The Strategic Science Plan for Florida Bay

Prepared by the Program Management Committee

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EXECUTIVE SUMMARY

Since 1997, the Florida Bay and Adjacent Marine Systems (FBAMS) Science Program has been organized around five central questions that directed efforts at identifying the basic structure of the Florida Bay ecosystem and the underlying causes of specific changes. These changes occurred in response to stressors, some local but others distant and outside of Florida Bay. One important external stressor was upstream water management.

The Strategic Science Plan for Florida Bay (2004) builds on these efforts by 'moving the existing science forward' to a more predictive state in order to help guide restoration planning and implementation and satisfy individual agency responsibilities (e.g., natural resource management).

To function in a predictive capacity, the FBAMS Science Program will emphasize those activities that yield information which refines understanding of critical linkages expressed in regional conceptual ecological models, improves definition of restoration targets, and assists in developing, calibrating and validating the numerical or statistical models used to make system predictions. This emphasis is consistent with the "ecosystem approach to management"[1] as recommended by the Science Coordination Group to the South Florida Ecosystem Restoration Task Force.

Program Profile

Name:
Florida Bay and Adjacent Marine Systems Science Program

Details:
- Initiated in 1993 in response to public concerns regarding changes in Florida Bay
- Comprises research, monitoring, and modeling activities conducted and/or funded by cooperating federal and state agencies
- Includes independent expert scientific review
- Guided by a strategic science plan
- Coordinated through an interagency Program Management Committee

Mission:
- Generate science for restoration and natural resource management
- Advance basic understanding of the Florida Bay ecosystem
- Facilitate efficient exchange of scientific information

Given the needs to evolve with and respond to new demands from the implementation of restoration, specific science priorities (i.e., needs) have been identified and organized by theme. These include Physical Processes, Water Quality, Benthic Habitats, Higher Trophic Levels, and the Mangrove-Estuarine Transition Zone. Each theme is then organized into two sets of questions (Section 3.0). The first addresses restoration modeling needs and the second addresses other science needs. Where possible, the questions include specific associated tasks or projects.

[1] An *ecosystem approach to management* is management that is adaptive, geographically specified, takes account of ecosystem knowledge and uncertainties, considers multiple external influences, and strives to balance diverse societal objectives (NOAA 2004).

Science Priorities - Themes

Physical Processes. To date, research and monitoring of physical processes has encompassed all major physical driving forces (i.e., winds and storms, precipitation, evaporation, surface water inflow, groundwater, sea level and tides, and boundary currents) and the hydrodynamic character of Florida Bay (i.e., varying salinity and circulation patterns, and exchanges with adjacent waters). Although considerable data exist on each of these processes, more work remains to fully characterize their relative importance and variability, particularly in the case of groundwater inputs and evaporation for which available estimates vary over a significant range of values. The degree to which these processes need to be better defined will be determined by the needs of the suite of hydrological and hydrodynamic models used to predict bay salinity and circulation patterns. The same can be said for improved measurements of such hydrodynamic characteristics as bathymetry and flow across the extensive mud banks that divide the inner portion of Florida Bay. The sufficiency of the physical models will have to be assessed in light of the requirements of the numeric and statistical water quality and ecological models and improved or modified if necessary. Furthermore, to the degree that predictions of rapid local sea level rise can be verified, the relationship between sea level and bay flushing processes will need to be better understood given the multi-decadal time span of the CERP implementation.

Water Quality. Water quality has been shown to have substantial ecological consequence and be related to upstream water management and human development. The foremost need regarding water quality is to accurately predict the sensitivity of Florida Bay's nutrient regime and phytoplankton to changes in freshwater flow into the bay. For much of the bay, any factor that increases P availability either by increasing sources or decreasing removal would likely have substantial effects. The effects of increased nitrogen, potentially introduced as DON from the Everglades, are uncertain. Alteration of contaminant exposures is also possible with changes in the sources of water introduced into the bay. In general, a more thorough understanding of the bay's nutrient cycles is critical to making predictions and evaluating restoration alternatives.

Benthic Habitats. Seagrass and hardbottom habitats account for a large portion of primary production, provide food and/or shelter to many organisms, and are critical to the ecological function of Florida Bay. These habitats strongly influence water quality and have themselves been affected by freshwater inflow and water quality changes attributable to upstream water management practices. Research has yet to address critical metabolic and community responses to sediment characteristics, water temperature, salinity, and light levels.

Higher Trophic Levels. Advances in understanding higher trophic level responses to restoration require an interdisciplinary approach with input from all the other science themes. For instance, the basic question of "how do changes in stressors affecting the bay affect pathways of higher trophic species' movement within and between FBAMS" requires information from physical processes, water quality, benthic habitats and the mangrove-estuarine transition zone. As many higher trophic level species initially settle in seagrass, hardbottom and mangrove communities, we cannot predict the impact of various stressors on their recruitment without understanding the impact of stressors on juvenile habitat. These nursery areas need to be delineated so that the potential effect of water management changes on salinity patterns, nutrient inputs, seagrass community structure and other conditions in these areas can be predicted. For some species such as gray snapper and sea trout, these nursery areas are within the Florida Bay geographic scope. However, other sought-after gamefish species such as red drum, snook, tarpon and bonefish are found in Florida Bay as pre-adults and adults, but the current nursery grounds of most of their populations are not delineated and are likely located outside of Florida Bay. Linking the higher trophic level theme to the other themes will require complete GIS integration data layers as they become available including salinity, fresh-water flows, benthic communities, and habitat structure and appropriate species distribution and abundance patterns.

Mangrove-Estuarine Transition Zone. The Florida Bay mangrove-estuarine transition zone has many important ecological attributes, many of which have been affected by altered freshwater inflow from upstream water management practices. Some of these attributes will likely be affected by restoration activities and respond more quickly than the same attributes within Florida Bay.

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Primary Role:
To establish direction and priorities for science activities

Details:
- Voluntary interagency committee
- Initiated in 1993, approved by SFERTF in 1994
- Coordinates and supports scientific research, monitoring, and modeling activities
- Lacks mandate in law or regulation
- Operates without an integrated program budget

Participating Agencies:
- Florida Department of Environmental Protection
- Florida Fish and Wildlife Conservation Commission
- Miami-Dade Department of Environmental Resources Management
- South Florida Water Management District
- National Oceanic and Atmospheric Administration
- National Park Service
- U.S. Army Corps of Engineers
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service
- U.S. Geological Survey

The Program Management Committee (PMC) recognizes the need for integration across ecosystem type and region to answer restoration and natural resource management questions. Thus, every effort will be made to ensure that PMC supported physical modeling activities will address ecological and water quality modeling needs and water quality modeling will be sufficient for ecological uses and other cross-disciplinary requirements.

The PMC will also continue to rely upon many of the same organizational elements that have been responsible for the program's success. These include a standing Science Oversight Panel, topical workshops, science conferences, and technical contributions from the local scientific community. However, given the present funding climate and constraints of PMC agencies, it will not be possible to maintain active science teams at this time. Should support become available, the PMC intends to reinitiate theme-based science teams, including an additional model integration team.

LIST OF ACRONYMS

BNP	Biscayne National Park
BRD	Biological Research Division
CERP	Comprehensive Everglades Restoration Plan
CSOP	Combined Structural and Operational Plan
DERM	Department of Environmental Resources Management
ENP	Everglades National Park
EPA	Environmental Protection Agency (U.S.)
FBAMS	Florida Bay and Adjacent Marine Systems
FBFKFS	Florida Bay/Florida Keys Feasibility Study
FDEP	Florida Department of Environmental Protection
FKNMS	Florida Keys National Marine Sanctuary
FWC	Florida Fish and Wildlife Conservation Commission
FWS	Fish and Wildlife Service (U.S.)
GD	Geologic Division
HTL	Higher Trophic Levels
MAP	Monitoring and Assessment Plan
NAS	National Audubon Society
NBS	National Biological Service
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PMC	Program Management Committee
RECOVER	Regional Coordination and Verification
SCT	Science Coordination Team
SCG	Science Coordination Group
SFER	South Florida Ecosystem Restoration
SFERTF	South Florida Ecosystem Restoration Task Force
SFWMD	South Florida Water Management District
SOP	Science Oversight Panel
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WG	Working Group

PREFACE

The Florida Bay and Adjacent Marine Systems Science Program embodies 10 years of scientific research, monitoring and modeling activities in support of both South Florida Ecosystem Restoration and individual (i.e., participating) agency natural resource or environmental management mandates. Guiding the program is a committee of agency representatives with science program management responsibilities within their respective federal and state agencies.

