on abundance of benthic vegetation and associated fauna in northeastern Florida Bay.

Publication: Estuaries 16:703-717

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Moser, M.L. and L.R. Gerry **Date:** 1989

Title: Differential effects of salinity changes on two estuarine fishes, Leiostomas xanthurus and Micropogonias undulatus

Publication: Estuaries 12:35-41

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: National Park Service Southeast Region **Date:** 1989

Title: Canal discharge impacts on Biscayne Bay salinities, Biscayne National Park

Publication: Research/Resources Management Report SER-89

Publisher:

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☑	**Hydrologic Data**	☑

Author: Neill, W.H., J.M. Miller, H.W. Van der Veer, and K.O. Winemiller **Date:** 1994

Title: Ecophysiology of marine fish recruitment: a conceptual framework for understanding interannual variability

Publication: Netherlands Journal of Sea Research 32: 135-152

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Nelson, D., E. Irlandi, L. Settle, M. Monaco and L. Coston-Clements **Date:** 1991

Title: Distribution and abundance of fishes and invertebrates in southeast estuaries. ELMR Rep. No. 9.

Publication: NOAA/NOS Strategic Env. Assess. Div., Silver Spring, MD. 167

Publisher: NOAA/NOS

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: NOAA **Date:** 1973

Title: Estuarine-dependent marine fishes. Appendix E

Publication: South Florida ecological study. National Oceanographic and Atmospheric Administration, National Marine Fisheries Service

Publisher: NOAA

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Complete Alphabetical Listing by Author

Author: NOAA **Date:** 1973

Title: Section IV major environmental factors affecting fishery resources

Publication: South Florida Ecologicla Study, Appendix E-Estuarine Dependent Marine Fishes 60-65

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Nordlie, F.G. **Date:** 1987

Title: Plasma osmotic, Na+ and Cl- regulation under euryhaline conditions in Cyprinodon variegatus lacepede

Publication: Comp. Biochem. Physiol. 80A: 57-61

Publisher: Pergamon Journals Ltd.

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Nordlie, F.G. **Date:** 1986

Title: Salinity tolerance and osmotic regulation in the diamond killfish, Adinia xenica

Publication: Environmental Biology of Fishes 20: 229-232

Publisher: Dr W. Junk Publishers

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Odum, W **Date:** 1970

Title: Insidious alteration of the estuarine environment

Publication: Transactions of the American Fisheries Society

Publisher: American Fisheries Society

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Ogden, J.C. **Date:** 1994

Title: A comparison of wading bird nesting colony dynamics (1931-1946 and 1974-1989) as an indication of ecosystem conditions in the southern Everglades

Publication: Everglades: The Ecosystem and Its Restoration

Publisher: St. Lucie Press

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Ogden, J.C. **Date:** 1978

Title: Status and nesting biology of the American crocodile, Crocodylus acutus, (Reptilia, Crocodilidae) in Florida

Publication: Journal of Herpetology 12: 183-196

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Ogden, J.C. **Date:** 1977

Title: Status of Crocodylus actus

Publication: 192-196

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Ortega, S. and J.P. Sutherland **Date:** 1992

Title: Recruitment and growth of the eastern oyster, Crassostrea virginica, in North Carolina

Publication: Estuaries 15(2): 158-170

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Parado-Estepa, F.D. **Date:** 1991

Title: Survival of newly-hatches larvae of Epinephelus malabaricus at different salinity levels

Publication: Proceedings of Larvi '91 - Fish & Crustacean Larviculture Symposium

Publisher: European Aquaculture Society

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Patterson, E. and E.A. Irlandi **Date:** 1998

Title: Seasonal and inter-annual comparisons of density, biomass, and morphometrics of Thalassia testudinum at sites of varying salinity in Biscayne Bay, FL

Publication: Proceedings of the American Society of Limnology and Oceanography/Ecological Society of America Annual Meeting

Publisher: American Society for Limnology and Oceanography

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Patterson, K. **Date:** 2002

Title: Final Project Report for Suwannee River Water Management District Suwannee Estuary 2001 Oyster Habitat Mapping Project

Publication:

Publisher: AGRA Baymont, Inc.

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Pattillo, M., T. Czapla, D. Nelson and M. Manaco **Date:** 1997

Title: Distribution and abundance of fishes and invertebrates in Gulf of Mexico estuaries. Volume II:

Publication: Species life history summaries. ELMR Rep. No. 11

Publisher: NOAA/NOS

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Perez, M.A. **Date:** 1987

Title: Physiological response of the early juvenile snook (Centropomus undecimalis) to different salinities

Publication: University of Miami Thesis

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Platt, S.G., T.R. Rainwater, and J.B. Thorbjarnarson **Date:** 2002

Title: Crocodylus acutus. Hatchling diet.

Publication: Herpetol. Rev. 33(3):202-203

Publisher: Society for the Study of Amphibians and Reptiles

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Poirrier and Partridge **Date:** 1979

Title: The barnacle, Balanus subalbidus, as a salinity bioindicator in the oligohaline estuarine zone

Publication: Estuaries 2: 204-206

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Powell, G.L., J. Matsmoto, and D.A. Brock **Date:** 2002

Title: Methods for determining minimum freshwater inflow needs of Texas bays and estuaries

Publication: Estuaries 25(6B): 1262-1274

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species ☐ **Aquatic Plants/Habitat** ☐ **Ecological Indicators** ☐

Impact Approach ☑ **Water Quality Data** ☐ **Hydrologic Data** ☐

Author: Provencher, L., Munro, J., and J.D. Dutil **Date:** 1993

Title: Osmotic performance and survival of Atlantic cod (Gadus morhua) at low salinities

Publication: Aquaculture 116: 219-231

Publisher: Elsevier Science B.V.

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species ☑ **Aquatic Plants/Habitat** ☐ **Ecological Indicators** ☐

Impact Approach ☐ **Water Quality Data** ☑ **Hydrologic Data** ☐

Author: Quammen, M.L. and C.P. Onuf **Date:** 1993

Title: Laguna Madre: Seagrass changes continue decades after salinity reduction

Publication: Estuaries 16(2): 302-310

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species ☐ **Aquatic Plants/Habitat** ☑ **Ecological Indicators** ☐

Impact Approach ☐ **Water Quality Data** ☑ **Hydrologic Data** ☐

Author: Reagan, R.E. **Date:** 1985

Title: Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Gulf of Mexico): Red drum

Publication: U.S. FWS Biological Report 82

Publisher: USFWS

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Roessler, G.L. Beardsley and R. Smith **Date:** 1973

Title: Benthic communities of Biscayne Bay, Florida

Publication: Unpublished report. University of Miami Sea Grant 12 pp.

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Roessler, M.A. **Date:** 1965

Title: An analysis of the variability of fish populations taken by otter trawl in Biscayne Bay, Florida

Publication: Transactions of the American Fisheries Society 94: 311-318

Publisher: American Fisheries Society

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Ross, M.S., et al **Date:** 2002

Title: Multi-taxon analysis of the "white zone", a common ecotonal feature of South Florida coastal wetlands

Publication: The Everglades, Florida Bay, and Coral Reefs of the Florida Keys: An Ecosystem Sourcebook

Publisher: CRC Press

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Ross, M.S., J. Meeder, J. Sah, P. Ruiz, and G. Telesnicki **Date:** 1999

Title: The southeast saline Everglades revisited: a half-century of coastal vegetation change

Publication:

Publisher:

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Rozas, L.P. and C.T. Hackney **Date:** 1984

Title: Use of oligohaline marshes by fishes and macrofaunal crustaceans in North Carolina.

Publication: Estuaries 7(3): 213-224

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Russell, G. **Date:** 1987

Title: Salinity and seaweed vegetation

Publication: Plant life in aquatic and amphibious habitats: Special Publication of the Britsh Ecologcial Society 35-52

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Saoud, I.P., and D.A. Davis **Date:** 2003

Title: Salinity tolerance of brown shrimp Farfantepenaeus aztecus as it relates to postlarval and juvenile survival, distribution, and growth in estuaries

Publication: Estuaries 26(4A): 970-974

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Savarese, M. and A.K. Volety **Date:** 2001

Title: Impact of waterflow alteration upon oyster growth and distribution within estuaries of southwest Florida: implications for management and restoration

Publication: Aquaculture 2001: Book of Abstracts

Publisher: World Aquaculture Society

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Sayer, M.D.J., J.P. Reader **Date:** 1996

Title: Exposure of goldshiny, rock cook and corkwing wrasse to low temperature and low salinity: survival, blood physiology and seasonal variation

Publication: Journal of Fish Biology 49: 41-63

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Schubert, A. **Date:** 1994

Title: Conservation of American crocodile

Publication: Crocodile Specialist Group Newsletter 13(3):14

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Seaman, W., and M. Collins **Date:** 1983

Title: Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Florida) -- snook

Publication: USFWS

Publisher: USACE

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Serafy, J.A., C.H. Faunce, J.J. Lorenz **Date:** 2003

Title: Mangrove shoreline fisheries of Biscayne Bay, Florida

Publication: Bulletin of Marine Science

Publisher:

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Serafy, J.E. and K.C. Lindeman **Date:** 2000

Title: Overview of studies on Biscayne Bay fishes

Publication:

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Serafy, J.E., K.C. Lindeman, T.E. Hopkins, J.S. Ault **Date:** 1997

Title: Effects of freshwater canal discharge on fish assemblages in a subtropical bay: field and laboratory observations

Publication: Marine Ecology Progress Series 160:161-172

Publisher: Inter-Research

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: SFWMD **Date:** 2002

Title: Biscayne Bay MFLs Technical Discussion Group Summary

Publication: SFWMD

Publisher: SFWMD

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: SFWMD **Date:** 2003

Title: Draft evaluation performance indicator documentation sheet

Publication:

Publisher: SFWMD

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: SFWMD **Date:** 2000

Title: Draft minimum flows and levels for Lake Okeechobee, the Everglades, and the Biscayne Aquifer

Publication: SFWMD

Publisher: SFWMD

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: SFWMD **Date:** 2000

Title: Lower east coast regional water supply plan, Planning document, 3 volumes.

Publication: SFWMD

Publisher: SFWMD Palatka Florida

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☑

Author: SFWMD **Date:** 2002

Title: Reservations of water for the environment and assurances for existing legal sources consistent with federal and state law

Publication:

Publisher: SFWMD

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: SFWMD **Date:** 2001

Title: SFERPM 2000: Linking Everglades restoration and enhanced freshwater flows to elevated concentrations of mercury in Florida Bay fish

Publication:

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: SFWMD **Date:** 2003

Title: Technical documentation to support development of minimum flows and levels for the Caloosahatchee River and Estuary

Publication: Caloosahatchee River MFL Research Program Progress Report

Publisher:

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: SFWMD **Date:** Unknown

Title: Technical documentation to support development of minimum flows and levels for the Northwest Fork of the Loxahatchee River

Publication: SFWMD

Publisher: SFWMD

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: SFWMD **Date:** 2002

Title: Upper Peace River: an analysis of minimum flows and levels

Publication:

Publisher: SFWMD

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Sheaves, M. **Date:** 1996

Title: Do spatial differences in the abundance of two serranid fishes in estuaries of tropical Australia reflect long-term salinity patterns?

Publication: Marine Ecology Press Series 137: 39-49

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Sheldon, J.E. and M. Alber **Date:** 2002

Title: A comparison of residence time calculations using simple compartment models of the Altamaha River Estuary Georgia

Publication: Estuaries 25(6B): 1304-1317

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Sheridan, P. and C. Hays **Date:** 2003

Title: Are mangroves nursery habitat for transient fishes and decapods?

Publication: Wetlands 23(2): 449-458

Publisher: The Society of Wetland Scientist

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Siegsmondi, Linda A., L.J. Weber **Date:** 1998

Title: Changes in avoidance response time if juvenile chinook salmon exposed to multiple acute handling stresses

Publication: Transactions of the Amercian fisheries Society 117:196-281

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Skinner, R.H. and W. Kandrashoff **Date:** 1988

Title: Abnormalities and diseases observed in commercial fish catches from Biscayne Bay, Florida

Publication: Water Resources Bulletin: 24: 961-996

Publisher: American Water Resources Association

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Sklar, F.H. and J.A. Browder **Date:** 1998

Title: Coastal environmental impacts brought about by alterations to freshwater flow in the Gulf of Mexico

Publication: Environmental Management 22: 547-562

Publisher: Springer-Verlag New York Inc.

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Smith, H.M. **Date:** 1895

Title: Notes on Biscayne Bay, Florida with reference to its adaptability as the site of a marine hatching and experiment station

Publication: U.S. Report of Commissioner of Fish and Fisheries, 168-191

Publisher: U.S. Government Printing Office

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Sternberg, L.D.S.L. and P.K. Swart **Date:** 1987

Title: Utilization of freshwater and ocean water by coastal plants of southern Florida

Publication: Ecology 68:6 1898-1905

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Stone, J.R., T. M. Cronin, G. L. Brewster-Wingard, S.E. Ishman, B.R. Wardlaw, and C.W. Holmes **Date:** 2000

Title: A paleoecologic reconstruction of the history of Featherbed Bank, Biscayne National Park, Biscayne Bay, Florida

Publication: USGS Report 00-191

Publisher: USGS

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Surge, D.M. and K.C. Lohmann **Date:** 2002

Title: Temporal and spatial differences in salinity and water chemistry in southwest Florida estuaries: effects of human-impacted watersheds

Publication: Estuaries 25(3): 393-408

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Tagatz, M.E. **Date:** 1971

Title: Osmoregulatory ability of blue crabs in different temperature-salinity combinations

Publication: Chesapeake Science 12(1): 14-17

Publisher:

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Tamburri, M.N., R.K. Zimmer-Faust, M.L. Tamplin **Date:** 1992

Title: Natural sources and properties of chemical inducers mediating settlement of oyster larvae: a re-examination

Publication: Biological Bulletin 183: 327-338

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Complete Alphabetical Listing by Author

Author: TBD **Date:** 1996

Title: Red Drum

Publication:

Publisher:

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: TBD **Date:** Unknown

Title: Seagrasses

Publication:

Publisher: FWS

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Thomas, D.L. and B.A. Smith **Date:** 1973

Title: Studies of young of the black drum, Pogonias cromis, in low salinity waters of the Delaware estuary

Publication: Chesapeake Science 14(2): 124-130

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Thorbjarnarson, J. **Date:** 1989

Title: Ecology of the American crocodile, Crocodylus acutus

Publication: Crocodiles. Their Ecology, Management, and Conservation. A Special Publication of the Crocodile Specialist Group

Publisher: IUCN

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Tilmant, J.T. and R.D. Conant **Date:** 1980

Title: Distribution, abundance and growth of commercially important sponges within South Biscayne Bay, Dade County, Florida

Publication: Florida Scientist 43

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Tsou, T.S. and R.E. Matheson, Jr. **Date:** 2002

Title: Seasonal changes in the nekton community of the Suwannee River Estuary and potential impacts of freshwate withdrawal

Publication: Estuaries 25(6B): 1372-1381

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Turner, E.J., R.K. Zimmer-Faust, M.A. Palmer, M. Luckenbach, N.D. Pentcheff **Date:** 1994

Title: Settlement of oyster (Crassotrea virginica) larvae: effects of water flow and a water-soluble chemical cue

Publication: Limnology and Oceanography 39:1579-1593

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: U.S. Geological Survey **Date:** 2000

Title: Studies supporting restoration of mangrove habitat in Everglades National Park: Faunal Component

Publication: USGS Bulletin

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Ulanowicz, R.E. and J.H. Tuttle **Date:** 1992

Title: The trophic consequences of oyster stock rehabilitation in Chesapeake Bay

Publication: Estuaries 15: 298-306

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Valesini, F.J., I.C. Potter, M.E. Platell, and G.A. Hyndes **Date:** 1997

Title: Icthyofaunas of a temperate estuary and adjacent marine embayment. Implications regarding choice of nursery area and influence of environmental changes

Publication: Marine Biology 128: 317-328

Publisher: Springer-Verlag New York Inc.

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Van de Kreeke, J. and J.D. Wang **Date:** 1984

Title: Hydrography of north Biscayne Bay. Part I: Results of field measurements

Publication: RSMAS

Publisher: DERM and Sea Grant

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☑

Author: Volety, A.K., S.G. Tolley, and J.T. Winstead **Date:** 2002

Title: Using responses of oysters in establishing minimum flows and levels in the Caloosahatchee Estuary, Florida

Publication: Proceedings of the 6th International Conference on Shellfish Restoration, Charleston, SC

Publisher: SC Sea Grant Consortium

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☑
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Wade, J.S. **Date:** 1992

Title: Maintenance and restoration of freshwater flows to estuaries for fisheries habitat purposes

Publication: Florida Sea Grant Technical Paper 65

Publisher: FL DNR, FL Sea Grant College Program

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Wakeman, J.M. and D.E. Wohlschlag **Date:** 1977

Title: Salinity stress and swimming performance of spotted seatrout

Publication: Proceedings, the Thirty-first Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 357-361

Publisher:

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Wanless, H **Date:** 1969

Title: Sediments of Biscayne Bay: Distribution and depositional history

Publication: Rosenstiel School of Marine and Atmospheric Science Technical Report 69-2

Publisher: University of Miami, Miami. FL

High Relevance ☑ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Wanless, H.R., R.W. Parkinson, and L.P. Tedesco **Date:** 1994

Title: Sea level control on stability of Everglades wetlands

Publication: Everglades: The Ecosystem and Its Restoration

Publisher: St. Lucie Press

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Wanless, Harold R. **Date:** 1989

Title: The inundation of our coastlines

Publication: Sea Frontiers 264-269

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Ward, G.H., M.J. Irlbeck, and P.A. Montagna **Date:** 2002

Title: Experimental river diversion for marsh enhancement

Publication: Estuaries 25(6B): 1416-1425

Publisher: Estuarine Research Federation

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Whitfield, A.K. **Date:** 1994

Title: Abundance of larval and 0+ juvenile marine fishes in the lower reaches of three southern African estuaries with differing freshwater inputs

Publication: Marine Ecology Press Series 105: 257-267

Publisher: Inter-Research

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Whitfield, A.K. and M.N. Bruton **Date:** 1989

Title: Some biological implications of reduced fresh water inflow into eastern Cape estuaries: a preliminary assessment

Publication: South African Journal of Science 85: 691-694

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Wilson, J.G. **Date:** 1994

Title: The role of bioindicators in estuarine management

Publication: Estuaries 17(1A): 94-101

Publisher: Estuarine Research Federation

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☑
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Woodward-Clyde **Date:** 1998

Title: St. Lucie estuary historical, SAV, and American oyster literature review

Publication: South Florida Water Management District, West Palm Beach, FL. 14 sections

Publisher: South Florida Water Management District

High Relevance ☑ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Yobbi, D.A. and L.A. Knochenmus **Date:** 1989

Title: Salinity and flow relations and dffects of reduced flow in the Chassahowitzka River and Hommosassa River Estuaries, Southwest Floirda.

Publication: Water Resource Investigations Report 88-4044

Publisher: U.S. Geological Survey, Tallahassee, Fla.

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☑	**Water Quality Data**	☑	**Hydrologic Data**	☑

Author: Zale, A.V., and S.G. Merrifield **Date:** 1989

Title: Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Florida) - ladyfish and tarpon

Publication: USFWS Biol. Rep. 82(11.104)

Publisher: USACE

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☐	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

Author: Zieman, J.C. **Date:** 1975

Title: Seasonal variation of turtle grass, Thalassia testudinum Konig, with reference to temperature and salinity effects

Publication: Aquatic Botany (1): 107-123

Publisher:

High Relevance ☐ **Biscayne Bay** ☑

Other Categories:

Animal Species	☐	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☑	**Hydrologic Data**	☐

Author: Zimmer-Faust, R.K. and M.N. Tamburri **Date:** 1994

Title: Chemical identity and ecological implications of a waterborne, larval settlement cue

Publication: Limnology and Oceanography 39: 1075-1087

Publisher:

High Relevance ☐ **Biscayne Bay** ☐

Other Categories:

Animal Species	☑	**Aquatic Plants/Habitat**	☑	**Ecological Indicators**	☐
Impact Approach	☐	**Water Quality Data**	☐	**Hydrologic Data**	☐

APPENDIX B

TASK 3 REPORT
INTERVIEWS WITH EXPERTS

SUMMARY OF TASK 3
CONTACTS AND EXPERTS INTERVIEWS

FOR THE PROJECT

FRESHWATER FLOW AND ECOLOGICAL RELATIONSHIPS IN BISCAYNE BAY

BY

BARNES FERLAND AND ASSOCIATES, INC.