Since 1997, the program has been organized around five central questions that directed efforts at identifying the basic structure of the Florida Bay ecosystem and the underlying causes of specific changes. This strategic science plan builds on the results of those efforts by 'moving the existing science forward' to a more predictive state in order to help guide restoration planning and implementation and natural resource management. To operate in a predictive state implies the use of models. Therefore, models and the information needed to support them will, henceforth, be used as a major organizing structure to identify and prioritize science information needs in Florida Bay.

Although predicting ecosystem response to restoration activities represents a fundamental shift and major additional demand upon the program, critical information gaps will continue to be identified and addressed to support the needs of individual agency mandates. Information needs for adjacent marine systems are described in the science plans for Biscayne Bay (see Appendix C [On-line Resources]) and the Florida Keys National Marine Sanctuary (draft in review).

1.0 BACKGROUND

1.1 History

The Florida Bay and Adjacent Marine Systems (FBAMS) Science Program had its beginnings in 1993 when managers from Everglades National Park (ENP) and the National Oceanic and Atmospheric Administration's (NOAA) Looe Key National Marine Sanctuary, in response to increasing local concerns over changes in Florida Bay, formed the informal Florida Bay Working Group. The purpose of the working group was to build a strong scientific information and modeling base to support plans for restoring Florida Bay. Although the bay lies entirely within ENP or the Florida Keys National Marine Sanctuary (FKNMS) (ca. 80% and 20%, respectively), additional agencies were represented on the working group because of their management responsibilities regarding water delivery or state fisheries or for their role in developing and maintaining long-term monitoring of water flows into and effects upon coastal areas and living marine resources (South Florida Water Management District [SFWMD], Florida Department of Environmental Protection [FDEP], United States Geological Survey [USGS], and NOAA's National Marine Fisheries Service [NMFS], respectively).

In April 1994 the Florida Bay Working Group developed the first interagency science plan. Shortly thereafter, it was presented to and approved by the recently appointed South Florida Ecosystem Restoration Task Force's (SFERTF) Working Group. That plan established the Florida Bay Program Management Committee (PMC) whose agency representatives (local science program managers) were to be appointed by the Working Group (WG).

The *Florida Bay Science Plan* of 1994 was the basis for the present program and identified 14 questions encompassing 72 associated tasks of varying urgency that needed to be addressed to further understanding of the Florida Bay ecosystem. In addition, the plan provided the framework for the creation of a standing science review panel for Florida Bay.

Over the next several years the PMC expanded to include representatives from the U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers (USACE), U.S. Fish and Wildlife Service (FWS), and USGS's Geologic Division (USGS/GD). Additionally, some of the ENP participants were reorganized into the National Biological Service (NBS) and, ultimately, into the USGS's Biological Research Division (USGS/BRD).

In 1997, at the urging of the PMC's Science Oversight Panel (SOP) – an independent science review panel, the *Florida Bay Science Plan* was substantially revised into the *Strategic Plan for the Interagency Florida Bay Science Program*. Whereas the initial plan focused on developing and describing the program process as well as generic information needs, the 1997 plan was organized around five central questions (Table 1-1), each examining different ecosystem characteristics and the relation of these to particular driving processes and attributes of the geomorphic setting. It also defined the specific elements needed (some of which were already in progress) to address each of the five central questions and, where possible, which agency(ies) would be responsible for those elements:

Table 1-1. Central questions from the 1997 *Strategic Plan for the Interagency Florida Bay Science Program*

CENTRAL QUESTION #1: *How and at what rates do storms, changing freshwater flows, sea level rise, and local evaporation/precipitation influence circulation and salinity patterns within Florida Bay and the outflow from the Bay to adjacent waters?*
CENTRAL QUESTION #2: *What is the relative importance of the influx of external nutrients and of internal nutrient cycling in determining the nutrient budget of Florida Bay? What mechanisms control the sources and sinks of the Bay's nutrients*?
CENTRAL QUESTION #3: *What regulates the onset, persistence and fate of planktonic algal blooms in Florida Bay*?
CENTRAL QUESTION #4: *What are the causes and mechanisms for the observed changes in the seagrass community of Florida Bay? What is the effect of changing salinity, light, and nutrient regimes on these communities*?
CENTRAL QUESTION # 5: *What is the relationship between environmental and habitat change and the recruitment, growth and survivorship of animals in Florida Bay*?

Shortly after the 1997 revision, and at the specific request of the SFERTF's Science Coordination Team (SCT) and WG, the PMC expanded its geographic scope to include not only Florida Bay but those marine systems adjacent to it e.g., Biscayne Bay (see Section 2.2). Although much of the program focus would remain on Florida Bay, representatives from Biscayne National Park (BNP), Miami-Dade Department of Environmental Resource Management (DERM) and the FKNMS were added to the PMC to ensure close coordination of science activities. The expansion has been advantageous, especially given the similarity of issues between Florida Bay and Biscayne Bay and the fact that the FKNMS lies downstream of both.

1.2 Rationale for a New Plan

By establishing five central questions, initiating the projects necessary to address those questions, and maintaining continuity within the science program we have, by and large, accomplished our basic goal of identifying and understanding causes of specific changes in the ecology of Florida Bay. These changes occurred in response to stressors, some local but others distant and outside of Florida Bay. One important external stressor was upstream water management. This is especially important given that Florida Bay lies downstream of changes planned under the Comprehensive Everglades Restoration Plan (CERP) and, in the interim, the Combined Structural and Operational Plan (CSOP), both of which are key elements of greater South Florida Ecosystem Restoration (SFER).

Three overarching goals have been identified for SFER. They are to: 1) get the water right, 2) restore and enhance the natural system, and 3) assure the compatibility of the built and natural systems (SFERTF 2000). Given that Florida Bay drains much of the adjacent mainland and receives flows of freshwater from both marshes and canals in the region, the most important of these to Florida Bay is to 'get the water right'. This goal is the primary focus of CERP – the largest single component of SFER. Getting the water right means providing freshwater flows with the right quality, quantity, timing and spatial distribution. Because CERP may profoundly affect Florida Bay, the FBAMS Science Program has little choice but to emphasize the relationship of Florida Bay to Everglades hydrology and systematic evaluation of the effects of alternative upstream water management scenarios. To function in such a deliberately predictive capacity represents a fundamental shift in program focus.

Concurrently, individual agency responsibilities require a predictive understanding which necessitates continuing basic process research albeit in a more focused and targeted manner. This would be true regardless of SFER but is all the more necessary to ensure that SFER does not proceed at the expense of agency mandates including, among others, the Endangered Species Act, the National Park Service's Organic Act, and the National Marine Sanctuaries and Florida Keys National Marine Sanctuary and Protection Acts.

2.0 INTERAGENCY SCIENCE PROGRAM

The FBAMS Science Program comprises all research, monitoring, and modeling activities conducted and/or funded by the cooperating agencies in the geographic area described in Section 2.2. Although under the general umbrella of the SFERTF, the program exists as an essentially voluntary collaboration, lacks a mandate in law or regulation, and operates without an integrated program budget. The self-maintaining group behavior of the PMC that has guided the program has been described as a "community of practice"[2] (Nuttle, 2001).

2.1 Mission

The mission of the program is threefold: 1) to generate the requisite science to support restoration-related and other natural resource management decisions, 2) to advance basic understanding of the Florida Bay ecosystem, and 3) to facilitate efficient exchange of scientific information. Although each mission is distinct, important crosscutting relationships exist.

2.1.1 Generate Science for Restoration and Management

A number of restoration projects or other activities (including water supply) that could directly affect FBAMS are shown in Table 2-1. Of particular interest are CERP's Florida Bay/Florida Keys Feasibility Study (FBFKFS)[3] and the Combined Structural and Operational Plan (CSOP). Specific objectives of the FBFKFS are to (FBFKFS 2002):

- Determine the quantity, quality, timing and distribution of freshwater that should flow to Florida Bay and provide recommendations for any modifications of water deliveries that will result from current CERP plans for Everglades wetlands.
- Determine the nutrient sources and loads to the study area, evaluate their impacts to reef and bay ecosystems, and recommend restoration targets and implementation plans.
- Establish water quality and ecological performance measures.
- Evaluate the effects of restoring historical connectivity between Florida Bay and the Atlantic Ocean.
- Evaluate management action scenarios in a holistic manner employing, where necessary, hydrodynamic, water quality and ecological models.
- Make specific recommendations to Congress as to additions or modifications to CERP that are needed to improve the water quality and ecological conditions of the Florida Bay ecosystem.

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[2] "Community of practice" refers to a group of people bound by shared expertise and interest in a topic or an enterprise. These groups are, by nature, informal, self-selecting and self-directed. They exist outside of the formal structure of an organization but, when aligned with the goals of an organization, can expand and enhance the capabilities of that organization (Wenger and Snyder 2000).

[3] The prior scientific findings of the FBAMS Science Program were, in a large part, the rationale behind the FBFKFS.

Table 2-1. Key restoration projects and other relevant management activities.

Activity/Project Name		Description
CERP	FBFKFS	Determine modifications needed to restore water quality and ecological conditions of the bay.
	C-111 Spreader	Alter the C-111 canal system to rehydrate and establish sheet flow through Model Lands, Southern Glades, Florida Bay and Manatee Bay/Card Sound.
	Florida Keys Tidal Restoration	Pilot project to restore a tidal connection between Florida Bay and the Atlantic Ocean. It is hoped that results of this pilot project can be scaled up to assess potential ecological impacts from future tidal restoration activities at more significant sites.
	Biscayne Bay Coastal Wetlands	Redirect water from local conveyance canals into adjacent wetlands to rehydrate wetlands and restore natural salinity regime to Biscayne Bay and Card and Barnes Sounds.
	L-31 Pilot	Examine alternatives to reduce underground water seepage from the Everglades.
	WCA 3 Decompartmentalization and Sheet Flow Enhancement	Modification of water control structures to restore sheet flow to the Everglades landscape.
	Florida Keys Water Quality Improvements Program	Improve the quality of nearshore waters within the FKNMS.
	Wastewater Reuse Technology Pilot Project	Determine ecological effects of using treated reclaimed water to augment water deliveries to natural areas in Miami-Dade.
CSOP	Modified Water Deliveries (MWD) to Everglades National Park Project	Modification of water control structures to re-establish historic Shark River Slough flow-way from WCA 3A and WCA 3B to ENP.
	C-111 Project	Modification of southern portion of the canal system along southeastern ENP boundary to improve hydrologic and ecological conditions of Taylor Slough, ENP panhandle, and Florida Bay
Other	Minimum Flows and Levels (MFLs)	Determine water levels and flows necessary to prevent significant harm for biota and habitat of Everglades, Greater Biscayne Bay and Florida Bay.
	ENP Internal Management Programs	Exotics, human use, etc.

Specific objectives of CSOP are as follows (CSOP [in prep]):

- Restore historic hydrologic conditions in the Taylor Slough, Rocky Glades, and the eastern Panhandle of ENP.
- Protect the natural values associated with ENP.
- Eliminate the damaging freshwater flows to Manatee Bay/Barnes Sound and increase flows to northeast Florida Bay from the lower C-111.
- Maintain the level of flood protection.

- Mitigate project-induced flood damage in the East Everglades, including the 8.5 Square Mile Area, the Osceola Indian Camp, and the Tiger Tail Indian Camp.
- Ensure that C-111 project waters diverted to ENP meet all applicable water quality criteria.
- Construct modifications to improve water deliveries into ENP and take steps to restore natural hydrologic conditions in ENP by:

  - Timing: Changing the schedule of water deliveries so that it fluctuates in consonance with local meteorological conditions, including providing for long term and annual variation in ecosystem conditions in the Everglades;
  - Location: Restoring Water Conservation Area (WCA) 3B and Northeast Shark Slough as a functioning component of the Everglades hydrologic system; and
  - Volume: Adjusting the magnitude of water discharged to ENP to minimize the effects of too much or too little water.

Although many of the projects and activities in Table 2-1 are in their initial stages of implementation, the targets and performance measures necessary to assess ecosystem response to, and thereby determine the success of, these activities have already been developed, in large part based upon the scientific information generated by the FBAMS Science Program. This same information has allowed the FBAMS scientific community (through the PMC) to provide Modeling Terms of Reference, a Standard Data Set, FBFKFS Performance Measures, Florida Bay and Biscayne Bay Interim Goals and Targets[4], and develop the Southern Estuaries section of the CERP Monitoring and Assessment Plan (MAP) including the conceptual ecological models for Florida Bay (see Section 2.3.1) and Biscayne Bay. Additionally, a sub panel of the PMC developed Biscayne Bay's first science plan (see Appendix C [On-line Resources]), which has been supplied to the Biscayne Bay Regional Coordination Team and relevant CERP projects. Many other opportunities have and will continue to exist by which the program can contribute information that can be used to help restoration planners and natural resource managers make sound, scientifically-based, decisions.

It is the PMC's expectation that scientific information generated from continued research, modeling and monitoring activities of the FBAMS Science Program will be integrated into ongoing restoration decisions through the formal process of

[4] The congressional requirement of interim goals and targets requires model predictions of restoration success at 5-year intervals (see *Recommendations for Interim Goals and Interim Targets for the Comprehensive Everglades Restoration Plan: Indicators and Prediction Methods* in Appendix C).

adaptive assessment (see *An Adaptive Assessment Strategy for the Comprehensive Everglades Restoration Plan* referenced in Appendix C, Online Resources). Assessments are based upon comparisons between baseline and post-project monitoring. The Southern Estuaries Module of the CERP MAP incorporates and extends several FBAMS Science Program monitoring efforts.

2.1.2 Advance Basic Understanding of the Florida Bay Ecosystem

Since the program's inception ten years ago, substantial progress has been made in understanding the physical, biological and chemical factors that regulate change and stability within the Florida Bay environment. Highlights are abstracted from *A Synthesis of Research on Florida Bay* (PMC [in press]) and included in Appendix A. Nonetheless, the FBAMS Science Program's interest in and support for targeted research, modeling and monitoring that continues to advance basic scientific understanding of Florida Bay is undiminished.

2.1.3 Facilitate Exchange of Scientific Information

Because of the complex nature of the ecosystem, the large number of agencies with management or regulatory responsibilities, and the ever-evolving needs of restoration, the FBAMS Science Program serves a vital role by furnishing a vehicle in which to foster the exchange of scientific data and information. It provides:

- An unbiased assessment of scientific issues;
- Identification of science needs and priorities;
- Accessibility to a broad body of information;
- Coordination of activities and, therefore, best use of limited funds;
- An enlarged pool of expertise;
- A holistic perspective upon the coastal marine ecosystem;
- Cooperation and sharing among individuals and agencies;
- Credibility i.e., establishes consensus within scientific community;
- Better science-based management decisions;
- An independent forum for science;
- A safe place for vetting ideas on unpopular or sensitive issues.

Communication of scientific results and progress is a high priority of the program and occurs at four levels: 1) the general scientific community, 2) the participating agencies, 3) CERP and SFER, and 4) the public.