AND SUBCONSULTANTS

APPLIED TECHNOLOGY & MANAGEMENT, INC.
LEWIS ENVIRONMENTAL SERVICES, INC.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT
WEST PALM BEACH, FLORIDA

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INTRODUCTION

The State of Florida has adopted rules for Water Management Districts to establish Minimum Flows and Levels (MFLs) for identified priority water bodies and to implement these MFLs through water shortage plans and or the water use permitting process. Specifically, Biscayne Bay has been identified as a priority water body in which MFLs must be developed by the South Florida Water Management District (SFWMD) by December, 2004.

As one component of the SFWMD efforts to establish MFLs for Biscayne Bay, the SFWMD issued a work order to undertake a study titled, *Freshwater Flow and Ecological Relationships in Biscayne Bay*. SFWMD entered into an agreement to with the consultant team of Barnes, Ferland and Associates, Applied Technology Management, Inc. and Lewis Environmental Services, Inc. to conduct the necessary activities to complete this project.

The overall objectives of this project are to assist District staff with identifying significant harm and with development of the technical criteria for the Biscayne Bay MFLs, including:

- Performing an intensive review and documentation of existing literature and information to determine the technical relationships among freshwater flow, salinity and watershed/estuary hydrodynamics that impact key indicator biological communities or species present throughout Biscayne Bay; and

- Evaluating approaches that can be used to develop the MFLs significant harm technical criteria.

This summary of interviews with experts is part of the overall project scope and is presented in fulfillment of the requirements of Task 3 – Contacts and Experts Interviews as detailed in Contract No. C-15967-WO04-06. In this task, members of the project team have interviewed and obtained information and data from local contacts and experts in the areas of estuarine/marine water chemistry, phytoplankton, zooplankton, algae, seagrasses, invertebrates, fisheries, ecology, and paleoecology. In completing these interviews, the project team has:

- Confirmed the literature review information and obtained recommendations for additions to the literature database (which were subsequently incorporated into the Task 2 bibliography),

- Identified additional recent and/or ongoing relevant research and data collection, and new information, and

- Identified additional sources of information (i.e., unpublished documentation, personal opinion, etc.) regarding ecological dependencies on freshwater in Biscayne Bay or other south Florida estuaries and/or other estuaries where such information could be helpful.

The SFWMD provided an initial list of recommended contacts/interviewees that were to be contacted regarding the project purpose and to discuss project aspects. It was acknowledged in initial meetings between SFWMD and the project team that this list would serve as an initial basis, that completing interviews with all of these individuals within the project schedule may not be possible, that some potential interviewees may not have the time or inclination to participate, and that, as the project progressed, additional and/or substitute interviewees would be identified. Table 1 identifies experts that were contacted and their respective areas of expertise. Attachment A provides a summary of the interview process.

An interview form (Attachment B) was developed to ensure consistency in covering the requested topics and/or aspects of the project in each interview. Interviews were conducted by senior ecologist project team members Robin Lewis and Greg Braun, during September and October, 2003. Some interviews were conducted in person, while others by telephone. The following provides a summary of these interviews and the general findings.

It is important to note that the majority of the information that follows may not represent the opinions and/or conclusions of the project team or the SFWMD; it merely recounts the essence of the opinions, comments and suggestions of the various interviewees. In several circumstances, the interviewee(s) provided comments and/or suggestions that, while pertinent to the overall issue of MFLs for Biscayne Bay, may not have been directly related to the interviewer's tasks of identifying indicator species, suites of indicators of ecosystem health and/or significant harm. In some cases, information regarding these tangential issues is included in the interview summaries, in order for the District to be aware of the opinions of the interviewees. Ultimately, it will be the responsibility of the project team to evaluate these comments and suggestions in relation to the team's scope of work. Then, with consideration of the information gleaned from the Task 2 Literature and Data Review, the team will use its best professional judgment to identify potential MFL approaches, recommend a preferred approach and finally, in the fifth and final task, summarize the information and identify potential information needs.

SUMMARY OF INTERVIEWS WITH EXPERTS

The interview summaries are organized alphabetically by agency/entity within the following three major categories: Governmental Entities, Academia, and Other Non-Governmental Organizations.

GOVERNMENTAL ENTITIES

Florida Department of Environmental Protection
Interviewees: Daniel Apt, Stacey Feken (participated by conference call), Marsha Colbert (Manager of BB Aquatic Preserve). Interviewer: G. Braun. Interview date: Sep. 3, 2003.

These interviewees were only vaguely aware of the MFL process. None conduct original research in Biscayne Bay, but discussions led to numerous suggestions of various people (researchers, planners…) not on our contact list who they think could provide additional info. They suggested that maintenance of seagrass beds of *Halodule wrightii* and *Syringodium filiforme* near mouths of canals and re-establishment of salinity regimes that would sustain the historic distribution of oyster populations be considered as the mechanisms to prevent significant harm in the northern portions of the Bay; pink shrimp for southern

Summary of Contacts and Expert Interviews

Expert Name	Agency or Association	General Area of Expertise	Team Interviewer	Interview Date
Mr. Richard Alleman	SFWMD	Biscayne Bay	G.B & R.L.	1-Oct-03
Mr. Daniel Apt	FDEP - (CERP)	CERP	G. Braun	3-Sep-03
Ms. Sarah Bellmund	Biscayne National Park	Marine Ecology	R. Lewis	23-Sep-03
Mr. Steven Blair	DERM (Restoration)	Seagrasses	G. Braun	4-Sep-03
Mr. David Boyd	FDEP-Reg. Biologist Pks	Marine Ecology	G. Braun	10-Oct-03
Dr. Joseph Boyer	Fl. International Univ.	Bisc Bay water quality	G. Braun	24-Sep-03
Dr. Joan Browder	NOAA NMFS CASC	Marine Ecology	R. Lewis	26-Sep-03
Mr. Rick Clark	Biscayne National Park	Marine Ecology and Mgmt.	R. Lewis	23-Sep-03
Ms. Marsha Colbert	FDEP	Bisc Bay Aquatic Preserve	G. Braun	3-Sep-03
Mr. Richard Curry	Biscayne National Park	Marine Ecology	G. Braun	23-Sep-03
Mr. Guillermo Diaz	U of Miami	Fishes	G. Braun	10-Oct-03
Mr. Steven Dale	Oleta River State Pk	Park Management	G. Braun	20-Oct-03
Dr. Ernie D. Estevez	Mote Marine Laboratory	Marine Ecology	R. Lewis	29-Sep-03
Dr. Craig Faunce	U of Miami	Fishes	G. Braun	21-Oct-03
Ms Stacey Feken	FDEP - Water Quality	Water Quality	G. Braun	3-Sep-03
Mr. Sid Flannery	SWFWMD	MFLs	R. Lewis	29-Sep-03
Dr. James Fourqurean	Fl. International Univ.	Seagrasses	R. Lewis	29-Oct-03
Dr. Grant Gilmore Jr.	Dynamac Corporation	Ichthyology	R. Lewis	27-Oct-03
Mr. Greg Graves	FDEP - Water Quality	Water Quality	G. Braun	7-Oct-03
Mr. Craig Grossenbacher	DERM	Biology	R. Lewis	31-Oct-03
Dr. Sonny Hall	SJRWMD - MFL Mgr	MFLs	G. Braun	16-Sep-03
Mr. Scott Ishman	S. Illinois Univ.	Paleo-ecology - Forams	G. Braun	9-Oct-03
Ms. Jennifer Jacukiewicz	NMFS	Protected marine species	G. Braun	23-Oct-03
Dr. Diego Lirman	U of Miami	Seagrasses	G. Braun	9-Oct-03
Dr. Jerome Lorenz	National Audubon Society	Ornithology	R. Lewis	24-Sep-03
Dr. Susan Markley	DERM	Manatees	G. Braun	4-Sep-03
Dr. John Meeder	Fl. International Univ.	Marine Ecology and Geology	R. Lewis	25-Sep-03
Danielle Mir-Gonzalez	Fl. International Univ.	Submerged Aquatic Veg	G. Braun	8-Oct-03
Mr. Patrick Pitts	U.S. Fish & Wildlife Service	Listed Species	G. Braun	11-Sep-03
Dr. Mike Robblee	U.S. Geological Survey	Marine ecology	G. Braun	21-Oct-03
Dr. Martin Roessler	M.A. Roessler Assoc., Inc.	Fishes, marine ecology	G. Braun	20-Oct-03
Mr. Michael Ross	Fl. International Univ	Coastal Wetlands	G. Braun	22-Oct-03
Dr. Joseph Serafy	NOAA NMFS CASC	Fisheries	R. Lewis	23-Sep-03
Mr. Joel VanArman	SFWMD	Estuarine Ecology	G.B & R.L.	1-Oct-03
Ms. Lynn Wingard	USGS	Molluscs	G. Braun	10-Oct-03
Mr. Herbert Zebuth	FDEP	Loxahatchee River	G. Braun	10-Sep-03

areas. They are involved with various Bay management teams, and believe that sub-surface freshwater input to the Bay should not be overlooked – suggests investigating Miami-Dade project at Deering Estate to attempt to re-establish historical water tables in a local pilot project. They also suggest investigating the State's Impaired Waters rule, as it uses chlorophyll as an indicator.

Florida Department of Environmental Protection, (Continued)
Interviewee: Herb Zebuth, FDEP. Interviewer: G. Braun. Interview date: Sep. 10, 2003.

Mr. Zebuth is very knowledgeable about MFL process, and critical of SFWMD's development of the MFL rule for the Loxahatchee River. He opines that the methodology followed was flawed – agrees with premise that sedentary organisms are preferable to motile species as indicators of MFL (even though the fishes and other non-sedentary species (e.g., arthropods, mollusks) may be the more valued ecosystem components), but believes shortcomings are that the adopted rule 1) does not use a combination of both sessile and motile indicator species, 2) does not identify the levels and durations that the adopted criteria can be violated, and; 3) restricts vegetative indicators to canopy species (where adverse impacts will be less visible) and should have included understory species and seedling health. He is not all that familiar with Biscayne Bay, but sees parallels in: a) existing conditions in Biscayne Bay, similar to the Loxahatchee River, are degraded and that WMD's interpretation of MFL authority should not be interpreted to be restricted to preventing significant harm to existing degraded condition; that the rule should target restoring degraded systems, particularly if they are currently in states of significant harm, and b) due to CERP projects and additional research being conducted, the rule needs to specifically identify the triggers for re-evaluation and re-setting of MFL criteria as new info becomes available.

Florida Department of Environmental Protection, (Continued)
Interviewee: Dana Fike for Greg Graves, FDEP – Port St. Lucie. Interviewer: G. Braun. Interview date: October 7, 2003.

FDEP's Office of Water Quality is involved in a monitoring project in Biscayne Bay that could ultimately be of significant value to the MFL effort. Their project, which is in an early stage and has not yet evolved to the point of having any definitive results, involves repetitive sampling and analysis of water quality and benthos (both macro invertebrates and SAV) at locations along fixed transects in Biscayne Bay. They monitor conditions along two transects that extend eastward from the mouth of C-103 (Mowery Canal) for several hundred meters ending at locations where they believe that the effects from the canal discharges are minimal or non-existent. They simultaneously monitor the same parameters at a 'control' site to the north near the C-2 (Snapper Creek Canal). They collected the majority of the samples during April and July 2003, and followed-up with additional sediment samples taken during Sept, 2003.

Although FDEP taxonomists have not completed their work, Ms. Fike expects that when the data are analyzed, there will be noticeable trends in the presence/absence, abundance, distribution and species diversity along the gradient from westward locations that are heavily influenced by canal discharges to easterly locations where the impacts of canal discharges are minimal. Preliminary results suggest that non-salinity water quality parameters (e.g., nitrate nitrogen) may be having a more significant role in determining the make-up of benthic communities than salinity.

Florida Department of Environmental Protection, (Continued)
Interviewees: Steven Dale (Manager, Oleta River State Park), and David Boyd (Regional Biologist for the Florida Park Service). Interviewer: G. Braun. Interview date: October 20, 2003.

Spoke with Mr. Dale and Mr. Boyd after receiving and reviewing the Unit Management Plan for Oleta River State Park. The Plan, which was most recently updated in Oct 2002, identifies coordinating with WMD regarding management of Snake Creek Canal and coordinating with "the various governmental agencies involved with resource management activities along the Oleta River and Biscayne Bay" as goals and objectives in the section on Natural Resources and Cultural Resources.

The plan also includes an inventory of flora and fauna identified within park boundaries. Regarding identification of potential indicators, they suggest that they have had some seagrass mapping done, and they do have *Halodule wrightii*, *Halophila decipiens* and *H. johnsonii*, and that *Thalassia testudinum* is nearby in areas that likely have a higher salinity regime.

Mr. Boyd feels neither oysters nor mullet would be good indicators, due to their wide salinity tolerances, but offers that his experience with blue crabs in the Chesapeake Bay suggests that this species is differentially distributed by gender based on salinity preferences. In areas where salinities are less than 10 ppt, there are proportionally more adult blue crabs and immature females, but "almost no mature females". In areas of higher salinity, he reports that commercial catches of crab average 80-90% mature females. He therefore suggests that the catch ratio of mature males to mature females might be a good indicator of the prevailing salinity regime in that portion of Biscayne Bay. Although neither interviewee had been there very long, and they offered to speak with others (Renate Skinner) and to research their files to see if there is any additional information that would be helpful, no additional feedback was received.

If additional insight is needed regarding fisheries, they suggest contacting Dr. Christopher Brown (FIU 305-919-4793) for additional information regarding fishes, Dr. Jim Bohnsack (NOAA – regarding recreational fisheries) and Nancy Cummings regarding stock assessments.

Miami-Dade County Department of Environmental Resources Management
Interviewees: Susan Markley and Steve Blair, Miami-Dade DERM. Interviewer: G. Braun. Interview Date: Sep. 4, 2003.

S. Markley is aware and knowledgeable about MFL process; S. Blair largely unaware. Collectively, they suggest that the performance measures already developed for various CERP projects (e.g., Coastal Wetlands, C-111) should guide the development of MFLs for Biscayne Bay, as they have all been developed with broad input and peer review and acknowledge that the existing conditions are degraded and should not be considered target communities. They suggest oysters, crocodiles, and pink shrimp as likely key species. DERM developed the county-wide Manatee Protection Plan, and it documents that manatees are attracted to the canal discharges along the west shore of Biscayne Bay, particularly during winter-time cold fronts, when the inflowing water is comparatively warmer than chilled bay waters. They have no data to distinguish the extent to which the attracting feature is freshwater or warm water, but they think that temperature is the more significant component.

S. Blair is overseeing a long-term SAV monitoring project in Biscayne Bay; he has hundreds of stations throughout Bay, but thinks that the few along the western edge are so widely spaced that they probably would not be of much help in the understanding of salinity-related ecosystems, ecologies, habitats and/or the identification of key indicator species.

They suggest that the project team contact Scott Ishman regarding his paleo-ecological study in Biscayne Bay, and recommend attendance at 10/03 Estuarine Indicator Workshop to be held at Ding Darling NWR.

Miami-Dade County Department of Environmental Resources Management (Continued)
Interviewee: Craig Grossenbacker, Miami-Dade DERM. Interviewer: R. Lewis. Interview Date: October 31, 2003, by phone.

Mr. Grossenbacker was generally familiar with the MFL process. The interviewer described the process underway and mentioned that since Mr. Grossenbacker was the last interviewee, much had been learned about middle and southern Biscayne Bay, but that we still felt additional information was needed on north BB. Mr. Grossenbacker mentioned a book, "The Story of the Commodore" (may not be exact title) with anecdotal descriptions of the north bay soon after the turn of the century and before many of the changes had occurred. He suggested we review it. He also asked if plants as well and animal communities were to be considered and I indicated yes, and described the potential use of shoal grass as an indicator and why. He agreed that was a good idea. He asked specifically about tidal marsh species and we talked about the herbaceous fresh and brackish marshes that likely were more extant in BB before Baker's Haulover Canal was constructed and were replaced by mangroves. He asked if we had and were using the Dace County ADID with its wetlands maps. I indicated I had not seen it on our list. He volunteered to provide a copy and access to the maps and would get back with me on it. He indicated that only about 70 acres of brackish marsh may exist in the bay and that it may be continuing to shrink due to replacement by mangroves due to higher salinities and less fire. Finally he asked about whether we were looking at the early life history of snook and tarpon and volunteered he had observed large snook in canals along the western shore of BB during the winter when cold snaps pushed manatees into the same areas. I indicated were were.

National Marine Fisheries Service
Interviewee: Jennifer Jacukiewcz. Interviewer: G. Braun. Interview dates: September - October 23, 2003.

Ms. Jacukiewcz is the contact for federally listed marine species that occur in Biscayne Bay, replacing Shelly Norton who is temporarily on maternity leave. After discussing the MFL process during a September telephone conversation, Ms. Jacukiewcz offered to talk with NMFS experts regarding the potential need to consider impacts to Johnson's seagrass and smalltooth sawfish. After completing her in-house coordination, she responded that MFL rule development need not give special to consideration to either of these species. Her explanations are that, although the spatial distribution of *Halophila johnsonii* does end part way through the project area, this species has been documented to survive in salinities of up to 70 ppt. Although NMFS is not sure exactly what factors or combination of factors are precluding its presence in southern Biscayne Bay, they surmise that increased maximum water temperatures may be a factor.

Regarding smalltooth sawfish, Ms. Jacukiewcz advises that in south Florida, this species is primarily known from Florida Bay. Even if it is present in Biscayne Bay (and she knows of no documentation of such), its presence, preferred habitats of open substrate with patches of seagrass, and life cycle would not likely to be adversely affected by reduced freshwater inflows.

National Oceanographic and Atmospheric Administration

Interviewee: Joan A. Browder, Ph.D., Systems Ecologist, NOAA Fisheries, Virginia Key, Miami. Interviewer: R.R. Lewis. Interview date: Sep. 26, 2003

Ms. Browder provided copies of two documents from the Biscayne Bay Partnership Initiative (BBPI), and introductory booklet (January 2001) and "Survey Teams Final Reports" (319 pages). With regard to literature she mentioned the annotated bibliography of literature about Biscayne Bay prepared by the RSMAS library and the BBPI publication. She said she had prepared "South Biscayne Bay Performance Measure Documentation Sheets" that could also be helpful in understanding existing conditions in relation to target communities.

Concerning ongoing research, she is currently monitoring benthic invertebrates, primarily pink shrimp, with Mike Robblee using three methods: throw traps inshore (Robblee), small trawls and larger commercial roller trawls. The work, which is being done as a result of the PPBI reports, began in August 2002 and ends during October 2003. Ms. Browder noted that the predicted model salinities by Wang et. al. do not match field measured salinities due to the coarseness of the model. As mentioned by Jack Meeder, inshore salinities have note been adequately characterized.

When asked about VECs she said that establishing a gradient of salinities and not targeting just one or a few species would be the ecosystem approach which she recommended. Obviously there is a short list of possible indicator species (similar to Alleman 2003) but accurately predicting what MFLs might provide the ideal polyhaline salinities for juvenile pink shrimp inshore on the west side of Central Biscayne Bay, for example, is not possible at this time. Thus the "Performance Standards" document she mentioned is the closest thing to an attempt at this time. A goal of trying to provide a system with a gradient from freshwater to marine, favoring oysters in shore and increasing diversity of estuarine species seems feasible. 10 years of background may be necessary to truly measure the impact of restoration with additional monitoring after restoration of habitat and flows is complete in such areas as Historic Creek.

Ms. Browder corroborated the concept offered by other interviewees that at least the Central and Southern Biscayne Bay areas suffer from "dry season shortages of freshwater", and that freshwater discharges are not "rainfall controlled" or patterned, and that freshwater pulses are a problem.

National Oceanographic and Atmospheric Administration (Continued)

Interviewees: Joseph E. Serafy, Ph.D., Research Fishery Biologist, NOAA Fisheries, Miami. Interviewer: R.R. Lewis. Interview date: Sep. 23, 2003.

Discussed the lack of success with the red drum stocking in Biscayne Bay due to stocking “in the right bay, but the wrong century.” Historic conditions are described in Chardon (1975) for Biscayne Bay in 1776, and by Smith (1896) clearly show conditions in which much larger amounts of freshwater entered Central Bay. The Bay now is a “freshwater pulsed lagoon” and with any further reductions in freshwater flow, it could move to a marine lagoon and then a hypersaline lagoon.

Salinity variation is an important as quantity of water. Abrupt salinity change leads to a natural selection for “tough guys” (limited suite of fish and invertebrates, or lack of certain benthic plants). He suggests that the evidence of historic oyster reefs and remnant oysters and oyster reefs define the very limited current extent of real estuarine habitat (very small).