Various mechanisms exist to facilitate exchange of information within the general scientific community. These include science teams, topical workshops, panel discussions, conferences, the program web site (see Appendix C [On-line Resources]), and publication of peer-reviewed literature and white papers.

At the participating agency level, PMC members communicate the collective understanding of the FBAMS Science Program and specific recommendations of the SOP to the rest of their agency. The program's strategic science plan is one mechanism by which scientific accomplishments and information and institutional needs are communicated, and it has been regularly used to guide the funding decisions of the participating agencies.

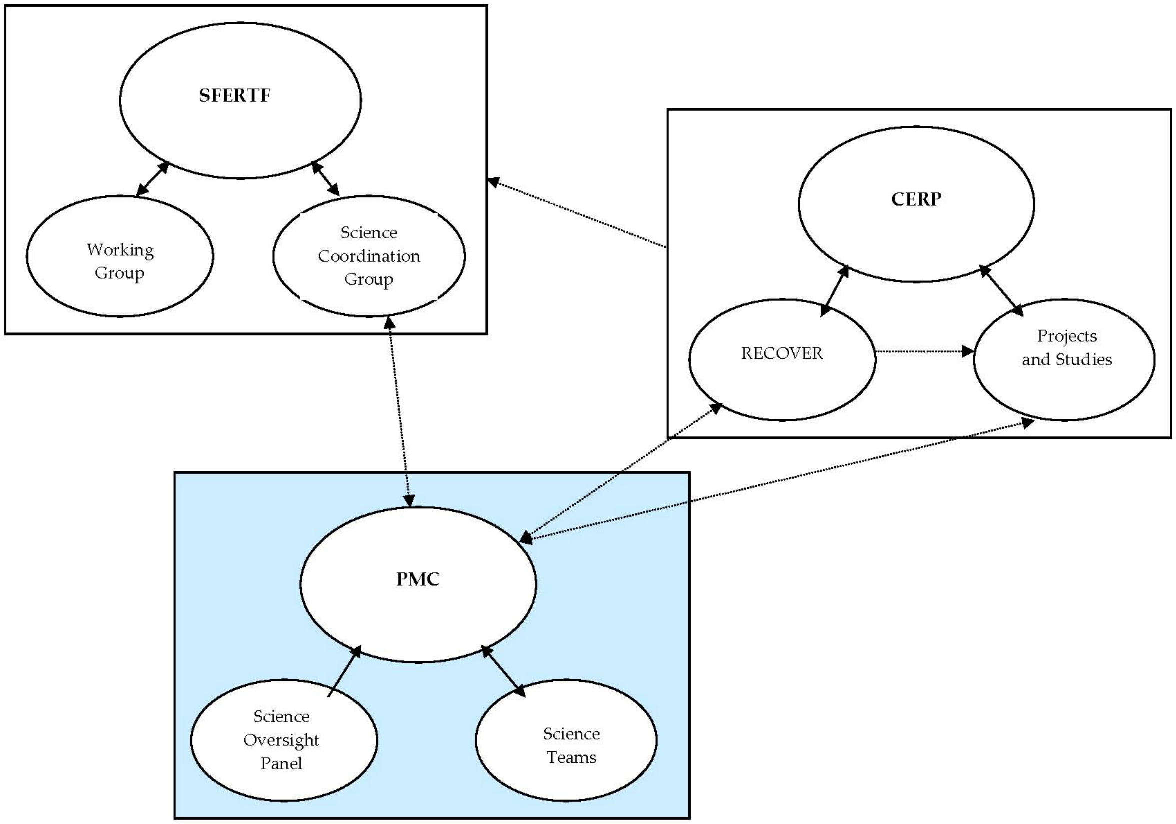
With the initiation of CERP's FBFKFS and RECOVER and the SFERTF's Science Coordination Group (SCG), the PMC now has explicit communication linkages with restoration managers (see Fig. 2-1).

PMC members sit on CERP's regional project committees and RECOVER teams and the SFERTF's SCG to: 1) keep informed of and help guide restoration activities, 2) help identify science information needs, and 3) better coordinate the research, modeling and monitoring activities of the FBAMS Science Program to meet those needs. Although the PMC is now better integrated into the restoration process, it will continue to seek out additional opportunities for informing restoration with the best available science.

The FBAMS Science Program also provides an essential linkage between the independent academic science community and the agency-dominated CERP and SFER bureaucracies. Specific relationships between these entities can, at times, be difficult given the constraints of the Federal Advisory Committee Act, the State Sunshine Act, and agency processes, cultures and legal restrictions.

While the PMC recognizes the importance of outreach and education, it has no resources to support this activity. Instead, it relies on individual efforts of the participating agencies, many of which have established outreach programs and cooperate at present in a CERP-funded coastal ecosystem outreach program.

Figure 2-1. FBAMS Science Program relationships with restoration managers.

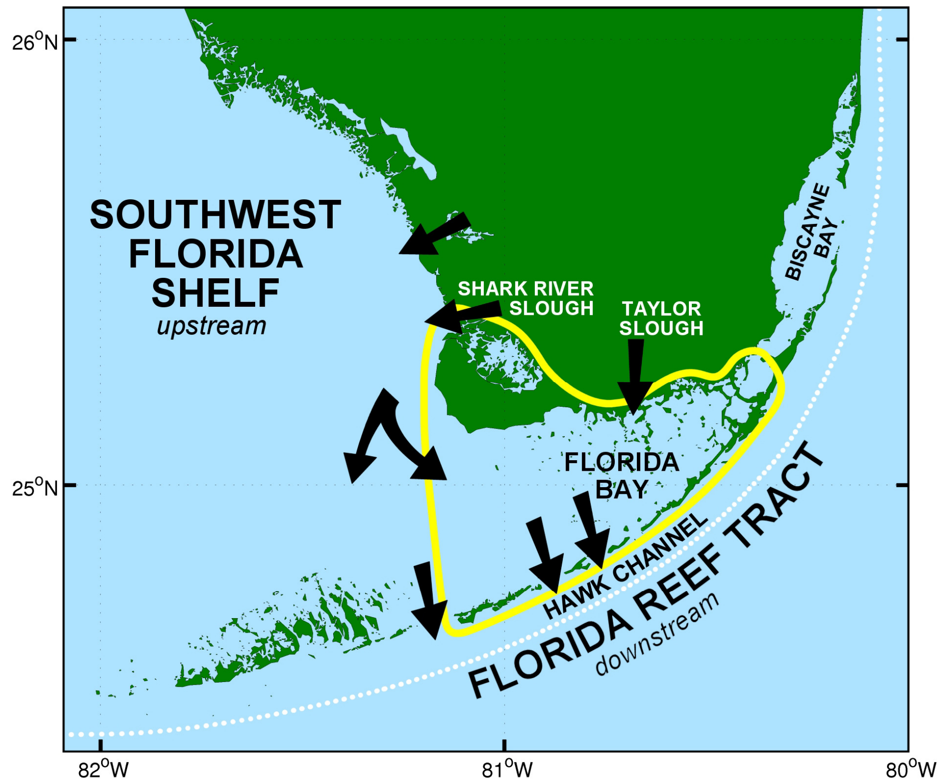


2.2 Geographic Scope

The geographic scope of the FBAMS Science Program includes the Southwest Florida Shelf and Gulf of Mexico, Florida Bay, Biscayne Bay, and the Florida Reef Tract. The primary focus of this strategic science plan, however, is the Florida Bay ecosystem. As demarcated by the yellow boundary in Figure 2-2, this includes not only Florida Bay but also the mangrove-dominated estuarine transition zone along the northern shore of Florida Bay as well as Whitewater Bay. The arrows in Figure 2-2 denote either dominant flow regimes or major freshwater inputs.

The Everglades supplies freshwater, nutrients and contaminants to Florida Bay directly through the Taylor Slough/C-111 watershed and indirectly from the Shark River Slough watershed. Hydrodynamics, salinity, and water quality in Florida Bay are affected by exchanges with the Southwest Florida Shelf and the Gulf of Mexico across the bay's western boundary and by exchanges with the Atlantic Ocean through Keys' passes. In turn, these exchanges also affect hydrodynamics and water quality in Hawk Channel and potentially in waters along the Florida Reef Tract.

Figure 2-2. Geographic scope of this strategic science plan.



2.3 Science Strategy

The PMC will continue to rely upon many of the same organizational elements that have been responsible for the program's success. These include topical workshops to seek resolution to and establish consensus on high profile scientific issues, science conferences to facilitate exchange of technical information throughout the scientific community, a standing Science Oversight Panel to ensure independent expert peer review of the FBAMS Science Program, and technical contributions from the scientific community in support of scientific tool development (e.g., performance measures) and document preparation (e.g., A *Synthesis of Research on Florida Bay*). Should additional funds become available, the PMC will make every effort to reinitiate formal science teams as well (see Appendix B for details).

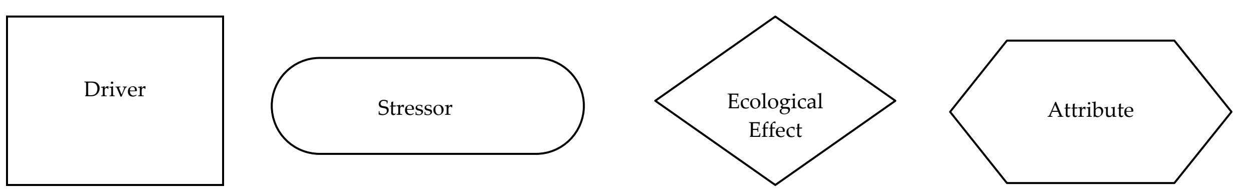
The FBAMS Science Program will emphasize those activities that yield information that refines understanding of critical linkages expressed in regional conceptual ecological models, improves definition of restoration targets, and assists in developing, calibrating and validating the numerical or statistical models used to make system predictions.

This emphasis is reflected in the priorities identified in Section 3.0 and is consistent with the "ecosystem approach to management"[5] as recommended by the SCG to the SFERTF.

2.3.1 Conceptual Models

The Florida Bay Conceptual Ecological Model (Fig. 2-3) and the Everglades Mangrove Estuaries Model (Fig. 2-4) reflect current understanding (RECOVER 2004) of external drivers and anthropogenic stressors upon these systems. Such conceptual models are planning tools that guide and focus scientific priorities. They are used to build understanding and consensus among scientists and managers on a set of working hypotheses regarding the major anthropogenically induced changes in the natural system. The models identify specific large-scale anthropogenic and natural drivers and associated stressors, ecological effects of these stressors, and recommended biological and ecological attributes of the natural systems that can best serve as indicators of the effectiveness of restoration programs designed to reduce, eliminate or minimize identified stressors. In other words, each hypothesis describes the ecological linkages between a stressor and a key attribute of the natural system that has been altered due to the effects of that stressor (Ogden et al. [in prep]). It is important to understand that these are not quantitative numerical models that can themselves be used for prediction purposes.

The symbols used to indicate conceptual ecological model components are shown below.



[5] An *ecosystem approach to management* is management that is adaptive, geographically specified, takes account of ecosystem knowledge and uncertainties, considers multiple external influences, and strives to balance diverse societal objectives (NOAA 2004).

Figure 2-3. Florida Bay Conceptual Ecological Model (Rudnick et al. [in prep]) .

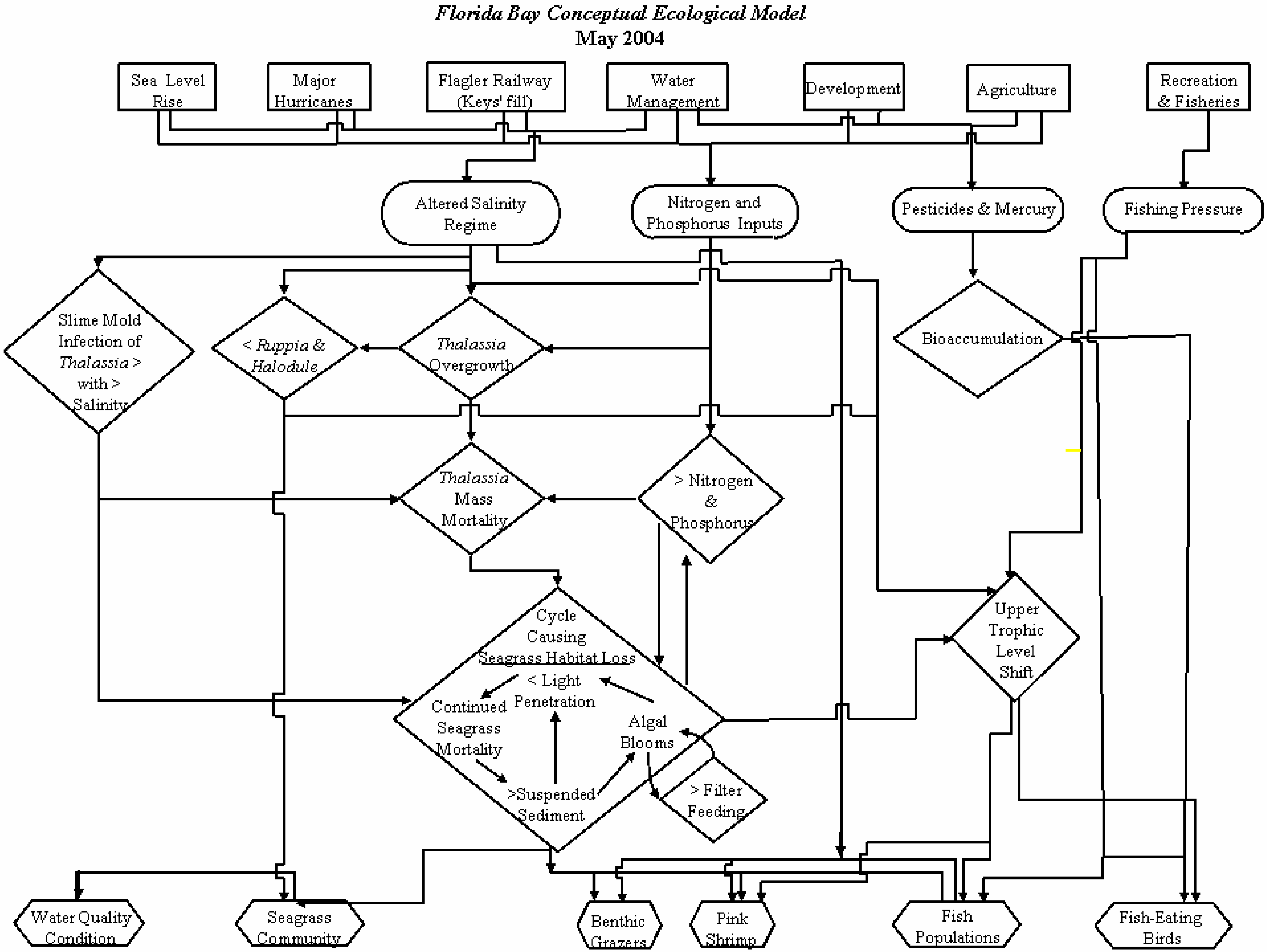
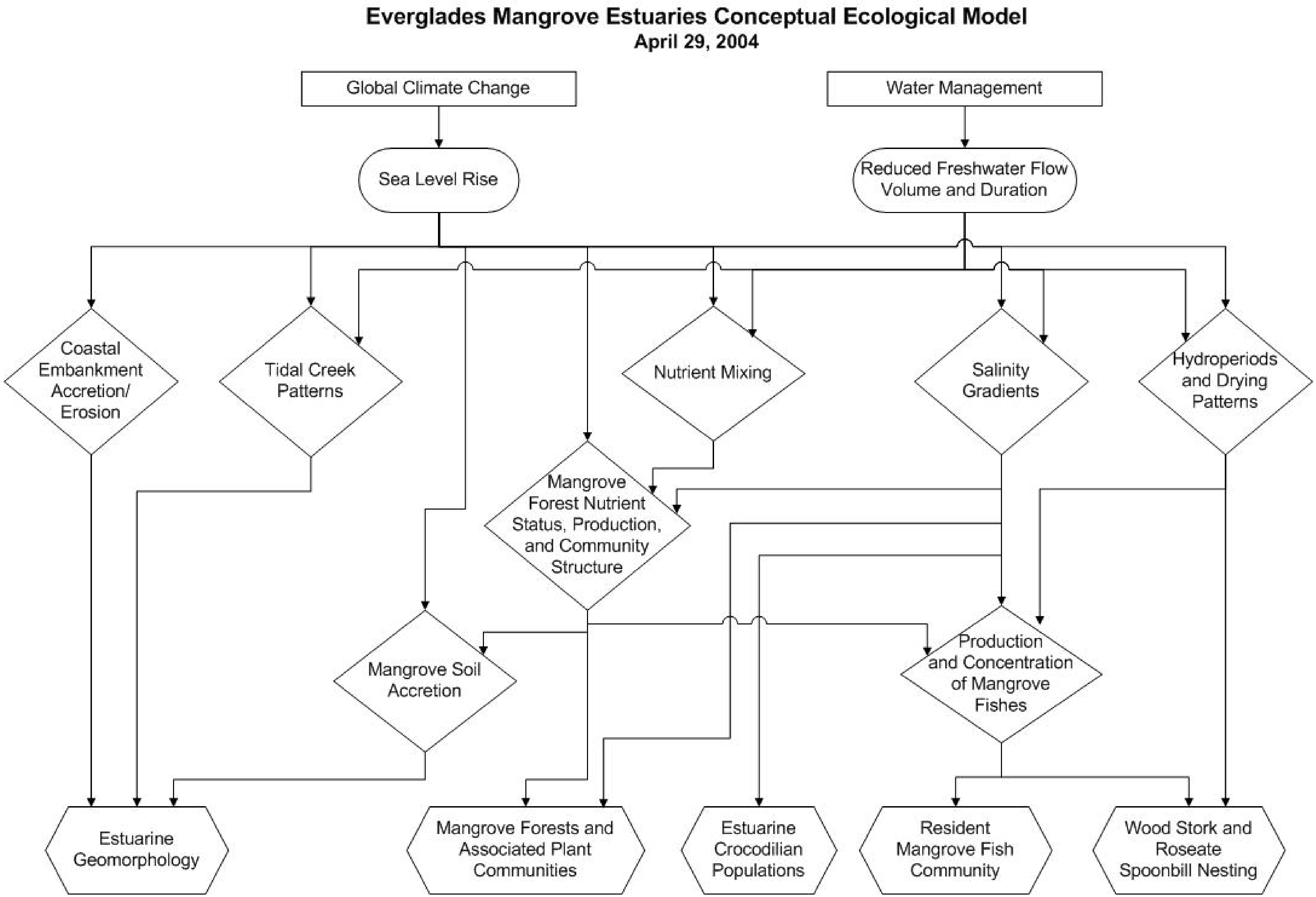