Would he recommend a VEC? No. He would rather use as an indicator of success of restoration, these items in this order of priority:

1. Change in species composition.
2. For a given list of species, an increase or decrease in abundance.
3. Density of given monitored species
4. Productivity of the restored ecosystem

The basic ecosystem indicators of diversity and species composition are easily monitored and are robust measures, if measured over a long enough period of time (e.g., 5 years minimum (10 years better), pre-restoration, and 5-10 years after with provisions for adjusting water flows through adaptive management using the collected data. Real monitoring periods should be some multiple of the life spans or generation times of the monitored species.

Dr. Serafy also laments that, for any monitored species, exploitation via fishing, etc., needs to be factored in.

National Park Service; Biscayne National Park

Interviewees: Rick Clark, Todd Kellison, Sarah Bellmund, Max Flandorfer, Richard Curry and Amanda Bourque, of Biscayne National Park in Homestead. Interviewer: R.R. Lewis. Interview date: Sep. 23, 2003.

After an introduction to the MFL program by R. Lewis, and introductions to Park staff by Rick Clark (RC), which he described as an “interdisciplinary team”, Sarah Bellmund (SB) was introduced as the key contact on MFL issues.

Ms. Bellmund expressed concern about a proposed flood prevention proposal for Dade County as further reducing freshwater flows to Biscayne Bay. She also mentioned the paleo-ecological studies that are underway to determine the historical estuarine conditions in Biscayne Bay. She believes that current conditions in the Bay are severely degraded, and indicated her opinion that the Bay meets the legal definition as being ‘significantly degraded.” Oysters are a VEC concerning restoration. Other potential species are sea trout, red drum and croaker. Preventing hypersaline conditions should be a key goal during the development of the MFL rule. Pulses of freshwater are a significant problem. Wide ranges in salinities are the issue, not a given salinity. Historically, she suggests that Biscayne Bay had fewer mangroves and more brackish and freshwater marshes than what presently exists. Historical photographs should be consulted to confirm this.

The interviewees questioned “What is the baseline? And during what time period?

RRL: Not sure. Rick Alleman will need to answer.

SB: Peer review group to BB MFL - delayed. holding pattern. This is a problem. Questions asked. No answers. Logistically housekeeping needed.

Richard Curry: Reference to look at: Iver Brook, dissertation on cores in BB. Pockets of artesian activity at shoreline and into BB. Existing system of monitoring wells from Black Point to Pacific Reef. 10 ppt drop in the middle of the reef 3 feet above bottom.

SB: Conduit v. diffuse flow. Ground water leakage is important. Peter Swart is studying.

Curry: "migration to marine systems" since 1976. 5 canals. Preventing water access to the Bay. 70-100 historical tidal creeks emptied into Biscayne Bay. Information contained in studies at Turkey Point prior to power plant. 1968 - 1969. Bader. Rosentstiel. 2-3 papers on larval fish.

Todd: Compared to historical conditions, transitional areas are reduced. Suggested Goal of "establish full salinity regime." Is the distribution of oysters important?

SB: We are concerned about OTHER factors other than salinity. No to single species as a VEC.

Curry: Estuarine systems have certain biological components, not one species.

SB: EJ sampling and larval fish by Serafy. Lutz redfish. Provided list of individuals who should be contacted.

St. Johns River Water Management District.

Interviewee: G.B. (Sonny) Hall, Div. of Water Supply Mgmt. Interviewer: G. Braun.
Interview date: Sep. 16, 2003.

Very familiar with MFL process, as SJRWM has developed and adopted rules for dozens of water bodies (primarily lakes and ponds) during the last ± 10 years. He is not at all familiar with Biscayne Bay, so discussion focused on the methodologies and approaches used by SJRWMD. They rely heavily on soil conditions as the key indicator in their development of MFL criteria for the many lakes and ponds in their region where MFL rules have now been developed.

They've interpreted the MFL statute to allow them to recognize that many of their surface water bodies are currently in unacceptable hydrological conditions and they've developed MFL rules that seek to restore levels and flows to conditions that more closely approximate natural conditions. Rule development for many individual water bodies has been contentious, as, in some situations, urban population growth has become established around degraded systems (i.e., areas with artificially lowered water tables), where restoring water levels could have adverse anthropomorphic effects. They have had difficulty in defining "acceptable levels of ecosystem change".

SJRWMD is currently in legal negotiations regarding ensuring that groundwater MFLs will be adequate to maintain acceptable conditions (both short-term and long term) for manatees.

SJRWMD does not focus on identifying single minimum flows in flowing systems; rather focuses on developing a minimum flow ***regime***, to allow for intermittent intentional drawdowns. Categories established within an elevation continuum include; permanently flooded, intermittently flooded, semi-permanently flooded, seasonally flooded, temporarily flooded, and intermittently flooded. Each category is given a frequency and duration for each water body. They consider not just harm to individual indicator species, but also: water quality, transfer of sediment and detritus, recreation, navigation, flood control, aesthetic attributes, fish and wildlife habitat, passage of fish, water storage and supply, listed plants and animal, estuarine resources, nutrient adsorption and soils.

South Florida Water Management District

Interviewees: Rick Alleman and Joel VanArman, SFWMD. Interviewers: G. Braun and R. Lewis. Interview date: October 1, 2003.

With both interviewees highly knowledgeable about both the MFL process and Biscayne Bay, this interview focused on a higher level of detail than most interviews. The interviewees answered a variety of questions that were primarily centered on the internal draft "Analysis of Beneficial Surface Freshwater Flows into Biscayne Bay" document that was developed by the District in January 2003 to document that existing flows (notwithstanding any water quality parameters) were not causing adverse impacts on the Bay. Regarding the boundaries for potential sub-regions, R. Alleman described that the six sub-regions described in the Beneficial Flows… document correspond to the boundaries included in CERP, and that the sub-divisions in the south portion of the Bay are based on the presence/absence of varying levels of overland flow. To gain increased knowledge of northerly portions of the Bay, it was agreed that we should obtain and review a copy of the Mgmt. Plan for Oleta River State Park. Although freshwater flows into northern portions of the Bay may be smaller than inflows in the south, the smaller size of the receiving body may result in the discharges having an equal or greater relative impact. Reviewing the plan might also help in determining if there is any basis for the speculation that there may be some biota (e.g., mullet) that are found primarily in the northern parts of the Bay.

Analysis of inflows is complicated by the fact that some of the automatic control structures open even when there is no rain, as a result of head pressure from higher inland water tables. Regarding other flows into the Bay, it was noted that there are a variety of non-SFWMD related discharges (e.g., storm sewers, injections wells and stormwater retention/detention systems…) and the quality of these waters may be having adverse impacts on the Bay, but that there is no comprehensive water budget for the bay and that the project teams is not to include or address these inflows in the technical review process. SFWMD and Corps are addressing some of these issues in the Biscayne Aquifer MFL and Biscayne Bay Hydrodynamic model, respectively.

Regarding indicators: it was noted that although pink shrimp may appear to be an appropriate species, their life cycle, which involves annual recruitment from the Tortugas area, may result in easily mis-construed determinations of when significant harm is reached. J. Ault's work re modeling of pink shrimp populations may be of interest, but a small sample size of predators (i.e., seatrout) in the model may present challenges. J. VanArman queried if a perceived reduction in the abundance of short-spine sea urchins had been noted by any of the interviewees; this species had not been mentioned. Grass shrimp (Genus and species not known at the time) may be a better indicator than pink shrimp due to their dependence on lower salinity water. The work by D. Deis (PBSJ) regarding development a performance measure for *Syringodium* in Biscayne Bay should be sought and reviewed.

Regarding the philosophical perspective of the MFL rule being designed to protect existing resources v. environmentally healthy communities, the interviewees advise that SFWMD legal counsel has determined that the MFL should be based on existing resources, and that, in the case of Biscayne Bay, CERP is the recovery plan that will address the fact that the existing condition is degraded. Other WMDs may have chosen to incorporate ecosystem recovery plans into their MFL rule, but as close as SFWMD has gotten to this is the highly-controversial rule for the Loxahatchee River.

Southwest Florida Water Management District
Interviewee: Sid Flannery, Senior Scientist. Interviewer: R. Lewis. Interview date: September 29, 2003.

Sid asked about what was going on as he was not at all familiar with the MFL process within the SFWMD. He has a lot of experience with MFLs for Tampa Bay and Charlotte Harbor, as he is considered the Florida West Coast expert (opinion of the interviewer) on MFLs.

After explaining the issues, and the highly modified nature of Biscayne Bay, he noted that few of the efforts he has underway are similar. The basic approach of SWFWMD has been to look at what percentage of the low flow water could be safely removed for consumptive use without causing significant harm. Several groups of scientists (including panels in which the interviewer was a participant) have examined the issue over the last 20 years. The conclusion has been that cumulative removals, including all current CUPs, should not exceed 10% of the 10 year average low flow, with particular consideration given to a reduction of that percentage during drought years if the flows fall below that average (both the estuary and the consumptive users share the load).

We discussed in some detail the role of "recovery plans" in establishing MFLs. The Lower Hillsborough River is currently in a situation similar to some of the canals into Biscayne Bay in that it has a dam on it, holding water for conversion to drinking water for the City of Tampa. Since 1972, there have been six years during which the number of zero flow days over the dam exceeded 200. In high rainfall years, large quantities of water are released into a relatively small area below the dam. These pulses have been controversial. A work plan has been prepared to test minimum flows of 10, 20 and 30 cfs through the dam to determine which of these values will be proposed for the MFL for the river. Documentation on this was provided.

His work (published in the special issue of *Estuaries* in 2002 which is included in the project team's report for Task 2) has documented the use of the Little Manatee River by early juvenile snook and other fish and shellfish of commercial and recreational importance. He is focusing now on the reason for this and preliminary evidence indicates that phytoplankton enriched zones are produced in particular reaches of estuarine rivers which subsequently may produce greater production to feed early juvenile fish and shellfish. He suggested that Chlorophyll a might me an indicator of this zone, and that it might be used as a monitoring tool in Biscayne Bay.

U.S. Fish and Wildlife Service
Interviewee: Patrick Pitts, USFWS. Interviewer: G. Braun. Interview date: Sep. 11, 2003.

Mr. Pitts is not particularly knowledgeable about MFL process, but did attend one meeting on the subject approximately one year ago. He is involved in a variety of Biscayne Bay projects, primarily CERP. He suggests that restoring water quality regimes (i.e., volumes, timing, quality [salinity & other parameters]) to re-establish sustainable population of oysters in historical ranges is a key target that should drive the MFL process.

FWS is charged with ensuring compliance with the federal Endangered Species Act (ESA), and as such, he is working on developing a "Programmatic Biological Opinion" that will identify all federally-listed endangered and threatened species that could be affected by CERP projects. He indicates that additional analysis in this regard will need to be done as individual CERP projects are designed and permitted. He suggests that there are several federally-listed aquatic organisms that should be given specific attention during MFL rule development, due to the additional protection afforded to them under the ESA. Species that came immediately to mind, include crocodiles, manatees, smalltooth sawfish, and Johnson's seagrass, but suggests that consideration should be given to other federally listed species that are known to occur within the project area (e.g., indigo snakes, panther, bald eagle).

Mr. Pitts identified that, in addition to oysters, there is an existing target of attempting to restore the historical transition zone from Everglade-type shallow freshwater sheet flow though an *Eleocharis* and graminoid marsh to mangroves and *Ruppia/Halodule* grass beds to the more hypersaline *Thalassia* beds and offshore reefs. He suggests that any MFL rule adopted include a strategy to re-evaluate flows, levels and water quality as additional research is completed and as CERP projects come on line. He provided copies of several documents that he thinks will be helpful, including Hill and Cichra (UF paper on Effects of water levels on Fish Populations), Reservations of Water for the Environment, Effects of freshwater canal discharges on fish assemblages, and S. Fl Ecological Report.

U.S. Geological Survey

Interviewee: Dr. Guillermo Diaz. Interviewee: G. Braun. Interview date: October 10, 2003.

Dr. Diaz was interviewed based on his many years of working with pink shrimp in Biscayne Bay. He currently works for U.S.G.S., but his job responsibilities are not related to anything that would be helpful in the Biscayne Bay MFL project. Although he is not familiar with the MFL program, after discussion of its objectives and goals, he advised that, in his opinion, pink shrimp would not be a good indicator species for MFLs in Biscayne Bay. He bases this decision both on the species' wide salinity tolerances and nearly constant recruitment from the Dry Tortugas area. Although he encountered other species of shrimp in his work, he really doesn't know of their salinity tolerances or life cycles, nor does he know of anyone who is studying them. His only suggestion for another individual species that might be a good indicator is oysters, but doesn't know of any oysters currently in Biscayne Bay. Regarding suggestions for other individuals who might be helpful in this regard, he suggested J. Browder and J. Serafy, both of whom are already on our contact list.

U.S. Geological Survey (Continued)

Interviewee: Dr. Michael Robblee. Interviewer: G. Braun. Interview date: October 21, 2003.

Dr. Robblee is currently working with J. Browder on a fisheries study in southern Biscayne Bay, centered near Mowery canal. Because his sampling technique is a 1-m throw net, he's getting different varieties of fish than J. Browder's trawl sampling, even when they sample in similar areas. He rarely gets seatrout or snook, and although there may be some species of fish that are more commonly found in the lower-salinity nearshore areas, he suspects their presence is more likely the result of habitat conditions than the salinity regime itself. When I mentioned the goldspotted killifish (potential indicator sp. that had been suggested by C. Faunce), he confirmed that he has gotten them fairly routinely (17 specimens in $\pm$ 30 samples) primarily in his lower-salinity (i.e., 15-20 ppt) sample sites.

Although fishes are his primary focus, he does suggest that our target should be to establish and/or maintain a salinity regime that is conducive to maintaining *Halodule wrightii* beds in the westerly areas of the bay.

U.S. Geological Survey (Continued)
Interviewee: Lynn Wingard. Interviewer: G. Braun. Interview date: October 10, 2003.

Ms. Wingard is a mollusk expert who has worked extensively with Scott Ishman regarding paleo-ecological investigations of sediment cores in Florida Bay and, to a lesser extent, in Biscayne Bay. She is familiar with the MFL process in general. She is working on a several-year project analyzing historical and current populations of mollusks in S. Florida, and by the project's conclusion, she may be able to identify species that would be good indicators for estuarine conditions in Biscayne Bay. At this time, however, her research indicates that most mollusks have broad tolerance ranges for salinity. Many species (e.g., scorched mussel (*Brachidontes exustis)* seem to do fine in salinities ranging from 10 ppt to 60 ppt. One species that does have oligohaline requirements is a member of the genus *Polymesota*, but she has yet to find one alive in Biscayne Bay. Her report is to be completed during July 2004. The project teams recommends that WMD receive and review this report once it becomes available, to see if there is any additional information that would be helpful.

ACADEMIA

Florida International University
Interviewee: Joseph Boyer, Ph.D., Southeast Environmental Research Center, FIU.
Interviewer: G. Braun. Interview date: Sep. 24, 2003.

Dr. Boyer is not really knowledgeable or familiar with MFL rule or process. His primary focus is water quality, and he has published several reports (some funded by SFWMD) regarding his water quality work in Southern Biscayne Bay. He has documented various water quality parameters, and suggests that it will be exceedingly challenging and expensive, if not impossible, to distinguish adverse ecological impacts that occur as a result of salinity changes alone, as his research has led him to believe that SAV communities are equally affected by other (i.e., non-salinity) water quality parameters. He suggests that subsurface flows have considerable effects on nearshore water quality, and must be considered during development of the MFL for Biscayne Bay. His "Total Ammonia Concentrations…along W shoreline of BB.." paper, that he and J. Meeder authored, identifies the results of water quality analyses, and relates SAV presence and distribution to salinity.

He believes that the current degraded ecological condition should not be the baseline for preventing significant harm, and that there is the need to establish a healthy estuarine system that includes seasonal variations as the target, and which recognize that the MFLs might have seasonal disparity.

Florida International University (Continued)
Interviewee: Dr. James Fourqueran. Interviewer: R. Lewis. Interview date: October 29, 2003.

Dr. Fourqueran indicated that he is "More or less familiar with the MFL process". Based on discussions with G. Braun, I was aware that Danielle Mir-Gonzalez was working on detailed seagrass maps of the distribution by species of seagrasses in relationship to groundwater discharges into Biscayne Bay as submerged discharges (boils, springs in the Bay). Although some detailed maps have been prepared, she is not yet finished with her degree work and her committee including Fourqueran, Boyer and Meeder (chair and most directly responsible for data distribution) is reluctant to release the information until her degree work is finished, however it was suggested that the FIU website (www.fiu.org/~seagrass) might have some seagrass data may be helpful.

Dr. Fourqueran suggested that correspondence be directed to Dr. Meeder inquiring about the release any of the maps. Attempts to reach Dr. Meeder recently have been unsuccessful. When asked about indicator species or VEC's, Dr. Fourqueran recommended shoal grass (*Halodule wrightii*). This is due to previous work in Florida Bay (Roblee and Thayer work over the last 10 years) that has shown greater habitat value for juvenile pink shrimp in shoal grass as compared to turtle grass. He acknowledged his opinion that historically there was probably more shoal grass in Biscayne Bay than now due to historical freshwater discharges, and that managing existing discharges to prevent "pulses" and encouraging more long-term modulated inputs of freshwater might convert existing turtle grass meadows to shoal grass meadows – a good thing in his opinion.

We briefly discussed the ecology of the large manatee grass meadow in north Biscayne Bay. He believes it persists due to its tolerance of lower light levels not any salinity related phenomenon. He suggested getting a copy of a ten year study of seagrass beds and water quality (produced by DERM 10 years ago).

We also discussed the distribution of *Halophila johnsonii* in Biscayne Bay. He confirmed he is not aware of any reports of it south of Rickenbacker Causeway. He described the species as having an optimum window for occurrence in "fine grained sediments in protected areas." He did not think the southern limit was related to temperature, but had no other explanation.

Florida International University (Continued)

Interviewee: John F. Meeder, Ph.D., Restoration Scientist, Florida International University.
Interviewer: R.R. Lewis. Interview date: Sep. 25, 2003.

Dr. Meeder indicated that he is very familiar with the MFL process and had attended many meetings on the subject. He described his work for both the SFWMD and BNP, and provided a number of papers as hard copies and on CDs. He indicated that there are two active combined MFL/habitat restoration projects underway that he has worked on; Historic Creek and Black Point, both of which are on the west side of Central Bay. He also mentioned the "L31E Surface Water Rediversion Pilot Project" as notable.

When asked about VECs he said "I don't like single species management." He supports the concept of introducing water into a restored system that includes all the parts (freshwater to estuarine to marine), monitoring, and adapting the system as needed. He doesn't think that there are any good reference sites existing today, but there is ample evidence that freshwater flows were much greater prior to channelization of the transverse glades and reduction in the head of water in the Everglades.

Discussion ensued regarding how wide a mesohaline zone could be established on the west side of Central Bay. Has had a number of discussions with Joan Browder and has looked at the available water to reduce salinities up to 1000 m offshore and he indicated that Rick Alleman (SFWMD) has the numbers. He noted a lack of historic salinity measurements in the nearshore zone on the west side of Central Bay.

Florida International University (Continued)
Interviewee: Danielle Mir-Gonzalez. Interviewee: G. Braun. Interview date: October 8, 2003.

Ms. Mir-Gonzalez is a graduate student who is working on a Master's thesis project that is focused on the relationship between submerged aquatic vegetation and water quality in westerly portions of southern Biscayne Bay. During the period from March-May, 2002, she documented the presence/absence and estimates of cover all species of seagrasses and macroalgae within 230 sample sites that are located from 50 m to 600 m from the western shore of Biscayne Bay in the area from Black Point to Turkey Point. She has also installed 20 seepage meters which will be monitored bi-monthly for two years. Although her work is still under way, (projected MS thesis completion/publication date is by mid-2004) preliminary results suggest that in areas of reduced salinity *Ruppia maritima* appears to be more abundant than other seagrasses. She has also documented the presence of the freshwater alga *Chara*, which is rooted in nearshore areas.

When published, the results of Ms. Mir-Gonzalez' work should be acquired and analyzed, as it may be helpful in understanding freshwater seepages and the presence and distribution of SAV in areas of Biscayne Bay that are affected by freshwater flows.

Florida International University (Continued)
Interviewee: Michael Ross. Interviewer: G. Braun. Interview date: October 22, 2003.

Mr. Ross has been involved with monitoring in coastal wetlands along the western shore of Biscayne Bay for nearly a decade. His study focuses on the 'white zone' including a transect located east of the L31 Canal near Card Sound Rd., which follows a salinity gradient from *Juncus* marsh through mangroves and includes nearshore seagrass beds, good descriptions of which are contained in a chapter in Porter and Porter. Although some individual species of plants could potentially be good indicators of varying salinities, the majority of the discussion centered on diatoms, as Mr. Ross' work in collaboration with Evelyn Gaiser has revealed that there are specific assemblages of diatoms that are present in specific salinity regime areas. He suggests that both she and WMD's Scott Hagerty, who is heavily involved with diatom work related to Everglades restoration, would be good sources for additional details regarding diatoms. His knowledge of them indicates that if we could identify a salinity regime that would maintain the existing assemblage of diatoms, maintaining that salinity regime would likely prevent significant harm to other biota. He further suggests that diatoms would be better indicators than macrophytes and/or soils because of; a) their comparatively instantaneous response to severe conditions, and b) their greater richness would allow more specific conditions to be monitored.

The Ph.D. dissertation by Marguerite Koch, which dealt with salinity tolerances of various macrophytes could also be a resource to us, if we decide to explore plants as indicators.

Southern Illinois State University
Interviewee: Scott Ishman. Interviewee: G. Braun. Interview date: October 9, 2003.

Mr. Ishman was the lead scientist in a mid-1990's paleo-ecological investigation of sediments in a single core sample taken in the Manatee Bay area of Biscayne Bay. The study used the presence/absence of foraminferans, ostracodes, mollusks and pollen to reconstruct ecological changes in the Bay that resulted from modifications to salinity regimes and changes in the water delivery system from the mid 1800's through the present. Mr. Ishman, whose primary area of expertise is forams, suggested that of the 24 species of foraminiferans that were present in the core sample, there are two taxa (*Ammonia parkinsoniana tepida* and *Elphidium galvestonense mexicanum*) that would potentially serve as indicators of conditions of ecosystem health. Both of these species have fairly narrow salinity tolerances and prefer oligohaline to mesohaline conditions. They are epi-benthic, are relatively easy to sample and count and have life cycles of ± one year. He offered to forward some reference papers that will describe salinity tolerances and life cycle info regarding these species.

He has done a little other foram work in Biscayne Bay, but thinks that the presence or absence of these and/or other foram species would be excellent indicators in the different areas of the Bay, particularly because they are benthic and respond quickly to changes. A potential downside is that these species could be affected by non-salinity water quality parameters (primarily D.O. and temp), which could make it challenging to know for sure that a die-off was exclusively the result of changes in salinity.

He is currently involved in other research in Biscayne Bay that will result in a greater understanding of the life cycles of forams.

Two of his co-authors of the "Record of Ecosystem Change…" paper could provide insight as to the extent to which ostracodes and mollusks could also be good indicators. The ostracode contact is Tom Cronin (USGS) 703-648-6366. The mollusk contact is Lynn Wingard 703-648-5352.

University of Miami - Rosensteil School of Marine and Atmospheric Science (RSMAS)
Interviewee: Craig Faunce. Interviewer: G. Braun. Interview date: October 21, 2003.

Mr. Faunce is a Ph.D. candidate at RSMAS doing work on Biscayne Bay fisheries, with the seasonal and spatial distribution of gray snapper as his specific area of focus. He has worked on Biscayne Bay fisheries for the last ± five years, but his work has all been south of the Rickenbacker Causeway. He has two major sampling areas: 1) offshore islands where the salinity regime is generally 28-35 ppt and 2) western shoreline areas where salinity is typically 7-28 ppt. We discussed various fish species that are more abundant in the shoreline areas and their potential usefulness as indicators. Although the presence of many of the species that are more abundant in the nearshore areas is more likely linked to non-salinity factors (e.g., increased nutrients which result in increased plankton populations) he does suggest the goldspotted killifish (*Floridichthys carpio*) as a species whose presence/absence *may* be related to appropriate salinity regimes and/or suitable water levels. Although this species may be somewhat too euryhaline to be an ideal indicator, he does think there is a linkage between its presence in oligohaline regimes and its replacement by sheepshead minnows in higher salinity areas. He speculates that there may also be a species of mud crab that could be a good indicator.

Mr. Faunce doesn't think that the southern bay is in all that degraded a condition, and thinks that it is reasonable to use existing conditions as what needs to be protected from adverse impacts. When his research project is completed during 2004, he expects the resulting data could be very useful in developing the MFL for Biscayne Bay. He does feel strongly that the variable of 'duration' of low flows is as important as the minimum flow itself, and that seasonality must be taken into account, because a specific low flow rate would have highly varying effects if it were to occur during the dry or wet season.

University of Miami (Continued) Interviewee: Dr. Diego Lirman. Interviewer: G. Braun. Interview date: October 9, 2003.

Dr. Lirman was the primary researcher and author of a paper entitled "The Influence of Salinity on Seagrass growth, Survivorship, and Distribution within Biscayne Bay, Florida: Field, Experimental, and Modeling Studies. The paper includes separate figures showing the results of seagrass blade densities of *Thalassia testudinum*, *Syringodium filiforme* and *Halodule wrightii* in Biscayne Bay. Dr. Lirman suggested *H. wrightii* would be an appropriate SAV indicator of estuarine health, as his research documented that its spatial distribution in the Bay is primarily restricted to nearshore areas that are currently subject to freshwater inflows. He is aware that oysters are present in northern portion of Biscayne Bay, and suggests that they may be a good non-floral indicator species of estuarine health in those areas where they currently exist.

Contrary to the perspectives provided by others (e.g., BNP staff), he contends Biscayne Bay is in very good ecological condition, and that while the structure of the benthic community may not be the same as it was decades ago, the presence of thriving hard coral, soft coral and sponge communities are indicators of its current state of good health. These organisms are extremely susceptible to reductions in salinity, and he has concerns that modifying the delivery of freshwater into the Bay would likely result in die-offs of these species. He has encountered *Ruppia maritima* only very rarely and has not ever observed *Chara* in the Bay. The modeling work he has done in collaboration with others (e.g., Wang) indicates that freshwater flows currently only affect a relatively narrow shoreline fringe of the Bay.

He suggests several other reference materials that may be of assistance to us, including: 1) a dissertation by UM/RSMAS' Patrick Biber regarding descriptions of the macroalgae communities in Biscayne Bay, 2) a paper on the corals of Biscayne Bay, 3) a paper on the sponges of Biscayne Bay, and 4) a dissertation regarding the presence, abundance and distribution of hydroids in Biscayne Bay.

Together with the National Geodetic Survey, Dr. Lirman is currently finishing an intensive one-year seagrass mapping effort in Biscayne Bay through which an extensive digital photographic file for existing seagrass and benthic conditions is being developed. By integrating a dGPS system into a high-resolution shallow-water video camera, the project will produce a comprehensive photographic catalog of existing conditions.

OTHER NON-GOVERNMENTAL ORGANIZATIONS

Audubon of Florida

Interviewee: Jerry Lorenz, Ph.D., Research Director, Audubon of Florida, Tavernier Science Center. Interviewer: R.R. Lewis. Interview date: Sep. 24, 2003.

Dr. Lorenz was only generally familiar with MFL process. He has only recently begun work east of US 1, and is now working in the "white zone" landward of Barnes Sound, having needed permission from FPL to access the site, which has taken a while. He has noted historical use of the area by Roseate spoonbills, which are about 10% of mixed flocks of feeding wading birds; but their visibility from the air makes them a good VEC. Feeding areas appear to be similar in cover and salinity regime to those used by juvenile (0-1 year)

American crocodiles. Food items also appear to be similar ("prey based or forage fishes"). He and Frank Mazzotti have discussed this, and his recollection is that "growth of juvenile crocodiles is directly related to salinity and that if during the first year of growth they do not reach a given biomass, they are subject to death from low temperatures." Lower salinities appear to produce greater benthic primary production with leads to more food for the prey based fishes which in turn are the food base for both juvenile crocodiles and the wading bird guild in the while zone, which includes the Roseate spoonbill. He has a recent report on up to 150 spoonbills using the white zone near the Turkey Point Power Plant radiator canal system, has not been able to confirm this report in person, but is beginning work there.

He suggested reviewing all the L31E experimental work as indicating what could be done, and suggested closing the C-111 and ensuring moderated sheet flows of freshwater as opposed to pulsed freshwater, which is a major problem. He described Manatee Bay as "dead" due to these continued pulsed flows.

Dynamac Corporation

Interviewee: Grant Gilmore, Ph.D., Senior Aquatic Ecologist, Dynamac Corporation, Vero Beach. Interviewer: R.R. Lewis. Interview date: October 27, 2003.

Dr. Gilmore is an ichthyologist who has some familiarity with the Biscayne Bay and its fish fauna. He indicated that was not familiar with any of the state MFL programs. After an explanation was provided about the state MFL law, and what BFA was hired to do, when asked about what fish species might be good indicators of the salinity regime, he mentioned the five species of snook in Florida, spotted sea trout and six species of "tropical peripherals" that he is working up life history descriptions for NMFS for their designation as "species of concern." One of these is the opossum pipefish (*Microphis brachyurus lineatus*). This is a species likely to occur along the western shore of Biscayne Bay if permanent freshwater is available for access from the sea. This species, like the others has some dependency on the existence of freshwater connected to the sea. Structures may impede migrations and prevent its existence.

His familiarity with spotted seatrout indicates that it is not a good indicator for lower salinities. Adult tarpon snook and fat snook might be as they are dependent on fresh water connected to the ocean.

Mote Marine Laboratory

Interviewee: Ernie Estevez, Senior Scientist. Interviewer: R. Lewis. Interview date: September 29, 2003.

Dr. Estevez has published several seminal pieces on the process of establishing MFLs, including a major summary paper in the same issue of *Estuaries* referenced by others. As with several other interviewees, he is not very familiar with Biscayne Bay, although he remembered the issue of groundwater flows and springs in the bay had been discussed in the past. He suggested that it might be helpful to obtain and review a paper about a circular spring in Biscayne Bay, around which circular zonation of seagrasses of various species was reported.

To save time, since it was a phone interview, I indicated that I was very familiar with his work (he and I co-authored the estuarine profile for Tampa Bay in 1987 for the U.S. Fish and Wildlife Service), and his recent publications on MFLs, and asked him if there was anything new to add subsequent to the publication of those papers. He indicated that his recent field work in several riverine estuaries in Charlotte Harbor and Tampa Bay had raised interest in oysters as VECs. During discussion concerning the potential use of VECs based on salinity, he noted that one needs to be careful about other factors that can influence the distribution and abundance of VECs besides salinity alone. He described his findings that oysters, if present, are often found in a bimodal distribution of small forms with the larger oysters found in the optimum salinity zone. Upstream of that zone, oysters are stressed or killed by freshwater, and downstream of that zone, oysters are frequently diseased, or have heavy predation, and are also very small compared to those in the optimum zone.

M.A. Roessler & Associates, Inc.
Interviewee: Martin A. Roessler. Interviewer: G. Braun. Interview date: October 20, 2003.

Mr. Roessler has been conducting research in Biscayne Bay for many decades in a variety of capacities, including as a researcher at RSMAS and as a consultant for BNP. We discussed the status of our search for suitable indicator organisms of ecosystem health and/or significant harm, and the potential benefits and drawbacks of several species, as follows. He does think that pink shrimp may be suitable indicators, as even though they are replenished on an annual basis from an external population (i.e. Tortugas); there may be a size class whose absence could be an indicator of significant harm. He suspects that there may be salinity-specific issues regarding the life cycles and/or presence of juvenile blue crabs, and thinks that the population of spotted seatrout is too low to be a good indicator, at least for the lower bay. He concurs that mullet may be a potential indicator, but that the relative absence of this species in the southern bay may be due to a variety of factors far outside the scope of salinity regimes.

He suggests that we investigate the salinity requirements for sustainable populations of land crabs (*Cardisoma guanhumi)* as successful reproduction in this species may be tied to lower-than-marine salinity regimes. He also suggests that there may be some species of barnacles that would be of assistance, although he could not identify any individual species.

Regarding potential use of seagrasses as indicators, he suggests that changing sediment conditions could be equally as important as salinity in determining their spatial distribution and health.

FINDINGS

1. Regarding the establishment of MFLs, it appears that Biscayne Bay (BB) should be separated into six sub-regions, based on varying levels of exchange between freshwater and marine conditions. Varying salinity regimes and the presence/absence and abundance of varying flora and/or fauna will likely result in different indicators being established for each sub-region.

2. The majority of the research and scientific data available for Biscayne Bay are focused on southern portions of the Bay, particularly those waters within Biscayne National Park (BNP). With an apparent lack of information on northern areas of BB, the team re-focused on searching for, obtaining and reviewing additional information about this portion of the study area (e.g., Management Plan for Oleta River State Park and the current draft of the Management Plan for Biscayne Bay Aquatic Preserve). Because

detailed information regarding the presence, absence and/or abundance of freshwater-dependant species in this area of the Bay remains in short supply, it is possible that Task 5 will include suggestions that additional information is needed in this area.

3. For the Central Bay (most of BNP), many of the interviewees indicated that the species that would be the best indicators of healthy estuarine conditions are currently no longer present or are present in such limited numbers or distribution that they would not serve as good indicators. In large part, the absence of these species seems to be the result of past modifications of the delivery of freshwater into the Bay, including highly variable fluctuations in freshwater flow and development, including canal construction and construction of features that have re-directed surface and/or subsurface flow. These interviewees suggested that even the existing minimum flows are sub-optimal, and that, because the ecosystem is currently in a state of significant harm, the MFL process should identify target estuarine systems, such as Historic Creek and Black Point (completed preliminary restoration design projects by SFWMD), which should be developed as "full range" estuarine systems with the target of reestablishing a continuum of freshwater marsh, brackish marsh, mangrove, and inshore estuarine (mesohaline) conditions along a gradient from upland to bay. The interviewers suggested that these projects should be monitored in advance of construction (5 years minimum) for baseline conditions (physical and biological), restored, monitored and water flows adjusted through adaptive management to achieve the full range of salinities targeted as performance standards.

4. For the South Bay, there are expansive wetlands (white zone and mangrove fringe) that lend themselves to monitoring of the VEC's of numbers of feeding Roseate spoonbills and survival of juvenile American crocodiles. The optimum salinity regime necessary for both of these species appears to be similar. Further review of information available for these species may reveal the exact target range, but this range has not yet been identified.

5. For central and southern areas of the Bay, several of the experts identified that, in their opinion, maintaining minimum flows is currently thought to be less of a problem than the large pulse discharges of freshwater that cause wide and rapid swings in salinity (i.e. 25 ppt in 24 hours or less). They indicated that, although it may be outside the specific scope of the MFL process, there needs to be consideration given to the fact that the existing floral and faunal assemblages near canal discharges are largely restricted to those organisms that can survive these un-natural changes in salinity, and that ideally, salinity changes should be moderated to reduce the wide swings to something less than 6 ppt per 24 hours period, and some range "not to exceed" to reduce the stresses to fish and wildlife using both areas. When asked, the BNP staff agreed that this approach may result in a conversion of turtle grass meadows to shoal grass or mixed shoal grass and widgeon grass meadows, and that was an acceptable change.

6. For the Central Bay, no further reduction in freshwater inputs should be allowed due to reservations of water currently available due to the potential for this portion of BB to become over time a hypersaline lagoon, similar to documented problems in Florida Bay and portions of northern Cuba.

7. In addition to the previously identified potential indicator species listed by Alleman (2003) (i.e., pink shrimp, blue crab, American oyster, stone crab, American crocodile,

mullet, Spanish mackerel, spotted seatrout, crevalle jack, gray snapper, common snook, and tarpon) as species that are present in the Bay and which some economic and/or ecological importance, interviewees have suggested the need for the MFL rule development process to consider the following species:

- Roseate spoonbill (*Ajaia ajaja*)
- West Indian Manatee, crocodiles and other species that are present within the project area and which are protected under federal and/or state protected species regulations
- Johnson's Seagrass (*Halophila johnsonii*)
- Shoal grass (*Halodule wrightii*)
- Grass Shrimp (Caridean shrimp, several species)
- Goldspotted killifish (*Floridichthys carpio*)
- Opossum pipefish (*Microphis brachyurus lineatus*)

Several interviewees suggested that it would be advantageous if indicator species for each region of the Bay could be identified and selected to include both sessile and mobile organisms. The project team concurs with this recommendation and will likely use the presence/absence of such a combination as a tool in evaluating alternative approaches for MFL development.

The project team acknowledges that the scope of work for the "Freshwater Flow and Ecological Relationships in Biscayne Bay" project identifies that the western boundary of the project is the western shoreline of Biscayne Bay. Based upon the results of the team's review of applicable literature and interviews with experts, it is the opinion of the project team that the District should consider modifying this boundary to include areas where floral and faunal assemblages of environmental significance are located to the west of the shoreline (i.e., the vegetation zone located between the western shoreline and the L-31 Canal, including the area referred to the "white zone"). The rationale for this addition is that the natural resources within this area could be adversely affected by reductions in freshwater flows. If areas west of the shoreline are to be included within the project area, several additional floral and faunal species should be considered as potential indicators of estuarine health and/or indicators of significant harm. These include:

- black needlerush (*Juncus roemarianus*) and spike rush (*Eleocharis* spp.)
- Sawgrass (*Cladium jamaicensis*)
- Land crabs (*Cardisoma guanhumi)*
- Forage fish species assemblages

8. Several interviewees have expressed their concerns that, in their opinion, it would be erroneous to attempt to establish an MFL rule for Biscayne Bay that is based solely on the water quality parameter of salinity. Previously-conducted water quality studies (e.g., Meeder & Boyer, 2001) have suggested that non-salinity water quality parameters (i.e., ammonia) have caused adverse ecological impacts on benthic communities in the Bay, and, in some specific areas, these discharges may be as much responsible for degradations as the extreme fluctuations in salinity. The project team acknowledges that addressing water quality parameters other than salinity is outside the team's scope of work, and it is our understanding that the District will address water quality issues in the MFL Plan.

9. FWS personnel suggest the need to give thoughtful consideration to the individual life histories of each species that inhabits Biscayne Bay and which is designated as 'endangered' or 'threatened' (e.g., west Indian manatee, American crocodile, Johnson's seagrass, Smalltooth sawfish). FWS is currently developing biological opinions regarding the impacts to each of the federally-listed species that may result from construction and operation of CERP projects. The project team agrees that potential impacts to listed species should be identified as a criterion during the evaluation of alternative approaches for MFL development.

10. The adopted Manatee Protection Plan (MPP) developed by Miami-Dade DERM documents the use of the mouths of canals as refugia by manatees during the winter months. Although water temperature data are lacking at these sites, it is likely that the combination of lower salinity water and temperatures that are thought to be several degrees warmer than bay waters makes these areas attractive to manatees during the winter. DERM recommends that development of the MFL rule consider that reductions in flow volumes at this time of year could have a negative affect on this listed species, but acknowledge that it may be difficult to identify the specific thresholds at which significant harm to manatees would be reached. The project team acknowledges that the water temperature element of this impact may be outside the scope of the team's work, but that it must be considered and addressed as part of the MFL rule.

11. SJRWM has relied heavily on soil conditions as the key indicator in their development of MFL criteria for the many lakes and ponds in their region where MFL rules have now been developed.

12. Several interviewees acknowledged that Chapter 373 FS gives WMDs the authority to consider situations in which the receiving waters are currently in a degraded state as a result of alterations in surface water flow. It has been urged that, in establishing the MFL rule for BB, the current ecological conditions should ***not*** be considered as baseline, and that there is the opportunity to adopt an MFL strategy that simultaneously identifies minimum flows to maintain existing systems, and uses the CERP, RECOVER and the Biscayne Bay Coastal Wetlands Program as the long-term recovery plan for Biscayne Bay. It was noted that various WMDs (including SFWMD in the Loxahatchee River) have identified restoration/recovery plans within the MFL rule adopted for some individual water bodies. It was suggested that the Ishman et. al. study of the presence of foraminiferans and ostracodes in benthic samples could be helpful in identifying target conditions. Also, the SWFWMD has developed a plan to test various MFLs for the Lower Hillsborough River (LHR) in a situation similar to many of the canals to BB. The LHR has a dam on it for a drinking water reservoir for the City of Tampa, and in recent years has had approximately 200 days a year of "no-flow" conditions, interspersed with flood flow discharges necessary to relieve stress on the dam.

13. In consideration of the various studies and research that are currently underway and the CERP projects that are being designed to improve water quality conditions in Biscayne Bay, several interviewees recommended that the rule specifically include processes for re-evaluating the MFL on a more frequent than usual basis.

14. Some interviewees suggested that it would be erroneous to attempt to develop the MFL for Biscayne Bay without considering subsurface inflows, which may have significant effects in the nearshore areas in some regions of the Bay. Research is currently under way in this regard by graduate students at Florida International University. The results of the monitoring of seepage wells in westerly areas of the Bay are expected to be available prior to the development of the MFL rule for Biscayne Bay, and the team anticipates recommending to the District that these results be obtained and reviewed and changes be considered to the MFL rule, if warranted.