Figure 2-4. Mangrove Estuaries Conceptual Ecological Model (Davis and Hopkins [in prep]).



Fundamental characteristics of Florida Bay and the mangrove-dominated estuarine transition zone that determine the specific linkages between stressors, ecological effects and attribute responses in the Florida Bay ecosystem include:

<u>For Florida Bay…</u>

- Physiochemical processes in the bay are highly influenced by physical compartmentalization of bay basins by a complex network of shallow mud banks, its shallow depth, and its carbonate sediments and their influence on availability of phosphorus.
- Bay salinity ranges widely because of its unique physiography leading to long residence times of water and external hydrological manipulation.
- Biotic feedbacks are essential to the function of the bay ecosystem. For example, primary producers (i.e., submerged aquatic vegetation, algae and mangroves) influence physical and chemical processes including mud bank and nutrient dynamics.
- Seagrasses are a critical habitat in the bay and are highly vulnerable to physiochemical stressors such as salinity, light, and oxygen depletion/sulfide toxicity. The spatial coverage, biomass, production, and taxonomic composition of seagrass beds are controlled by the combined and inter-related effects of sediment depth, light penetration, epiphyte load, nutrient availability, salinity, sulfide toxicity, and disease. The relationship between seagrasses, algal blooms and the potential for Everglades dissolved organic matter to support primary production are important components in understanding system dynamics.
- Hardbottom communities are another critical habitat of the bay. Beneficial habitat related spatial patterns between these communities and seagrass beds are not well understood. Filter feeding components of both communities (i.e., sponges and mollusks) and their relationship with water column phytoplankton biomass, nitrification, light availability, cyanobacteria and salinity may be essential to maintain bay ecosystem structure and function.
- There is a functional linkage between the Everglades, Florida Bay, the Gulf of Mexico, and the Atlantic Ocean.
- Sea level rise may affect the ecology of the bay due to the relationship between sea level, mudbank deposition and erosional processes, and general circulation.
- Tropical storms and hurricanes may influence key morphological and physiochemical attributes in the bay such as depth, salinity, circulation and sediment nutrient storage.
- Higher trophic level populations may be affected by water quality, habitat, and fishing pressure.

For the Mangrove-Estuarine Transition Zone…

- The mangrove-estuarine transition zone is spatially dynamic in response to hurricanes, sea level rise and changes in fresh water inflow.
- The oligohaline portion of the mangrove-estuarine transition zone provides essential nursery habitat for estuarine and marine organisms including pink shrimp, spotted seatrout and common snook and forage fish supporting wading bird populations. Appropriate salinity regimes in this zone are critical to support alligator and crocodile populations. The spatial distribution of the structured mangrove habitat, in combination with the overlaying salinity gradient, determines its suitability to support the faunal attributes mentioned above.
- The mangrove-estuarine transition zone may provide a sink for nitrogen in Everglades water entering Florida Bay.

2.3.2 Performance Measures and Targets

Performance measures reflect an important ecosystem structure or function (i.e., an attribute) and employing these requires both an agreed upon method of quantification and a restoration target. There are currently two sets of performance measures for Florida Bay, one to assess ecosystem response to restoration (assessment measures) and another, predictive in nature, to evaluate and chose between engineering or water management alternatives (evaluation measures). Both sets are CERP- specific and designed primarily to address changes in the system's hydrology. SFER will require a larger set of performance measures and targets to the degree that not all restoration goals can be achieved by changes in water management alone. Developing these will required additional scientific information.

Given the extent of growth and development in South Florida, restoration of Florida Bay to the conditions prevailing a hundred or more years ago is almost certainly impossible. Restoration to a healthy and sustainable condition, however, remains a reasonable goal, in part because much of the upstream watershed (i.e., the Everglades) and Florida Bay itself are held in public trust. To restore Florida Bay will require improved definition and rigorous implementation of targets and associated performance measures.

2.3.3 Numerical and Statistical Models

Quantitative models provide a means to integrate the non-linear physical, biological and chemical processes characteristic of the highly dynamic Florida Bay ecosystem and are, therefore, essential to our science strategy. Only through such modeling can quantitative predictions be developed to select those management alternatives that will best accomplish restoration.