15. FDEP's Office of Water Quality is involved in an on-going study/monitoring effort focusing on benthic macro-invertebrates and SAV along several fixed transects that extend from the western shore of the Bay eastward to the edge of impact at locations near C-103 and Snapper Creek Canal (Control). The project has just begun during 2003. The project team was represented when the project results were presented at the Sanibel "Ecological Indicators" workshop on October 30, 2003. As previously outlined above, the results confirm the premise that benthic faunal assemblages are not likely to be a good ecological indicator for salinity changes alone for Biscayne Bay due to multiparameter impacts of water quality and salinity.

16. Discussions with several experts who are involved with research in Biscayne Bay suggest that it may be prudent to use several individual species of foraminiferans and/or diatoms as indicators of estuarine health and/or measurements of significant harm. Being lower in the trophic hierarchy, these organisms would be better indicators than fish, macrophytes and/or soils because of; a) their comparatively instantaneous response to severe conditions, b) their greater richness would allow more specific conditions to be monitored; c) their comparative lack of mobility would reduce the potential for mis-interpreting absence (as could happen in more mobile species such as fishes); and d) the relative ease and low-cost for sampling and analysis. Two individual taxa (*Ammonia parkinsoniana tepida* and *Elphidium galvestonense mexicanum*) that would potentially serve as indicators of conditions of ecosystem health were identified. Both of these species have fairly narrow salinity tolerances and prefer oligohaline to mesohaline conditions. They are epi-benthic, are relatively easy to sample and count and have life cycles of $\pm$ one year. Potential downsides include that these species could be affected by non-salinity water quality parameters (primarily D.O. and temp), which could make it challenging to know for sure that a die-off was exclusively the result of changes in salinity, and selling them as a "Valued Ecosystem Component" to non-specialists.

17. Regardless of the extent to which other species of forams and diatoms could be identified as indicators for habitat restoration, if the MFL identifies a salinity regime that would maintain the existing assemblage of these organisms, maintaining that salinity regime would likely prevent significant harm to other biota.

18. R. Lewis attended the Ecological Indicators Workshop in Sanibel, 29-31 OCT 2003, and briefly interviewed Louis Toth after his presentation on the selection process for ecological indicators for success in the restoration of the Kissimmee River. Mr. Lewis requested that Mr. Toth send him the manuscript, which he is doing. Since the method has been used by the SFWMD already, it may have application to the MFL process for BB. Dr. Willian Dunson, Emeritus Professor of Biology, Penn. State Univ., made a

similar presentation on selection of ecological indicators for low salinity environments and his information may also have application.

ATTACHMENT A
INTERVIEW PROCESS

Initial SFWMD List of Recommended Contacts/Interviewees

Mr. Daniel Apt, Florida Department of Environmental Protection

Dr. Jerry Ault, University of Miami – Rosenstiel School of Marine and Atmospheric Science

Ms. Sarah Bellmund, Biscayne National Park

Mr. Steven Blair, Miami-Dade Department of Environmental Resources Management

Dr. Joseph Boyer, Florida International University

Dr. Joan Browder, National Oceanographic and Atmospheric Administration

Mr. Rick Clark, Biscayne National Park

Mr. Richard Curry, Biscayne National Park

Mr. Sid Flannery, Southwest Florida Water Management District

Dr. Ernie Estevez, Mote Marine Laboratory

Ms. Stacey Feken, Florida Department of Environmental Protection

Dr. James Fourqurean, Florida International University

Mr. Craig Grossenbacher, Miami-Dade Dept. of Environmental Resources Management

Dr. Jerome Lorenz, Audubon of Florida

Dr. Susan Markley, Miami-Dade Department of Environmental Resources Management

Dr. Frank Mazzotti, University of Florida, IFAS

Dr. John Meeder, Florida International University

Mr. William Nuttle

Dr. Peter Ortner, National Oceanographic and Atmospheric Administration

Dr. William Perry, Everglades National Park

Mr. Patrick Pitts, U.S. Fish and Wildlife Service

Dr. Mike Robblee, U.S. Geological Survey

Dr. Martin Roessler, M.A. Roessler Associates, Inc.

Dr. Joseph Serafy, National Oceanographic and Atmospheric Administration

Ms. Susan Teel, U.S. Environmental Protection Agency

Mr. Herbert Zebuth, Florida Department of Environmental Protection

Dr. Jay Zeiman, University of Virginia

During the course of the interviews, each interviewee was asked to review the list of people identified by SFWMD with whom interviews are to be conducted and to make suggestions of any other individuals who they believe could provide additional information and/or insight into the project. Suggestions received, and the results of discussions with WMD staff, shown in parentheses, regarding the merits of conducting interviews with these individuals in consideration of budgetary and schedule constraints include:

- Larry Brand, UM; working on a phytoplankton study in BB. (Budgetary and schedule constraints suggest that an interview should not be conducted).
- Gwen Burzecki, DERM –studying white mangrove community along w. shore of BB. (Budgetary and schedule constraints suggest that an interview should not be conducted).
- Joe Contillo; oversees a long-term study of bottlenose dolphins in BB. (Budgetary and schedule constraints suggest that an interview should not be conducted).
- Guillermo Diaz, UM; Ph.D. dissertation re population dynamics of Pink Shrimp in BB. (Yes, the team is directed to pursue an interview).
- Cindy Dwyer, Planner, Miami-Dade Planning and Zoning Dept.; (Project manager overseeing public land acquisition projects along BB for env. Enhancements). (Budgetary and schedule constraints suggest that an interview should not be conducted).
- Craig Faunce, UM; Ph. D. work re fishes in mangrove shorelines of BB. (Yes, the team is directed to pursue an interview).
- Janice Fleischer, J.D.; Program Manager for the SFRPC Institute for Community Collaboration. (Budgetary and schedule constraints suggest that an interview should not be conducted).
- Greg Graves, FDEP – Port St. Lucie; Oversees an FDEP bay-wide water quality monitoring program. (Yes, the team is directed to pursue an interview).
- Scott Ishman, principal investigator and lead author of a paleo-ecological analysis of BB sediments. (Yes, the team is directed to pursue an interview).
- Diego Lirman, UM; Abundances, Diversity and Distribution of Benthic Organisms in relation to Salinity Gradients in BB. (Yes, the team is directed to pursue an interview).
- Danielle Mir-Gonzalez, FIU; grad student working on seagrass distribution along W. shoreline of BB. (Yes, the team is directed to pursue an interview).
- Rene Price, FIU; using chemical tracers to evaluate changes in freshwater inputs into BB. (Budgetary and schedule constraints suggest that an interview should not be conducted).
- Mike Ross, FIU; working on a pilot project to re-introduce fresh water into cells E. of L-3. (Yes, the team is directed to pursue an interview).
- Gene Shinn, USGS, St. Petersburg. (Budgetary and schedule constraints suggest that an interview should not be conducted).

Approximately half-way through this interview period, the project team met with SFWMD to provide a status report as to the degree of progress in conducting the interviews. Prior to this team meeting, the project team developed and provided to SFWMD a summary of the interview component of the project. The summary, which included highlights of the individual interviews that had been completed by that time, also included a list of 14 potential additional interviewees and a list of 10 of the recommended interviewees with whom attempts to complete interviews had been unsuccessful. The merits of conducting interviews with these individuals were discussed, and a decision was made whether or not to pursue interviews in consideration of the area and/or level of pertinent knowledge of that expert within the budgetary and/or schedule constraints of the project. Results of this project status meeting were compiled into a "Task 3 – Interim Report for Contacts and Experts Interviews" which was provided to SFWMD on October 7, 2003.

Additionally, telephone conversations, messages and email correspondences and/or the lack of responses indicated that interviews are not likely to take place with several of the individuals with whom interviews were initially desired. The merits of continuing to pursue interviews with these individuals were discussed at the project team meeting with SFWMD on October 1, 2003. The results of these discussions are identified in parentheses, below.

Dr. Jerry Ault (OK to not pursue).
Dr. James Forqurean (Continue to pursue).
Craig Grossenbacher (OK to not pursue)(But interviewed after a return phone call after the meeting from Mr. Grossenbacher indicating his interest in the project)
Frank Mazzoti (Continue to pursue).
William Nuttle (OK to not pursue).
Peter Ortner (OK to not pursue).
Dr. William Perry (OK to not pursue).
Dr. Mike Robblee (Continue to pursue).
Susan Teel (OK to not pursue).
Dr. Jay Zieman (OK to not pursue).

ATTACHMENT B
INTERVIEW FORM

INTERVIEW FORM

BISCAYNE BAY MFL
SFWMD CONTRACT/WO No. C-15967-WO04-06

Date: ______________________________

Location: ____

Contact's Name, position and contact information (or attach business card)

____

____

____

____

QUESTIONS:

1. **Are you familiar with the MFL process?**

____

____

2. **Are you aware of the MFL process now beginning for Biscayne Bay?**

____

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____

3. **Did you receive a notification explaining the purpose of this interview?**

____

4. **What are your thoughts on which Biscayne Bay organisms or communities have a freshwater requirement for some or all of their life history?**

____

____

____

Contact/date: _____________, P 2

5. What literature sources would you recommend be reviewed concerning these organisms or communities?

____

____

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____

____

6. How could these freshwater requirements relate to development of MFLs for the bay?

____

____

____

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____

____

7. Can you recommend any recent or on-going relevant research and data sources that would discuss the salinity tolerance/freshwater requirements/habitat specificity for these organisms or communities, or that would be otherwise helpful in meeting the project goals?

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____

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____

8. Any other comments or suggestions?

____

____

____

APPENDIX C

LIFE HISTORY FIGURES OF SELECTED SPECIES

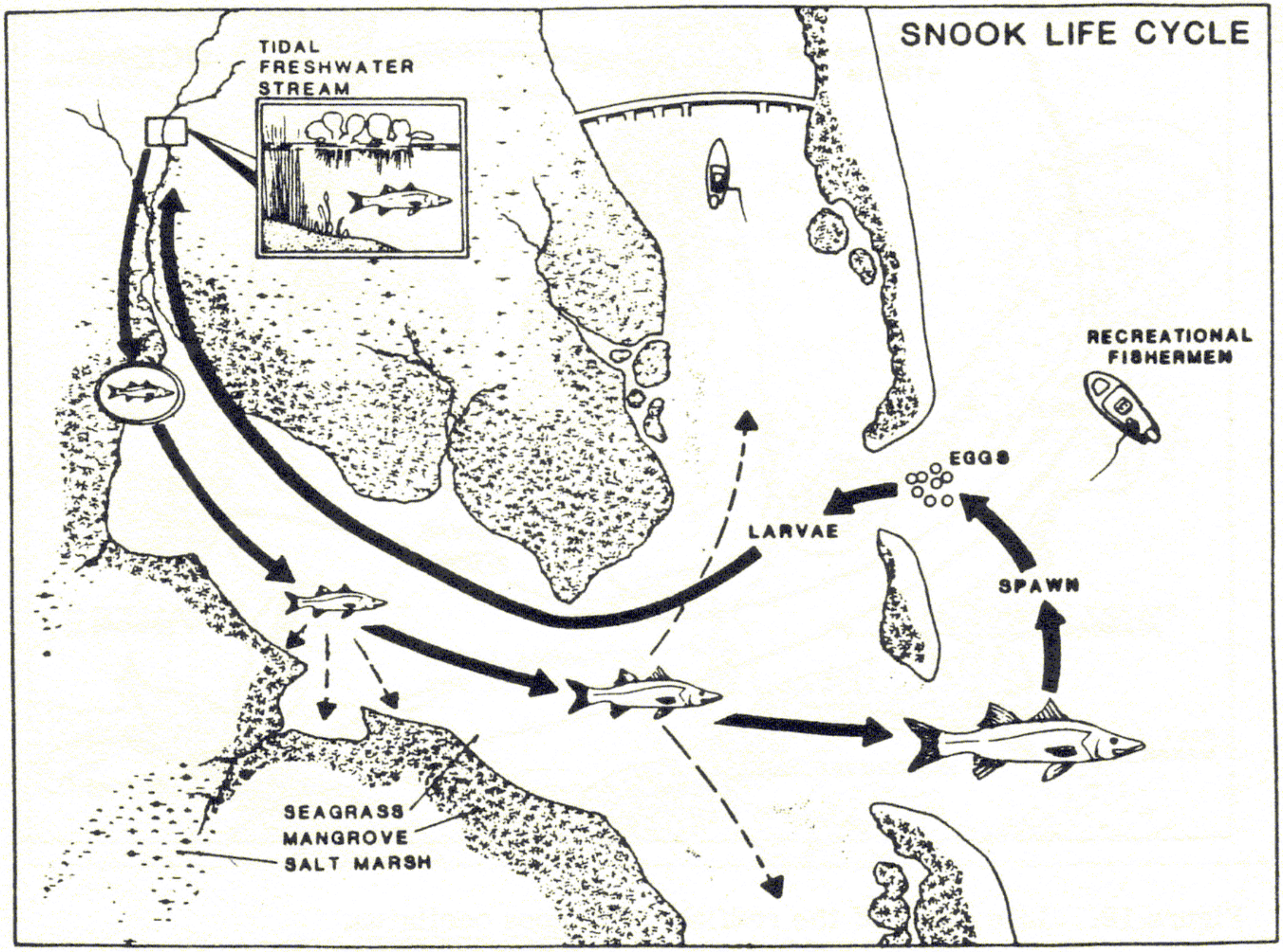

Figure C-1
Life cycle of the snook, Centropomus undecimalis,
(from Lewis at al. 1985).

B F A

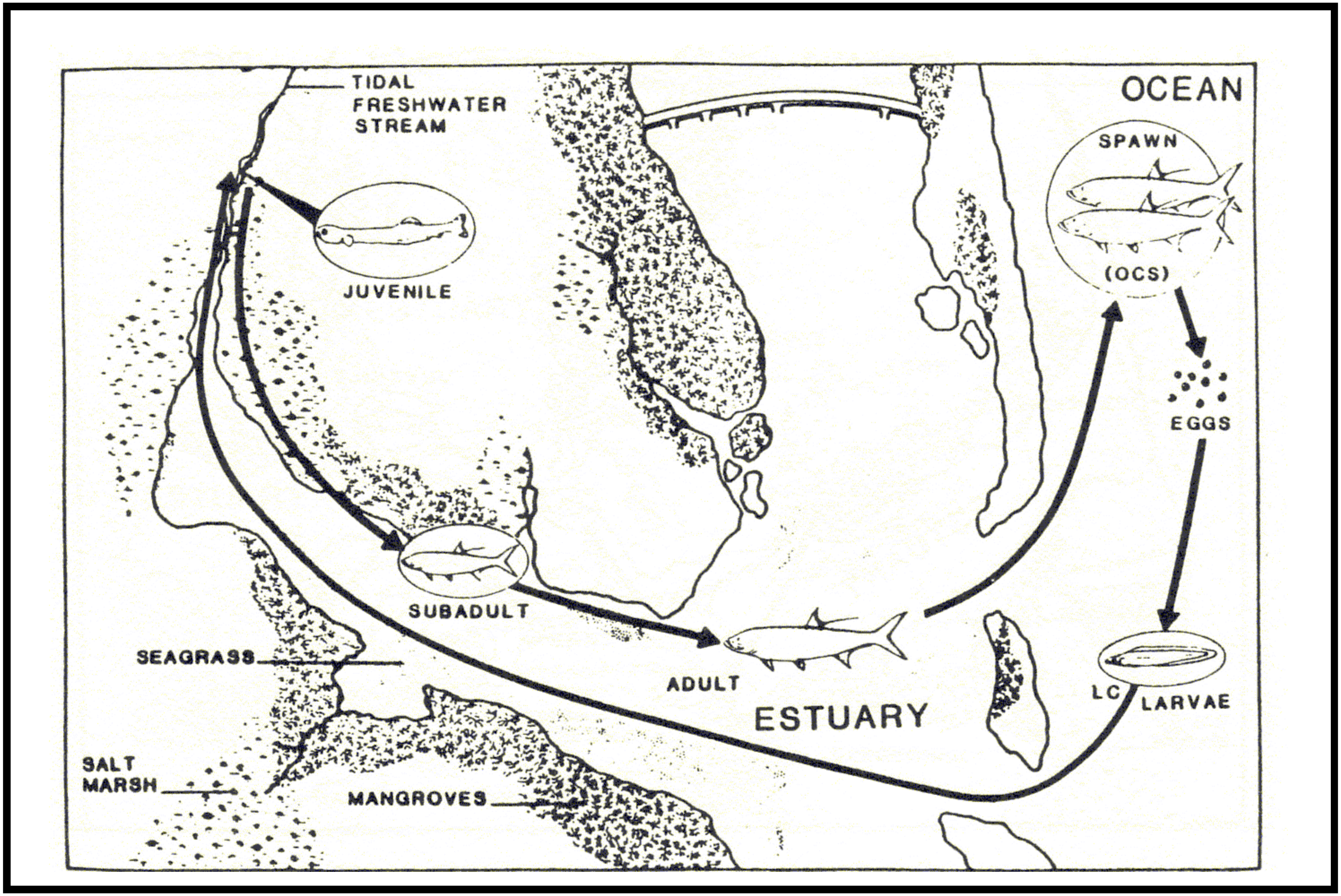

Figure C-2
Life cycle of the tarpon, Megalops atlanticus,
(from Lewis at al. 1985).

B F A

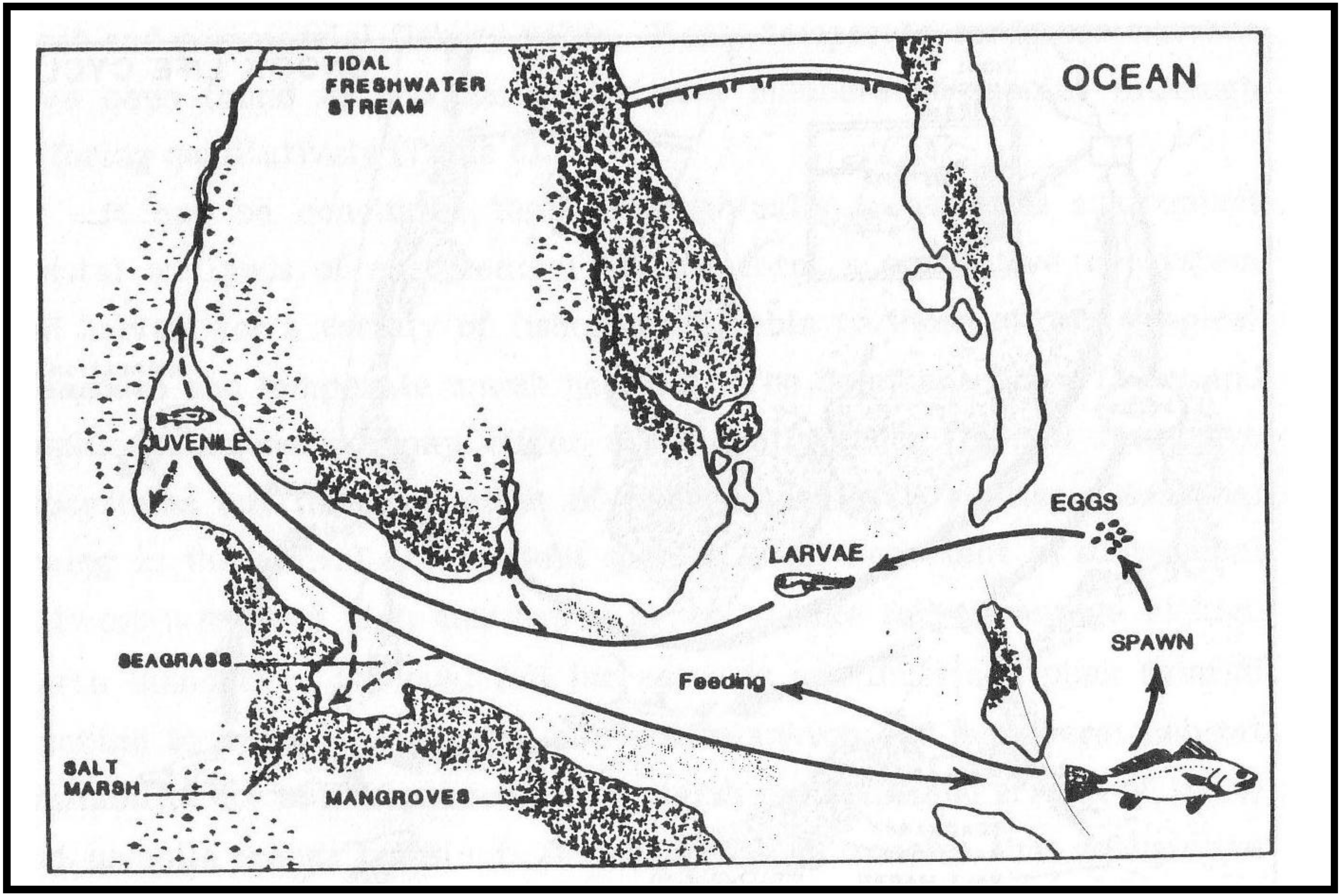

Figure C-3
Life cycle of the redfish, Scianops ocellatus,
(from Lewis et al. 1985).