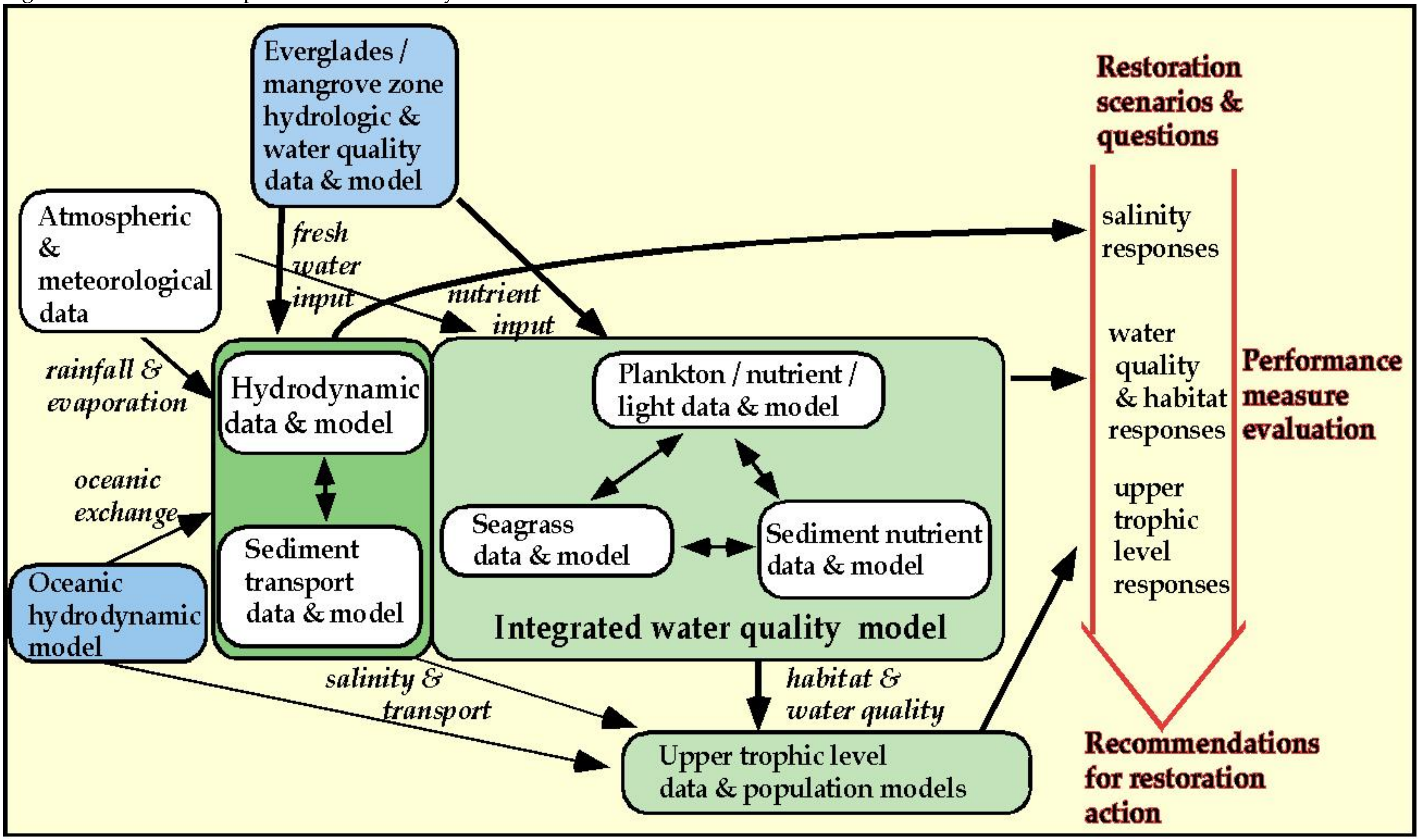
Although the 1997 strategic plan highlighted the use and utility of models, the FBAMS science community has, since that time, learned a great deal about their practical limitations. For example, in some cases it is unlikely that reliable fully-resolved numerical models will be available in the next few years. In these cases statistical models will have to be relied upon to make timely predictions. The predictions of either numerical or statistical models become hypotheses that will be testable by observation. The suite of models required for FBAMS evaluation are listed in Table 2-2.

Table 2-2. Predictive models for Florida Bay

Predictive Models		Agency/Sponsor
Physical Processes	Regional oceanographic model of SW Florida Shelf, Florida Straits and Gulf Stream (HYCOM)	NOAA/AOML
	Mass balance models for wetland hydrology and estuarine salinity (FATHOM)	NPS/ENP & SFWMD
	Hydrological models (SICS/TIME)	USGS/WRD & SFWMD
	Hydrodynamic model of inner Florida Bay overlapping with HYCOM (EFDC)	SFWMD & USACE
Water Quality	Integrated Water Quality Model based on EFDC	SFWMD & USACE
	General linear models for salinity (for RET)	SFWMD
Higher Trophic Levels	Pink shrimp - fishery predictive model and simulation models and other general additive statistical models applied to available fisheries independent data	NOAA/SEFSC
	Lobster and Hardbottom Community Model	NOAA/SEFSC & FWC
	Roseate Spoonbill model	NAS
Benthic Habitats	Species specific seagrass unit models/modules and landscape models	USGS/BRD & SFWMD
	Discriminant function seagrass community model	NPS/ENP

The PMC supports the continued development and use of these specific models and the present FBFKFS integrated modeling approach as depicted in Figure 2-5.

Figure 2.5. Model development for Florida Bay



3.0 Science Priorities

To support the scientific needs of restoration and the scientific needs related to agency responsibilities (e.g., FWS), science priorities have been organized thematically although, in practice, this separate thematic structure will be integrated for a holistic approach (see Appendix B). These themes include physical processes, water quality, benthic habitats, higher trophic levels, and the mangrove-estuarine transition zone. Within each theme, two sets of questions have been identified. The first addresses restoration modeling needs and the second addresses other science needs. Where possible, the questions include specific associated tasks or projects.

3.1 Physical Processes

Research and monitoring of physical processes has encompassed all major physical driving forces (i.e., winds and storms, precipitation, evaporation, surface water inflow, groundwater, sea level and tides, and boundary currents) and the hydrodynamic character of Florida Bay (i.e., varying salinity and circulation patterns, and exchanges with adjacent waters). Although considerable data exist on each of these processes, more work remains to fully characterize their relative importance and variability, particularly in the case of groundwater inputs and evaporation for which available estimates vary over a significant range of values. The degree to which these processes need to be better defined will be determined by the needs of the suite of hydrological and hydrodynamic models used to predict Bay salinity and circulation patterns. The same can be said for improved measurements of such hydrodynamic characteristics as bathymetry and flow across the extensive mud banks that divide the inner portion of Florida Bay. The sufficiency of the physical models will have to be assessed in light of the requirements of the numeric and statistical water quality and ecological models and improved or modified if necessary. Furthermore, to the degree that predictions of rapid local sea level rise can be verified, the relationship between sea level and bay flushing processes will need to be better understood given the multi-decadal time span of the CERP implementation.

3.1.1 Restoration Modeling Needs

- What is the relative influence on Florida Bay salinity of changing freshwater inflows compared to the natural variability of sea level, rainfall and evaporation, and to what degree do they affect residence times in specific basins and the occurrence of positive and negative (i.e., hypersaline, estuarine) salinity gradients?

- Conduct sustained, interdisciplinary observational programs in Florida Bay and the adjacent coastal waters.
- Examine and describe the role of natural versus anthropogenic variability of the relevant forcing functions on the observed salinity fields.

➢ What is the influence of groundwater exchange within the bay on salinity fields and water residence times? How do these vary spatially and temporally?

- Survey groundwater fluxes and salinity and compare to estimates from tracer studies.

➢ Is there a simple statistical transfer function sufficient to adequately describe the effect of fresh water flows on salinity for the purposes of predicting the effect of restoration scenarios upon nearshore Florida Bay salinity, and if so, over what spatial domain does it apply?

- Continue statistical transfer function analysis.

➢ To what degree is a better understanding of flow across banks, and bank characteristics in general (e.g., cover, elevation, salinity, and temperature), necessary for successful hydrodynamic modeling of the bay interior?