B F A

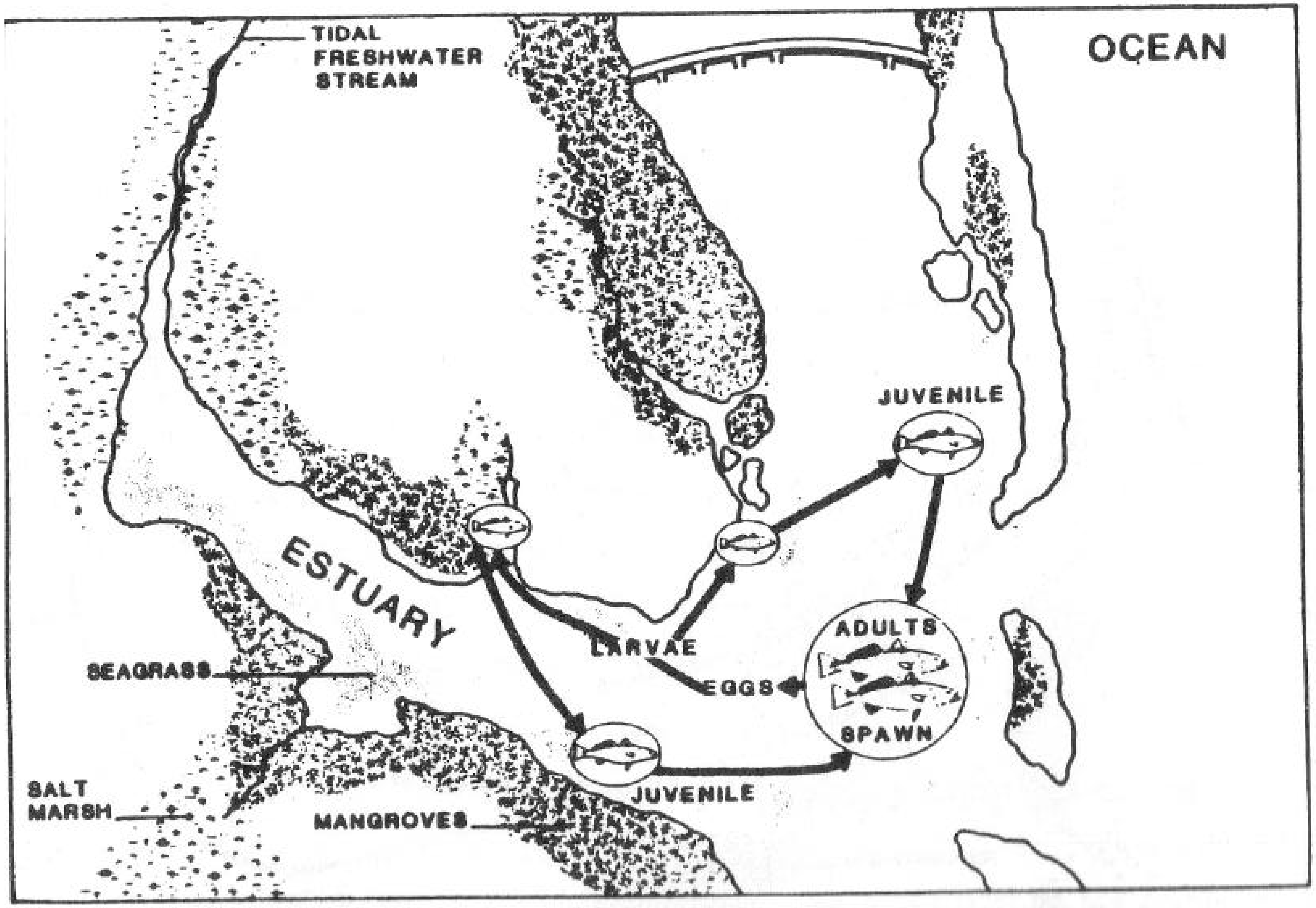

Figure C-4
Life cycle of the spotted seatrout, Cynoscion nebulosus,
(from Lewis at al. 1985).

B F A

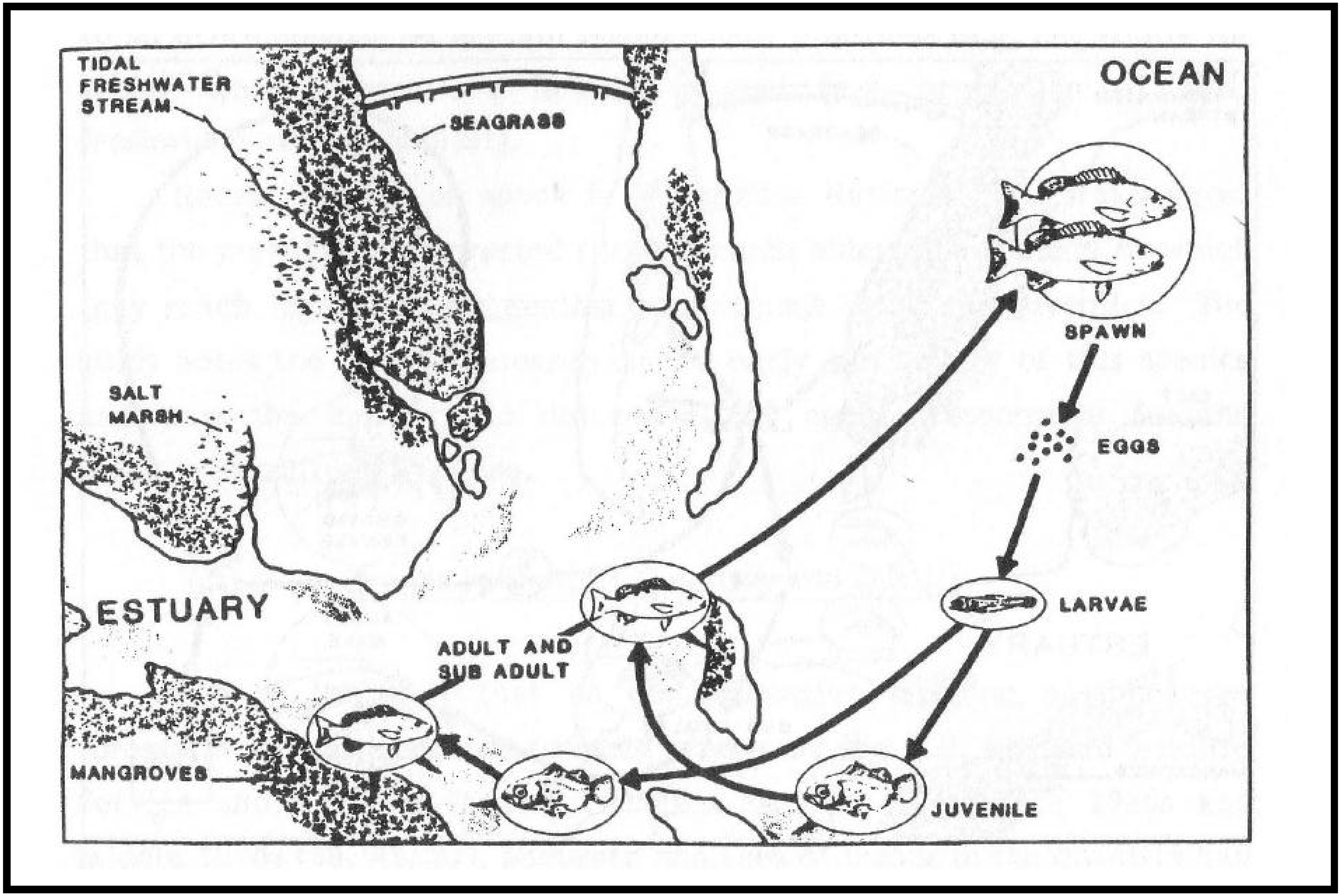

Figure C-5
Life cycle of the gray snapper, Lutjanus griseus, (from Lewis at al. 1985).

B F A

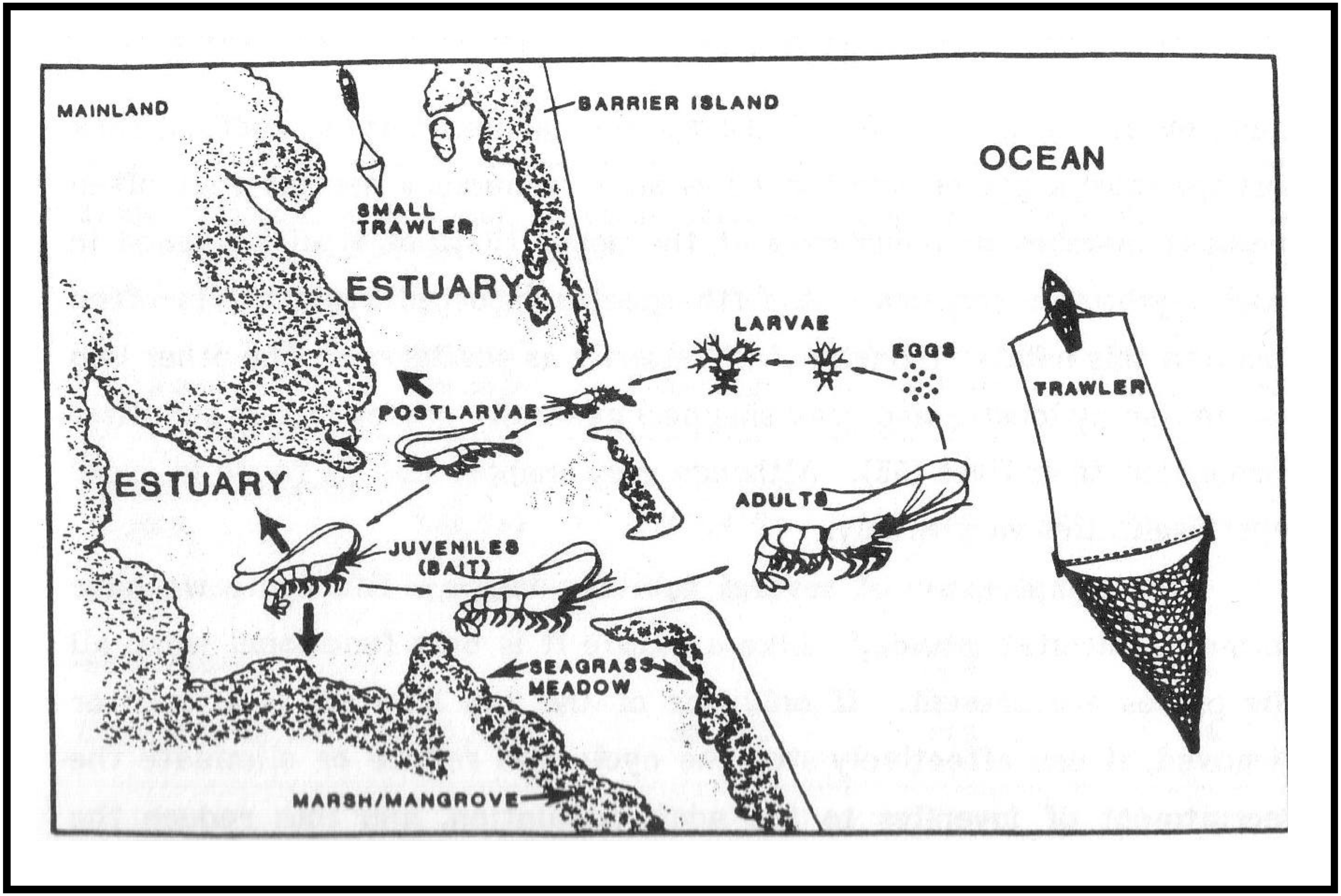

Figure C-6
Life cycle of the pink shrimp, Farfantepenaeus duorarum,
(from Lewis et al. 1985).

B F A

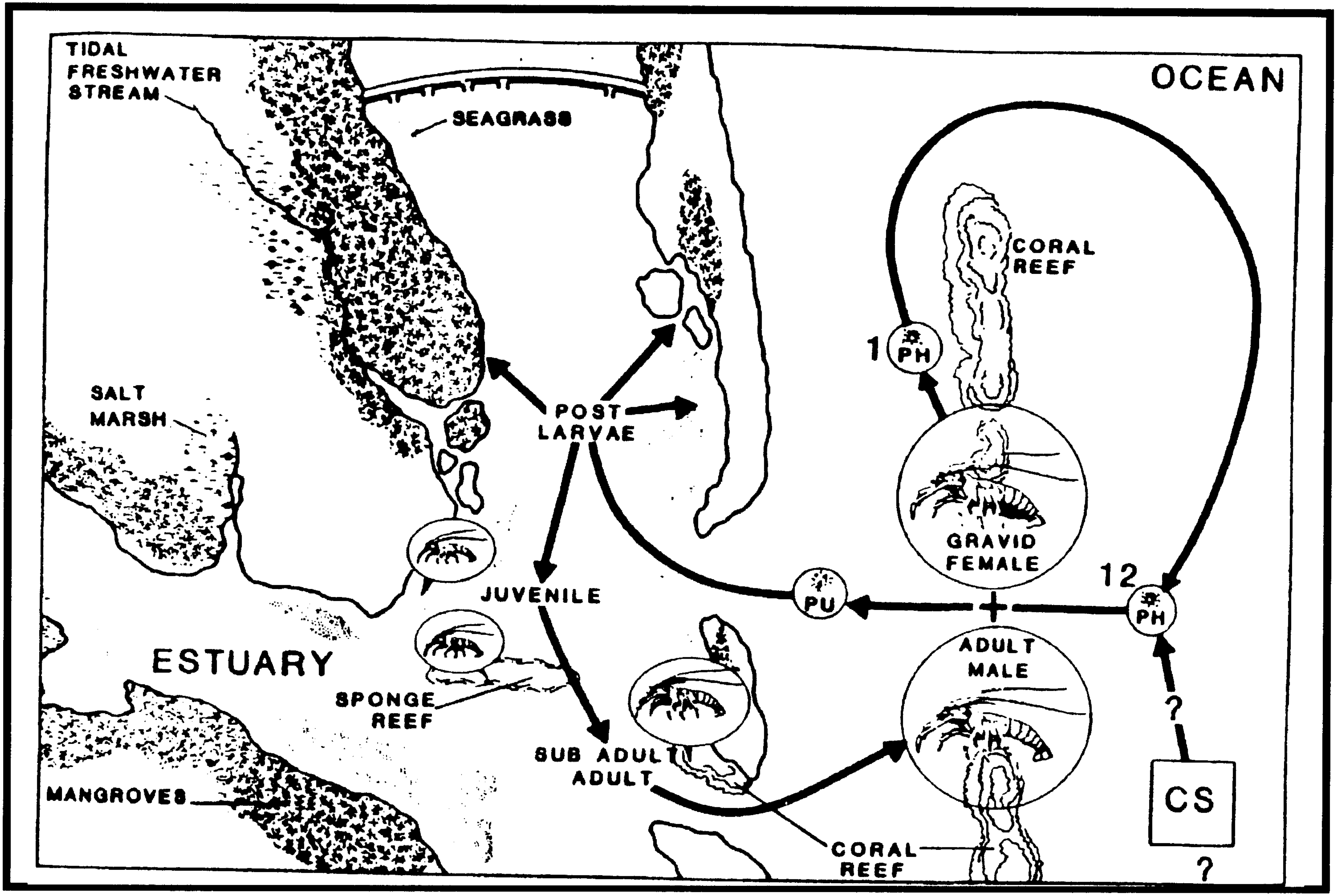

Figure C-7
Life cycle of the spiny lobster, Panulirus argus, (from Lewis at al. 1985).

BFA

APPENDIX D

TABLES OF
BIO-INDICATOR RANKING MATRIX
BY SUB-REGIONS

Table D-1
Bio-indicator Ranking Matrix
Oleta River - Snake Creek Sub-Region

SPECIES	Present in adequate numbers or distribution?	Sensitivity to Applicable Parameters	Reliability of Response	Rapidity of Response	Ease & Economy of Monitoring	Meaningful Feedback to Management	Importance of Endpoint	Total Score
Plants								
Diatoms	Yes	4	4	5	3	3	1	20
Avicennia germinans	Yes	0	0	0	3	3	0	6
Cladium jamaicense	No							
Conocarpus erecta	Yes	0	0	0	3	3	0	6
Distichlis spicata	No							
Eleocharis cellulosa	No							
Halophila decipiens	No							
Halophila englemanii	No							
Halophila johnsonii	Yes	0	0	0	3	3	0	6
Halodule wrightii	Yes	5	3	3	3	3	4	21
Juncus roemerianus	No							
Laguncularia racemosa	Yes	0	0	0	3	3	0	6
Rhizophora mangle	Yes	0	0	0	3	3	0	6
Ruppia maritima	No							
Spartina spartinae	No							
Syringodium filiforme	Yes	3	3	1	3	3	3	16
Thalassia testudinum	No							
ANIMALS								
Foraminiferans	Yes	4	4	5	3	3	1	20
Invertebrates								
Callinectes sapidus	Yes	5	3	3	1	3	1	16
Crassostrea virginica	Yes	5	5	3	5	5	5	28
Farfantepenaeus duorarum	Yes	5	3	3	3	3	0	17
Limulus polyphemus	Yes	0	0	0	3	0	0	3
Menippe mercenaria	Yes	0	0	0	3	0	0	3
Vertebrates								
Mammals								
Trichechus manatus	Yes	3	0	3	3	3	0	12
Turciops truncatus	Yes	0	0	0	3	0	0	3

Scoring System: 0 (Poor), Medium (3), Excellent (5)

Table D-1
Bio-indicator Ranking Matrix
Oleta River - Snake Creek Sub-Region

SPECIES	Present in adequate numbers or distribution?	Sensitivity to Applicable Parameters	Reliability of Response	Rapidity of Response	Ease & Economy of Monitoring	Meaningful Feedback to Management	Importance of Endpoint	Total Score
Reptiles								
Crocodylus acutus	No							
Birds								
Ajaia ajaja	Yes	0	0	0	5	3	0	8
Egretta caerulea	Yes	0	0	0	5	3	0	8
Egretta rufescens	Yes	0	0	0	5	3	0	8
Egretta thula	Yes	0	0	0	5	3	0	8
Egretta tricolor	Yes	0	0	0	5	3	0	8
Eudocimus alba	Yes	0	0	0	5	3	0	8
Mycteria americana	No							
Pelicanus occidentalis	Yes	0	0	0	5	3	0	8
Fish								
Bairdiella chrysoura	Yes	0	0	0	0	3	0	3
Centropomus undecimalis	No							
Cynoscion nebulosus	Yes	3	0	0	0	0	0	3
Cypinodon variegatus	No							
Eucinostomus gula	Yes	0	0	0	0	3	0	3
Floridichthys carpio	Yes	0	0	0	0	0	0	0
Fundulus confluentus	Yes	0	0	0	0	0	0	0
F. grandis	Yes	0	0	0	0	0	0	0
Haemulon sciurus	Yes	0	0	0	0	3	0	3
H. plumieri	Yes	0	0	0	0	3	0	3
H. parra	Yes	0	0	0	0	3	0	3
Lagodon rhomboides	Yes	0	0	0	0	0	0	0
Lucania parva	Yes	0	0	0	0	3	0	3
Lutjanus griseus	Yes	3	0	0	3	3	3	12
Myteroperca microlepis	No							
Megalops atlanticus	No							
Mugil spp	Yes	3	0	0	0	3	0	6
Opsanus beta	Yes	0	0	0	0	0	0	0
Sphyraena barracuda	Yes	0	0	0	0	0	0	0

Scoring System: 0 (Poor), Medium (3), Excellent (5)

Table D-2
Bio-indicator Ranking Matrix
Northern Biscayne Bay Sub-Region

SPECIES	Present in adequate numbers or distribution?	Sensitivity to Applicable Parameters	Reliability of Response	Rapidity of Response	Ease & Economy of Monitoring	Meaningful Feedback to Management	Importance of Endpoint	Total Score
Plants								
Diatoms	Yes	4	4	5	3	3	1	20
Avicennia germinans	Yes	0	0	0	3	3	0	6
Cladium jamaicense	No							
Conocarpus erecta	No							
Distichlis spicata	No							
Eleocharis cellulosa	No							
Halophila decipiens	No							
Halophila englemanii	No							
Halophila johnsonii	Yes	0	0	0	3	3	0	6
Halodule wrightii	Yes	5	3	3	3	3	4	21
Juncus roemerianus	No							
Laguncularia racemosa	No							
Rhizophora mangle	Yes	0	0	0	3	3	0	6
Ruppia maritima	No							
Spartina spartinae	No							
Syringodium filiforme	Yes	3	3	2	3	5	5	21
Thalassia testudinum	Yes	3	0	0	3	3	3	12
ANIMALS								
Foraminiferans	Yes	4	4	5	3	3	1	20
Invertebrates								
Callinectes sapidus	Yes	5	3	3	1	3	1	16
Crassostrea virginica	No							
Farfantepenaeus duorarum	Yes	5	3	3	3	3	0	17
Limulus polyphemus	Yes	0	0	0	3	0	0	3
Menippe mercenaria	Yes	0	0	0	3	0	0	3
Vertebrates								
Mammals								
Trichechus manatus	Yes	3	0	3	3	3	0	12
Turciops truncatus	Yes	0	0	0	3	0	0	3

Scoring System: 0 (Poor), Medium (3), Excellent (5)

Table D-2
Bio-indicator Ranking Matrix
Northern Biscayne Bay Sub-Region

SPECIES	Present in adequate numbers or distribution?	Sensitivity to Applicable Parameters	Reliability of Response	Rapidity of Response	Ease & Economy of Monitoring	Meaningful Feedback to Management	Importance of Endpoint	Total Score
Reptiles								
Crocodylus acutus	Yes	3	3	3	0	3	3	15
Birds								
Ajaia ajaja	Yes	0	0	0	5	3	0	8
Egretta caerulea	Yes	0	0	0	5	3	0	8
Egretta rufescens	Yes	0	0	0	5	3	0	8
Egretta thula	Yes	0	0	0	5	3	0	8
Egretta tricolor	Yes	0	0	0	5	3	0	8
Eudocimus alba	Yes	0	0	0	5	3	0	8
Mycteria americana	No							
Pelicanus occidentalis	Yes	0	0	0	5	3	0	8
Fish								
Bairdiella chrysoura	Yes	0	0	0	0	3	3	6
Centropomus undecimalis	No							
Cynoscion nebulosus	Yes	5	3	3	3	5	5	24
Cypinodon variegatus	No							
Eucinostomus gula	No							
Floridichthys carpio	No							
Fundulus confluentus	No							
F. grandis	No							
Haemulon sciurus	Yes	0	0	0	0	3	3	6
H. plumieri	Yes	0	0	0	0	3	3	6
H. parra	Yes	0	0	0	0	3	3	6
Lagodon rhomboides	Yes	3	0	0	0	3	3	9
Lucania parva	Yes	0	0	0	0	3	0	3
Lutjanus griseus	Yes	0	0	0	0	3	3	6
Myteroperca microlepis	No							
Megalops atlanticus	No							
Mugil spp	Yes	3	0	0	0	3	3	9
Opsanus beta	Yes	0	0	0	0	0	0	0
Sphyraena barracuda	No							

Scoring System: 0 (Poor), Medium (3), Excellent (5)

Table D-3
Bio-indicator Ranking Matrix
Miami River - Government Cut Sub-Region

SPECIES	**Present in adequate numbers or distribution?**	**Sensitivity to Applicable Parameters**	**Reliability of Response**	**Rapidity of Response**	**Ease & Economy of Monitoring**	**Meaningful Feedback to Management**	**Importance of Endpoint**	**Total Score**
Plants								
Diatoms	Yes	4	4	5	3	3	1	20
Avicennia germinans	Yes	0	0	0	3	3	0	6
Cladium jamaicense	No							
Conocarpus erecta	No							
Distichlis spicata	No							
Eleocharis cellulosa	No							
Halophila decipiens	No							
Halophila englemanii	No							
Halophila johnsonii	Yes	0	0	0	3	3	3	9
Halodule wrightii	Yes	5	3	3	3	3	0	17
Juncus roemerianus	No							
Laguncularia racemosa	No							
Rhizophora mangle	Yes	0	0	0	3	3	0	6
Ruppia maritima	No							
Spartina spartinae	No							
Syringodium filiforme	Yes	3	3	0	3	3	0	12
Thalassia testudinum	Yes	3	3	0	3	3	0	12
ANIMALS								
Foraminiferans	Yes	4	4	5	3	3	1	20
Invertebrates								
Callinectes sapidus	Yes	5	3	3	1	3	1	16
Crassostrea virginica	No							
Farfantepenaeus duorarum	Yes	3	3	3	0	3	3	15
Limulus polyphemus	Yes	0	0	0	3	0	0	3
Menippe mercenaria	Yes	0	0	0	0	0	0	0
Vertebrates								
Mammals								
Trichechus manatus	Yes	3	0	3	3	3	0	12
Turciops truncatus	Yes	0	0	0	3	0	0	3

Scoring System: 0 (Poor), Medium (3), Excellent (5)

Table D-3
Bio-indicator Ranking Matrix
Miami River - Government Cut Sub-Region

SPECIES	Present in adequate numbers or distribution?	Sensitivity to Applicable Parameters	Reliability of Response	Rapidity of Response	Ease & Economy of Monitoring	Meaningful Feedback to Management	Importance of Endpoint	Total Score
Reptiles								
Crocodylus acutus	No							
Birds								
Ajaia ajaja	No							
Egretta caerulea	No							
Egretta rufescens	No							
Egretta thula	No							
Egretta tricolor	No							
Eudocimus alba	No							
Mycteria americana	No							
Pelicanus occidentalis	Yes	0	0	0	5	3	0	8
Fish								
Bairdiella chrysoura	Yes	0	0	0	0	3	3	6
Centropomus undecimalis	No							
Cynoscion nebulosus	Yes	0	0	0	3	0	0	3
Cypinodon variegatus	No							
Eucinostomus gula	No							
Floridichthys carpio	No							
Fundulus confluentus	No							
F. grandis	No							
Haemulon sciurus	Yes	0	0	0	0	3	0	3
H. plumieri	Yes	0	0	0	0	3	0	3
H. parra	Yes	0	0	0	0	3	0	3
Lagodon rhomboides	Yes	0	0	0	0	0	0	0
Lucania parva	Yes	0	0	0	0	0	0	0
Lutjanus griseus	Yes	3	0	0	3	3	3	12
Myteroperca microlepis	No							
Megalops atlanticus	No							
Mugil spp	Yes	3	0	0	3	3	3	12
Opsanus beta	Yes	0	0	0	0	0	0	0
Sphyraena barracuda	Yes	0	0	0	0	0	0	0

Scoring System: 0 (Poor), Medium (3), Excellent (5)

Table D-4
Bio-indicator Ranking Matrix
Central Biscayne Bay Sub-Region

SPECIES	Present in adequate numbers or distribution?	Sensitivity to Applicable Parameters	Reliability of Response	Rapidity of Response	Ease & Economy of Monitoring	Meaningful Feedback to Management	Importance of Endpoint	Total Score
Plants								
Diatoms	Yes	4	4	5	3	3	1	20
Avicennia germinans	Yes	0	0	0	3	3	0	6
Cladium jamaicense	Yes	3	0	0	3	0	0	6
Conocarpus erecta	Yes	0	0	0	0	0	0	0
Distichlis spicata	No							
Eleocharis cellulosa	Yes	5	5	5	3	3	5	26
Halophila decipiens	No							
Halophila englemanii	No							
Halophila johnsonii	No							
Halodule wrightii	Yes	5	5	5	3	5	5	28
Juncus roemerianus	No							
Laguncularia racemosa	Yes	0	0	0	3	3	0	6
Rhizophora mangle	Yes	0	0	0	3	3	0	6
Ruppia maritima	Yes	5	5	5	3	3	3	24
Spartina spartinae	No							
Syringodium filiforme	Yes	3	3	0	3	3	3	15
Thalassia testudinum	Yes	3	3	0	3	3	0	12
ANIMALS								
Foraminiferans	Yes	4	4	5	3	3	1	20
Invertebrates								
Callinectes sapidus	Yes	5	3	3	0	3	1	15
Crassostrea virginica	Yes	5	0	3	5	5	5	23
Farfantepenaeus duorarum	Yes	5	4	3	5	5	5	27
Limulus polyphemus	Yes	0	0	0	3	0	0	3
Menippe mercenaria	Yes	0	0	0	3	0	0	3
Vertebrates								
Mammals								
Trichechus manatus	Yes	3	0	3	3	3	0	12
Turciops truncatus	Yes	0	0	0	3	0	0	3

Scoring System: 0 (Poor), Medium (3), Excellent (5)

Table D-4
Bio-indicator Ranking Matrix
Central Biscayne Bay Sub-Region

SPECIES	Present in adequate numbers or distribution?	Sensitivity to Applicable Parameters	Reliability of Response	Rapidity of Response	Ease & Economy of Monitoring	Meaningful Feedback to Management	Importance of Endpoint	Total Score
Reptiles								
Crocodylus acutus	Yes	5	5	3	3	4	4	24
Birds								
Ajaia ajaja	Yes	0	0	0	5	3	2	10
Egretta caerulea	Yes	0	0	0	5	3	0	8
Egretta rufescens	No	0	0	0	5	3	0	8
Egretta thula	No	0	0	0	5	3	0	8
Egretta tricolor	No	0	0	0	5	3	0	8
Eudocimus alba	No	0	0	0	5	3	0	8
Mycteria americana	No							
Pelicanus occidentalis	Yes	0	0	0	5	3	0	8
Fish								
Bairdiella chrysoura	Yes	3	3	0	0	3	3	12
Centropomus undecimalis	Yes	5	5	3	0	5	3	21
Cynoscion nebulosus	Yes	3	3	0	0	3	3	12
Cypinodon variegatus	Yes	3	3	3	0	3	3	15
Eucinostomus gula	Yes	0	0	0	0	3	0	3
Floridichthys carpio	Yes	3	3	3	0	3	3	15
Fundulus confluentus	Yes	3	3	3	0	3	3	15
F. grandis	Yes	3	3	3	0	3	3	15
Haemulon sciurus	Yes	0	0	0	0	3	3	6
H. plumieri	Yes	0	0	0	0	3	3	6
H. parra	Yes	0	0	0	0	3	3	6
Lagodon rhomboides	Yes	0	0	0	0	3	3	6
Lucania parva	Yes	3	3	3	0	3	3	15
Lutjanus griseus	Yes	3	0	0	3	3	3	12
Myteroperca microlepis	Yes	3	0	3	0	3	3	12
Megalops atlanticus	Yes	5	5	3	0	3	3	19
Mugil spp	Yes	0	0	0	0	0	0	0
Opsanus beta	Yes	0	0	0	0	0	0	0
Sphyraena barracuda	Yes	0	0	0	0	0	0	0

Scoring System: 0 (Poor), Medium (3), Excellent (5)

Table D-5
Bio-indicator Ranking Matrix
South Central Biscayne Bay Sub-Region

SPECIES	Present in adequate numbers or distribution?	Sensitivity to Applicable Parameters	Reliability of Response	Rapidity of Response	Ease & Economy of Monitoring	Meaningful Feedback to Management	Importance of Endpoint	Total Score
Plants								
Diatoms	Yes	4	4	5	3	3	1	20
Avicennia germinans	Yes	0	0	0	3	3	0	6
Cladium jamaicense	Yes	3	0	0	3	0	0	6
Conocarpus erecta	Yes	0	0	0	0	0	0	0
Distichlis spicata	Yes	3	0	0	3	0	0	6
Eleocharis cellulosa	Yes	5	5	5	3	3	5	26
Halophila decipiens	Yes	0	0	0	0	0	0	0
Halophila englemanii	No							
Halophila johnsonii	No							
Halodule wrightii	Yes	5	5	5	3	5	5	28
Juncus roemerianus	Yes	5	3	3	3	5	5	24
Laguncularia racemosa	Yes	0	0	0	3	3	0	6
Rhizophora mangle	Yes	0	0	0	5	3	0	8
Ruppia maritima	Yes	5	5	5	3	3	3	24
Spartina spartinae	Yes	3	3	3	3	3	3	18
Syringodium filiforme	Yes	3	3	0	3	3	3	15
Thalassia testudinum	Yes	3	3	0	3	3	0	12
ANIMALS								
Foraminiferans	Yes	4	4	5	3	3	1	20
Invertebrates								
Callinectes sapidus	Yes	5	3	3	0	3	1	15
Crassostrea virginica	Yes	5	0	3	5	5	5	23
Farfantepenaeus duorarum	Yes	5	4	3	5	5	5	27
Limulus polyphemus	Yes	0	0	0	3	0	0	3
Menippe mercenaria	Yes	0	0	0	3	0	0	3
Vertebrates								
Mammals								
Trichechus manatus	Yes	3	0	3	3	3	0	12
Turciops truncatus	Yes	0	0	0	3	0	0	3

Scoring System: 0 (Poor), Medium (3), Excellent (5)

Table D-5
Bio-indicator Ranking Matrix
South Central Biscayne Bay Sub-Region

SPECIES	Present in adequate numbers or distribution?	Sensitivity to Applicable Parameters	Reliability of Response	Rapidity of Response	Ease & Economy of Monitoring	Meaningful Feedback to Management	Importance of Endpoint	Total Score
Reptiles								
Crocodylus acutus	Yes	5	5	3	3	4	4	24
Birds								
Ajaia ajaja	Yes	5	5	3	3	3	3	22
Egretta caerulea	Yes	2	5	3	0	3	3	16
Egretta rufescens	Yes	2	5	3	0	3	3	16
Egretta thula	Yes	2	5	3	0	3	3	16
Egretta tricolor	Yes	2	5	3	0	3	3	16
Eudocimus alba	Yes	2	3	3	0	3	3	14
Mycteria americana	Yes	2	4	3	3	3	3	18
Pelicanus occidentalis	Yes	0	0	0	3	3	0	6
Fish								
Bairdiella chrysoura	Yes	3	3	0	0	3	3	12
Centropomus undecimalis	Yes	5	5	3	0	5	3	21
Cynoscion nebulosus	Yes	3	3	0	0	3	3	12
Cypinodon variegatus	Yes	3	3	3	0	3	3	15
Eucinostomus gula	Yes	0	0	0	0	3	3	6
Floridichthys carpio	Yes	3	3	3	0	3	3	15
Fundulus confluentus	Yes	3	3	3	0	3	3	15
F. grandis	Yes	3	3	3	0	3	3	15
Haemulon sciurus	Yes	0	0	0	0	3	3	6
H. plumieri	Yes	0	0	0	0	3	3	6
H. parra	Yes	0	0	0	0	3	3	6
Lagodon rhomboides	Yes	0	0	0	0	3	3	6
Lucania parva	Yes	3	3	3	0	3	3	15
Lutjanus griseus	Yes	3	0	0	3	3	3	12
Myteroperca microlepis	Yes	3	0	0	3	3	3	12
Megalops atlanticus	Yes	5	5	3	0	3	3	19
Mugil spp	Yes	0	0	0	0	0	0	0
Opsanus beta	Yes	0	0	0	0	0	0	0
Sphyraena barracuda	Yes	0	0	0	0	0	0	0

Scoring System: 0 (Poor), Medium (3), Excellent (5)

Table D-6
Bio-indicator Ranking Matrix
Southern Sub-Region

SPECIES	Present in adequate numbers or distribution?	Sensitivity to Applicable Parameters	Reliability of Response	Rapidity of Response	Ease & Economy of Monitoring	Meaningful Feedback to Management	Importance of Endpoint	Total Score
Plants								
Diatoms	Yes	4	4	5	3	3	1	20
Avicennia germinans	Yes	0	0	0	3	3	0	6
Cladium jamaicense	Yes	3	3	3	3	3	3	18
Conocarpus erecta	Yes	0	0	0	0	0	0	0
Distichlis spicata	Yes	3	3	3	0	0	0	9
Eleocharis cellulosa	Yes	5	5	3	3	5	3	24
Halophila decipiens	Yes	0	0	0	0	0	0	0
Halophila englemanii	No							
Halophila johnsonii	No							
Halodule wrightii	Yes	5	5	5	0	3	0	18
Juncus roemerianus	Yes	5	5	3	3	5	3	24
Laguncularia racemosa	Yes	0	0	0	3	3	0	6
Rhizophora mangle	Yes	0	0	0	3	3	0	6
Ruppia maritima	Yes	3	3	3	3	3	3	18
Spartina spartinae	Yes	5	5	3	3	5	3	24
Syringodium filiforme	Yes	3	3	0	3	3	3	15
Thalassia testudinum	Yes	3	3	0	3	3	0	12
ANIMALS								
Foraminiferans	Yes	4	4	5	3	3	1	20
Invertebrates								
Callinectes sapidus	Yes	3	3	3	0	3	1	13
Crassostrea virginica	No							
Farfantepenaeus duorarum	Yes	3	3	0	0	0	0	6
Limulus polyphemus	Yes	3	3	0	0	0	0	6
Menippe mercenaria	Yes	3	3	0	0	0	0	6
Vertebrates								
Mammals								
Trichechus manatus	Yes	3	0	3	3	3	0	12
Turciops truncatus	Yes	0	0	0	3	0	0	3

Scoring System: 0 (Poor), Medium (3), Excellent (5)

Table D-6
Bio-indicator Ranking Matrix
Southern Sub-Region

SPECIES	Present in adequate numbers or distribution?	Sensitivity to Applicable Parameters	Reliability of Response	Rapidity of Response	Ease & Economy of Monitoring	Meaningful Feedback to Management	Importance of Endpoint	Total Score
Reptiles								
Crocodylus acutus	Yes	5	5	4	4	5	5	28
Birds								
Ajaia ajaja	Yes	5	5	4	4	5	5	28
Egretta caerulea	Yes	2	4	3	0	3	3	15
Egretta rufescens	Yes	2	4	3	0	3	3	15
Egretta thula	Yes	2	4	3	0	3	3	15
Egretta tricolor	Yes	2	4	3	0	3	3	15
Eudocimus alba	Yes	2	4	3	0	3	3	15
Mycteria americana	Yes	2	4	3	3	3	3	18
Pelicanus occidentalis	Yes	0	0	0	3	3	0	6
Fish								
Bairdiella chrysoura	Yes	3	3	0	0	0	0	6
Centropomus undecimalis	No							
Cynoscion nebulosus	Yes	3	3	0	0	0	0	6
Cypinodon variegatus	Yes	5	5	3	3	5	4	25
Eucinostomus gula	Yes	0	0	0	0	3	3	6
Floridichthys carpio	Yes	5	3	3	3	5	4	23
Fundulus confluentus	Yes	5	3	3	3	5	4	23
F. grandis	Yes	5	3	3	3	5	4	23
Haemulon sciurus	Yes	0	0	0	0	3	3	6
H. plumieri	Yes	0	0	0	0	3	3	6
H. parra	Yes	0	0	0	0	3	3	6
Lagodon rhomboides	Yes	3	0	0	0	3	3	9
Lucania parva	Yes	5	5	3	3	5	4	25
Lutjanus griseus	Yes	3	0	0	3	3	3	12
Myteroperca microlepis	Yes	3	0	0	3	3	3	12
Megalops atlanticus	No							
Mugil spp	Yes	0	0	0	0	0	0	0
Opsanus beta	Yes	0	0	0	0	0	0	0
Sphyraena barracuda	Yes	0	0	0	0	0	0	0

Scoring System: 0 (Poor), Medium (3), Excellent (5)

APPENDIX E

TABLES OF
ADVANTAGES & DISADVANTAGES
OF DIFFERENT MFL APPROACHES
BY SUB-REGIONS

Table E-1
Advantages and Disadvantages of Different MFL Approaches for Biscayne Bay
Oleta River / Snake Creek Sub-region

POTENTIAL APPROACHES	STRENGTHS & Score (0 - no strengths, 5 = strong)		WEAKNESSES & Score (0 = Very weak, 5 = few weaknesses)		OPPORTUNITIES & Score (0 = creates numerous problems; 5 = creates few problems)		THREATS & Score (0 = large # of threats, 5= few)		SPEED OF ADAPTIVE MGMT (Slow (0), Medium (3) , Fast (5))		FEASIBILITY OF COST-EFFECTIVE PERFORMANCE STANDARDS (Very costly (0), Comparatively inexpensive (5))		APPROACH SCORE (Cumulative Total)
Valued Ecosystem Component (Oysters, Manatees and Johnson's seagrass)	Oyster resources are easily quantifiable High public visitation at State Park Designated critical habitat for manatees and Johnson's seagrass	3	Potential difficulties in relating population declines to reductions of fresh water flow Little public interest in *H. johnsonii*	2	Develop enhanced understanding of distribution of H. johnsonii Enhanced knowledge of H. johnsonii could cause permitting problems	3	Population declines may be unrelated to reductions in freshwater flow	2	Medium	3	Yes - Data already being compiled	5	18
Indicator Species (Oysters, Manatees & Johnson's seagrass)	Relatively easy to ID Significant Harm A lot of scientific work already done Designated critical habitat for manatees and Johnson's seagrass	5	Potential difficulties in relating population declines to reductions of fresh water flow Oysters not currently abundant Difficulty in monitoring minimal changes	3	Critical habitat already designated Would require add'l mapping and/or monitoring of oysters	3	Future reductions in Manatee presence may not be related to diminishing fresh water flows	3	Medium	3	Yes - Data already being compiled	5	22
Presence/Absence/Vitality of Preferred Habitats	If salinities are correct for oysters and sea grasses, conditions will be suitable for numerous other species	4	Existing oyster habitat is presently limited to riverine portions of waterways Little suitable habitat for Johnson's seagrass Mangrove community tolerant of varying S%	2	Public acceptance fairly high for manatees and oysters	3	Difficult to quantify "vitality" of Johnson's seagrass	4	Medium	3	Yes - Data already being compiled	1	17
Ecological Preservation	Would prevent continued degradation	3	Existing condition is severely degraded, but Significant Harm not yet reached Would maintain existing degraded condition	3	Add'l restrictions to maintain current status would not likely receive public acceptance	2	Additional restrictions to protect manatees are often highly controversial General ineffectiveness of existing regulatory programs	2	Medium	3	Yes - Data already being compiled	1	14
Pre-development Scenario	Historic mangrove shorelines would be recreated	1	Likely significant public opposition	1	Closing of Haulover Inlet and replacement of seawalls with mangroves not feasible	1	Likley significant public opposition	1	Slow	1	Restoration to pre-development conditions would be too expensive and not likely politically viable	1	6
Requirement for preferred fish communities	Would recreate viable fishery where none presently exists	5	Recreational fishing is popular, but most fishers do not understand fish life cycles Would involve restoration of mangrove and seagrass habitats	1	Public acceptance	1	Lack of scientific base to work from	2	Medium	3	Expensive and long term	2	14
Community Index	Common scientific tool	2	Not developed for Biscayne Bay	1	May be useful with much further study	3	Not understandable as real	1	Medium	3	Expensive and long term	2	12
Food Web Support	Common scientific tool	1	Not developed for Biscayne Bay	1	May be useful with much further study	2	Impacts from acts of nature (e.g., hurricanes)	4	Medium	3	Very expensive and long term	1	12
Soil Characteristics	Relatively easy to monitor	3	Not connected to salinity changes alone Only applicable upstream in riverine areas	1	Would require add'l approach for open-water areas	1	Adverse impacts from non-salinity water quality parameters	3	Slow	1	Inexpensive, but difficult to interpret	3	12

Table E-2
Advantages and Disadvantages of Different MFL Approaches for Biscayne Bay
Northern Biscayne Bay Sub-region

POTENTIAL APPROACHES	STRENGTHS & Score (0 - no strengths, 5 = strong)		WEAKNESSES & Score (0 = Very weak, 5 = few weaknesses)		OPPORTUNITIES & Score (0 = creates numerous problems; 5 = creates few problems)		THREATS & Score (0 = large # of threats, 5= few)		SPEED OF ADAPTIVE MGMT (Slow (0), Medium (3) , Fast (5))		FEASIBILITY OF COST-EFFECTIVE PERFORMANCE STANDARDS (Very costly (0), Comparatively inexpensive (5)		APPROACH SCORE (Cumulative Total)
Valued Ecosystem Component (Seatrout, Manatees and Johnson's Seagrass and Manatee grass)	Seatrout & manatees have public appeal; Reasonably good existing database; Designated critical habitat for manatees and Johnson's seagrass	5	Potential difficulties in relating population declines to reductions of fresh water flow; Little public interest in Johnson's Seagrass	2	Enhanced knowledge of H. johnsonii could cause permitting problems	3	Population declines may be unrelated to reductions in freshwater flow; Reductions in indicator species may not be related to diminishing fresh water flows	2	Medium	3	Yes - Some data already being compiled	3	18
Indicator Species (Seatrout & manatee grass)	Relatively easy to ID Significant Harm; A lot of scientific work already done	5	Potential difficulties in relating population declines to reductions of fresh water flow; Seatout not currently abundant; Difficulty in monitoring minimal changes	3	Critical habitat already designated; Would require more intensive monitoring of fish catches and seagrass mapping	3	Future reductions in seatorut and manatee gras presence may not be related to diminishing fresh water flows	3	Medium	3	Yes - Data already being compiled	5	22
Presence/Absence/Vitality of Preferred Habitats	If salinities are correct for seatrout and manatee grass, conditions will be suitable for numerous other species	4	Existing conditions are highly variable; Few shoreline mangroves	2	Public acceptance fairly high for seatrout and seagrasses	3	Difficult to quantify "vitality" of seagrasses; Pubic opposition to more detailed fishery monitoring	4	Medium	3	Yes - Data already being compiled	1	17
Ecological Preservation	Would prevent continued degradation	3	Existing condition is somewhat degraded, but Significant Harm not yet reached; Would maintain existing depauperate fishery	3	Add'l restrictions to maintain current status would not likely receive public acceptance	2	Additional restrictions to protect seagrasses are often highly controversial; General ineffectiveness of existing regulatory programs	2	Medium	3	Yes - Data already being compiled	1	14
Pre-development Scenario	Historic mangrove shorelines would be recreated	1	Likely significant public opposition	1	Replacement of seawalls with mangroves not feasible	1	Likley significant public opposition	1	Slow	1	Restoration to pre-development conditions would be too expensive and not likely politically viable	1	6
Requirement for preferred fish communities	Would maintain a viable fishery	5	Recreational fishing is popular, but most fishers do not understand fish life cycles; Would involve restoration of mangrove shorelines and seagrass habitats	1	Public acceptance	2	Lack of scientific base to work from	2	Medium	3	Expensive and long term	2	15
Community Index	Common scientific tool	2	Not developed for Biscayne Bay	1	May be useful with much further study	3	Not understandable as real	1	Medium	3	Expensive and long term	2	12
Food Web Support	Common scientific tool	1	Not developed for Biscayne Bay; Would require additional shorline vegetation	1	May be useful with much further study	2	Impacts from acts of nature (e.g., hurricanes)	4	Medium	3	Very expensive and long term	1	12
Soil Characteristics	Relatively easy to monitor	3	No soils present; Nearly entire shoreline bulkheaded	1	Would require add'l approach for open-water areas	1	Adverse impacts from non-salinity water quality parameters	3	Slow	1	Inexpensive, but difficult to interpret	3	12

Table E-3
Advantages and Disadvantages of Different MFL Approaches for Biscayne Bay
Miami River - Government Cut Sub-region

POTENTIAL APPROACHES	STRENGTHS & Score (0 - no strengths, 5 = strong)		WEAKNESSES & Score (0 = Very weak, 5 = few weaknesses)		OPPORTUNITIES & Score (0 = creates numerous problems; 5 = creates few problems)		THREATS & Score (0 = large # of threats, 5= few)		SPEED OF ADAPTIVE MGMT (Slow (0), Medium (3) , Fast (5))		FEASIBILITY OF COST-EFFECTIVE PERFORMANCE STANDARDS (Very costly (0), Comparatively inexpensive (5)		APPROACH SCORE (Cumulative Total)
Valued Ecosystem Component (Manatees and Johnson's Seagrass)	Manatees have high public appeal Reasonably good existing database Designated critical habitat for manatees and Johnson's seagrass	4	Potential difficulties in relating population declines to reductions of fresh water flow Healthy environment in this area is less important than sustaining the economy	2	Enhanced awareness of H. johnsonii could cause permitting problems Removal & disposal of sediments from River is problematic	2	Population declines may be unrelated to reductions in freshwater flow Reductions in indicator species may not be related to diminishing fresh water flows	2	Medium	3	Yes - Some data already being compiled	3	16
Indicator Species (Manatees and Johnson's Seagrass)	Somewhat easy to ID Significant Harm A lot of scientific work already done	3	Potential difficulties in relating population declines to reductions of fresh water flow Target population exceedingly small Difficulty in monitoring minimal changes	2	Critical habitat already designated Would require more intensive seagrass mapping and monitoring	2	Future reductions in Johnson's seagrass presence may not be related to diminishing fresh water flows	3	Somewhat Slow	2	Some data already being compiled	3	15
Presence/Absence/Vitality of Preferred Habitats	If salinities are correct for seagrasses, conditions will be suitable for numerous other species High levels of biodiversity	4	Existing conditions are highly variable due to unnaturally high tidal exchange	2	Public acceptance fairly high for fisheries habitat Creating estuarine conditions would require substantive infrastructure changes	3	Little public support likely	4	Medium	3	Yes - Data already being compiled	1	17
Ecological Preservation	Would prevent continued degradation	2	Existing condition is in Significant Harm Estuarine conditions currently absent Would maintain existing degraded condition	1	Add'l restrictions to maintain current status would not likely receive public acceptance	1	Additional restrictions to protect seagrasses are often highly controversial General ineffectiveness of existing regulatory programs	2	Slow	1	Yes - Data already being compiled	1	8
Pre-development Scenario	Historic mangrove shorelines would be recreated	1	Likely significant public opposition Economy viewed as more important than ecological conditions in this sub-region	1	Replacement of seawalls with mangroves not feasible	1	Significant public opposition likely	0	Slow	1	Restoration to pre-development conditions would be too expensive and not likely politically viable	1	5
Requirement for preferred fish communities	Would increase biodiversity by est-ablishing an estuarine condition	3	Recreational fishing is not important in Miami River Would require restoration of mangrove shorelines and seagrass habitats	1	Public acceptance would likely be low for replacing seawalls with shoreline vegetation	2	No public support - Area is the only major seaport in region	2	Slow	2	Very expensive and long term Likely politically unpopular	1	11
Community Index	Common scientific tool	2	Not developed for Biscayne Bay, but biodiversity	3	May be useful with further study	3	Biodiversity is a generally accepted "good thing"	3	Existing data base allows fast response	5	On going sampling programs could be a	4	20
Food Web Support	Common scientific tool	1	Not developed for Biscayne Bay Would require changing shoreline from bulkhead to vegetation	1	Would cause adverse impacts on existing industry	1	Toxins and heavy metals known to be pres-ent in sediments Impacts from acts of nature (e.g., hurricanes)	1	Slow	1	Very expensive and long term Likely politically unpopular	0	5
Soil Characteristics	Relatively easy to monitor	3	No soils present Entire shoreline bulkheaded	0	Would require add'l approach for open-water areas	1	Adverse impacts from non-salinity water quality parameters May reveal additional contaminated soils	1	Slow	1	Inexpensive, but difficult to inter-pret	0	6

Table E-4
Advantages and Disadvantages of Different MFL Approaches for Biscayne Bay
Central Sub-region

POTENTIAL APPROACHES	STRENGTHS & Score (0 - no strengths, 5 = strong)		WEAKNESSES & Score (0 = Very weak, 5 = few weaknesses)		OPPORTUNITIES & Score (0 = creates numerous problems; 5 = creates few problems)		THREATS & Score (0 = large # of threats, 5= few)		SPEED OF ADAPTIVE MGMT (Slow (0), Medium (3) , Fast (5))		FEASIBILITY OF COST-EFFECTIVE PERFORMANCE STANDARDS (Very costly (0), Comparatively inexpensive (5)		APPROACH SCORE (Cumulative Total)
Valued Ecosystem Components (Sustainable shrimp fishery, some shoalgrass, Manatees & Johnsons Seagrass N. of 27^0 45' N Latitude)	Easily quantifiable Public can relate	5	Difficulty in relating pop. declines to flow Confounding impacts re commercial harvest Would require monitoring 3 different comp-onents	3	Popular commercially harvested species used by recreational fishermen	4	Population declines may be unrelated to reductions in freshwater flow Increase in awareness of Johnson's seagrass could result in permitting problems	2	Medium	3	Yes - Data already being compiled	5	22
Indicator Species (Pink Shrimp and Shoal grass)	Relatively easy to ID Significant Harm A lot of scientific work already done	4	Pink shrimp annual recruitment Difficulty in monitoring minimal changes Impacts of commercial harvest unknown	3	Previously id'd in conceptual model	4	Suitability of unvegetated sediments for colonization by shoal grass unknown May require controls on commercial harvest of sh	3	Medium	3	Yes - Data already being compiled	5	22
Presence/Absence/Vitality of Preferred Habitats	Sounds good to the public	4	Preferred habitats is a 'fuzzy' concept - to many people, estuarine species may be less desirable than marine species in this part of the bay Heterogeneous habitats	2	Public acceptance	3	Difficult to quantify "vitality"	1	Fairly Slow	1	Expensive and long term	1	12
Ecological Preservation	Portions of Sub-region are presently in a condition of Significant Harm	2	Conceptually, "preserving the Bay" would be popular with the public, but preservation would likely involve maintaining degraded habitats	3	Public acceptance	3	The situation would only get worse with time	1	Fast	5	Inexpensive but not legal	1	15
Pre-development Scenario	CERP & other restoration projects have already been identified	1	There is general agreement that returning to anything close to predevelopment water flows is not likely	1	Few	1	Reduction in current legal uses of water	1	Slow	0	Restoration to pre-development conditions would be too expensive and not likely politically viable	1	5
Requirement for preferred fish communities	The preferred fish community based up-on harvests is reefs, not generally sensitive to freshwater flows in this area	1	Recreationally fishing is popular, but most fisherman do not understand fish life histories	1	Public acceptance	1	Lack of scientific base to work from	2	Medium	3	Expensive and long term	2	10
Community Index	Common scientific tool	2	Not developed for Biscayne Bay	1	May be useful with much further study	3	Not understandable as real	1	Medium	3	Expensive and long term	2	12
Food Web Support	Common scientific tool	1	Not developed for Biscayne Bay	1	May be useful with much further study	2	Impacts from acts of nature (e.g., hurricanes)	4	Medium	3	Very expensive and long term	1	12
Soil Characteristics	Easy to monitor	3	Not connected to salinity changes alone Only applicable west of shoreline	1	Would require add'l approach for open-water areas	1	Adverse impacts from non-salinity water quality parameters	3	Slow	1	Inexpensive, but difficult to inter-pret	3	12

Table E-5
Advantages and Disadvantages of Different MFL Approaches for Biscayne Bay
South-Central Sub-region

POTENTIAL APPROACHES	STRENGTHS & Score (0 - no strengths, 5 = strong)		WEAKNESSES & Score (0 = Very weak, 5 = few weaknesses)		OPPORTUNITIES & Score (0 = creates numerous problems; 5 = creates few problems)		THREATS & Score (0 = large # of threats, 5= few)		SPEED OF ADAPTIVE MGMT (Slow (0), Medium (3) , Fast (5))		FEASIBILITY OF COST-EFFECTIVE PERFORMANCE STANDARDS (Very costly (0), Comparatively inexpensive (5))		APPROACH SCORE (Cumulative Total)
Valued Ecosystem Component (Sustainable shrimp fishery)	Easily quantifiable Public can relate	5	Difficulty in relating pop. declines to flow Confounding impacts re commercial harvest	3	Popular commercially harvested species used by recreational fishermen	4	Population declines may be unrelated to reductions in freshwater flow	2	Medium	3	Yes - Data already being compiled	5	22
Indicator Species (Pink Shrimp & Shoal grass)	Relatively easy to ID Significant Harm A lot of scientific work already done	4	Pink shrimp annual recruitment Difficulty in monitoring minimal changes Impacts of commercial harvest unknown	2	Previously id'd in conceptual model	4	Suitability of unvegetated sediments for colonization by shoal grass unknown May require controls on commercial harvest of sh	3	Medium	3	Yes - Data already being compiled	5	21
Presence/Absence/Vitality of Preferred Habitats	Sounds good to the public	4	Preferred habitats is a fuzzy concept -for what sp Heterogeneous habitats	2	Public acceptance	3	Difficult to quantify "vitality"	1	Fairly Slow	1	Expensive and long term	1	12
Ecological Preservation	Existing condition is in Significant Harm	1	Conceptually, "preserving the Bay" would be popular with the public	4	Public acceptance	3	The situation would only get worse with time	1	Fast	5	Inexpensive but not legal	1	15
Pre-development Scenario	CERP & other restoration projects have already been identified	1	There is general agreement that returning to anything close to predevelopment water flows is not likely	1	Few	1	Reduction in current legal uses of water	1	Slow	0	Restoration to pre-development conditions would be too expensive and not likely politically viable	1	5
Requirement for preferred fish communities	The preferred fish community based up-on harvests is reefs, not generally sensitive to freshwater flows in this area	1	Recreationally fishing is popular, but most fisherman do not understand fish life histories	1	Public acceptance	1	Lack of scientific base to work from	2	Medium	3	Expensive and long term	2	10
Community Index	Common scientific tool	2	Not developed for Biscayne Bay	1	May be useful with much further study	3	Not understandable as real	1	Medium	3	Expensive and long term	2	12
Food Web Support	Common scientific tool	1	Not developed for Biscayne Bay	1	May be useful with much further study	2	Impacts from acts of nature (e.g., hurricanes)	4	Medium	3	Very expensive and long term	1	12
Soil Characteristics	Easy to monitor	3	Not connected to salinity changes alone Only applicable west of shoreline	1	Would require add'l approach for open-water areas	1	Adverse impacts from non-salinity water quality parameters	3	Slow	1	Inexpensive, but difficult to inter-pret	3	12

Table E-6
Advantages and Disadvantages of Different MFL Approaches for Biscayne Bay
Southern Sub-region

POTENTIAL APPROACHES	STRENGTHS & Score (0 - no strengths, 5 = strong)		WEAKNESSES & Score (0 = Very weak, 5 = few weaknesses)		OPPORTUNITIES & Score (0 = creates numerous problems; 5 = creates few problems)		THREATS & Score (0 = large # of threats, 5 = few)		SPEED OF ADAPTIVE MGMT (Slow (0), Medium (3) , Fast (5))		FEASIBILITY OF COST-EFFECTIVE PERFORMANCE STANDARDS (Very costly (0), Comparatively inexpensive (5)		APPROACH SCORE (Cumulative Total)
Valued Ecosystem Component (Crocodiles and Roseate Spoonbills)	Easily quantifiable In general, the public can relate	4	Possible difficulty in relating pop. Declines to reductions in freshwater flow Would require monitoring 3 different components	2	Would largely disregard conditions in open-water areas CERP may also address	3	Population declines may be unrelated to reductions in freshwater flow Impacts from acts of nature (e.g., hurricanes)	2	Slow	1	Some data already being compiled	4	16
Indicator Species (Crocodiles and Roseate Spoonbills)	Comparatively easy to monitor and to ID Significant Harm In general, the public can relate A lot of scientific work already done	4	Nesting success not necessarily tied to changes in salinity Impacts of commercial harvest unknown	2	Previously id'd in conceptual model CERP may also address	3	Suitability of unvegetated sediments for colonization by shoal grass unknown Impacts from acts of nature (e.g., hurricanes)	2	Slow	1	Some data already being compiled	4	16
Presence/Absence/Vitality of Preferred Habitats	Sounds good to the public Improvements west of shoreline may have positive effects on open-water areas	4	Preferred habitats is a 'fuzzy' concept - to many people, estuarine species may be less desirable than marine species Heterogeneous habitats	2	Public acceptance	4	Difficult to quantify "vitality" Impacts from acts of nature (e.g., hurricanes)	1	Fairly Slow	1	Expensive and long term	1	13
Ecological Preservation	Portions of Sub-region are presently in a condition of Significant Harm	2	Conceptually, "preserving the Bay" would be popular with the public, but preservation would likely involve maintaining degraded habitats	3	Public acceptance	3	The situation would only get worse with time	1	Fast	5	Inexpensive but not legal	1	15
Pre-development Scenario	CERP & other restoration projects have already been identified to address existing deteriorated condition	1	There is general agreement that returning to anything close to predevelopment water flows is not likely	1	Few	1	Reduction in current legal uses of water	1	Slow	0	Restoration to pre-development conditions would be too expensive and not likely politically viable	1	5
Requirement for preferred fish communities	The preferred fish community based upon harvests is reefs, not generally sensitive to freshwater flows in this area	1	Recreationally fishing is popular, but most fisherman do not understand fish life histories	1	Public acceptance	1	Lack of scientific base to work from	2	Medium	3	Expensive and long term	2	10
Community Index	Common scientific tool	2	Not developed for Biscayne Bay	1	May be useful with much further study	3	Not understandable as real	1	Medium	3	Expensive and long term	2	12
Food Web Support	Common scientific tool salinity and productivity of	5	Not developed for Biscayne Bay Indirect linkages largely unknown	3	Would be more useful with little further study, L-31E restoration and careful monitoring should provide data	5	Impacts from acts of nature (e.g., hurricanes)	4	Fast	5	Comparatively low cost on a per acre o	4	26
Soil Characteristics	Comparatively easy to monitor	3	Not connected to salinity changes alone Only applicable west of shoreline	1	Would require add'l approach for open-water areas	1	Adverse impacts from non-salinity water quality parameters	3	Slow	1	Inexpensive, but difficult to interpret	3	12