- Conduct a bathymetric survey of the bay's major banks.
- Conduct observational studies of the characteristics and flow over the banks and provide empirical input to hydrodynamic models of Florida Bay.
- Quantify the rates and pathways of exchange between the interior basins and across the banks in the western, central, and eastern regions of Florida Bay, and with the Southwest Florida Shelf.

➢ What are the hydrodynamic effects of restoring connectivity through the Keys passes and what is the spatial extent of these effects?

- Examine findings of monitoring the Florida Keys Tidal Restoration project.
- Model hydrodynamic impacts of restoring flow at additional occluded passes.

- What are the regional processes (e.g., Loop Current position and dynamics, flows along the West and Southwest Florida Shelf through the Middle and Lower Keys, and large-scale synoptic winds) that need to be better described in order for the regional model to provide sufficient boundary conditions to the bay interior model?

3.1.2 Other Science Needs

- What is the significance of forcing from winds and storms on the hydrodynamics and physical properties of Florida Bay, and how will the water balance of Florida Bay change if current climatic projections are valid and a period of higher tropical storm incidence is in the beginning stages?

    - Examine the effect of winds, including extreme events such as tropical storms, on salinity patterns, sea level, and residence times within the bay interior.
    - Examine and describe the effects of the daily development of mesoscale convergent wind patterns over Florida Bay.

- What are the causes and effects of regional evaporation and precipitation variability?

    - Examine the extent to which the spatial patterns of Florida Bay surface salinity measurably change as a result of the heterogeneity of evaporation and precipitation over the region.
    - Examine and describe the extent to which precipitation over the bay has been changing due to land use changes on the peninsula ("desertification").
    - Examine and describe the effect of the bay's bank and basin topography on evaporation.

- What are the effects of sea level variability on the circulation and exchange of Florida Bay and the adjacent coastal waters?

    - Examine and describe the effects of sea level differences on inter-basin exchange and upon flow through Keys' passes.
    - Examine the extent to which long-term sea level differences between the Gulf of Mexico and the Atlantic affect the observed mean southeastward flow that transports water to the Florida Reef Tract.

- What are the primary driving influences on salinity variability in Florida Bay?

- Examine and describe the influence of atmospheric forcing on time scales from daily to inter-decadal, including significant transient meteorological events such as hurricanes and tropical storms, on Florida Bay salinity.
- Examine and describe how temporal and spatial patterns of evaporation, precipitation and basin residence time affect Florida Bay salinity distributions.
- Examine and describe how salinity records inferred from paleoecological data over the past 150 years compare with salinity values measured over the past 45 years.

3.2 Water Quality

Water quality (i.e., salinity, nutrients, dissolved oxygen, contaminants, phytoplankton blooms, and water clarity) within the bay has been shown to have substantial ecological consequence and to be related to upstream water management and human development. Salinity is principally addressed in the physical processes theme. The foremost need regarding water quality is to accurately predict the sensitivity of Florida Bay's nutrient regime and phytoplankton to changes in freshwater flow into the bay. For much of the bay, any factor that increases P availability either by increasing sources or decreasing removal would likely have substantial effects. The effects of increased nitrogen, potentially introduced as DON from the Everglades, are uncertain. Alteration of contaminant exposures is also possible with changes in the sources of water introduced into the bay. In general, a more thorough understanding of the bay's nutrient cycles is critical to making predictions and evaluating restoration alternatives.

3.2.1 Restoration Modeling Needs

➢ How will changing freshwater flow directly and indirectly alter the supply and availability of nutrients in the bay? What effect does changing salinity have on nutrient availability in the bay?

- Conduct sustained measurements of the quality and quantity of nutrients exported from the Everglades and determine how changes in flow and salinity alter this export via creeks and overland flow.
- Measure the decomposition rates of dissolved organic matter from the Everglades, how rates vary with different fresh water sources, and how rates vary within the bay as a function of location, salinity, and P availability.
- Determine the effects of changing salinity on nitrogen fixation and

coupled nitrification – denitrification.

- Determine the rate of nutrient input to Florida Bay from groundwater and how this varies spatially and temporally.

➢ What is the quantitative role of microphytobenthos in nutrient cycling and how is this likely to change with Everglades restoration?

- Determine the distribution, productivity, and nutrient flux associated with microphytobenthos mats.

➢ How will changing salinity, fresh water flow, nutrient supply, and circulation patterns alter the magnitude, duration, and distribution of phytoplankton blooms?

- Determine the direct and indirect (via microbial decomposition) effect of dissolved organic nutrients on phytoplankton productivity, considering decomposition rates, competition for limiting nutrients among different autotrophs (including seagrass) and heterotrophs, and water residence time.
- Determine the physiological requirements of major phytoplankton groups associated with algal blooms in different regions (e.g. cyanobacteria in the central bay region, red tides and black water events on the southwest Florida shelf) and incorporate these characteristics in the water quality model.

➢ What will be the short- and long-term effects of re-establishing connectivity by reopening the Keys passes on Florida Bay, nearshore and outer reef water quality?

- Ensure that the spatial domain of hydrodynamic and water quality models extend through the passes past the reef tract.

3.2.2 Other Science Needs

➢ What effect does a change in seagrass community structure have on nutrient availability in the bay? Following seagrass mortality events, what is the relative influence of detrital decomposition and sedimentary dynamics on nutrient availability to phytoplankton?

➢ To what degree does benthic microbial activity, dissolved oxygen concentration, and salinity regulate the availability of nutrients to seagrasses?

➢ What is the influence of benthic filter feeders on algal blooms and light attenuation in the bay and how does this vary as a function of bloom composition and seagrass habitat?

- To what extent is atmospheric deposition of nutrients contributing to ecological changes in Florida Bay and is there a long-term trend in this source?
- What is the role of discharge through Charlotte Harbor and other west coast rivers upon black water and red tides incidence and intensity?
- What is the history of nutrient loadings from the South Florida peninsula? Can we make reliable estimates beyond the recent monitoring data record (ca. 13 years)?
- How does changing fresh water flow affect the input of toxic compounds to Florida Bay?

  - Determine the degree to which changing hydrologic conditions near South Dade agricultural areas results in the introduction of endocrine disrupting pesticide residues into Florida Bay.

- How will exposure to mercury and other contaminants change with anticipated changes in water management in the Everglades?
- What are the threshold levels of mercury and other contaminants (e.g., pesticides) resulting in significant biological effects upon key species?
- How do biogeochemical processes/conditions in the water column and the sediments influence the bioavailability of mercury and other contaminants?

3.3 Benthic Habitats

Seagrass and hardbottom habitats account for a large portion of primary production, provide food and/or shelter to many organisms and are critical to the ecological function of Florida Bay. These habitats strongly influence water quality and have themselves been affected by freshwater inflow and water quality changes attributable to upstream water management practices. Research has yet to address critical metabolic and community responses to sediment characteristics, water temperature, salinity, and light levels.

3.3.1 Restoration Modeling Needs

- How will submerged aquatic vegetation community structure, distribution and productivity change with changes in freshwater and nutrient input? What impact will sea level rise have on these relationships?

- Expand the Florida Bay seagrass landscape model domain to include the upper estuaries and tidal creeks of northern Florida Bay. Incorporate *Ruppia* and algae (e.g., *Chara*) into the Florida Bay seagrass simulation model.
- Further develop, within a landscape context, quantitative relationships and predictive models of plant community dynamics relative to freshwater inflow, salinity patterns, nutrient inputs, sediment accretion, and sea level rise.

➢ How will hardbottom community structure, distribution, and function change with changes in freshwater and nutrient input?

- Determine quantitative relationships between major hardbottom populations and salinity, temperature, and water quality (particularly phytoplankton, light, dissolved oxygen).
- Determine the effect of environmental (especially salinity) variance and the timing of this variance on the reproduction and propagation of major hardbottom species.
- Initiate development of models that include major hardbottom species (especially sponges and mollusks), considering energetics, filtration rates, recruitment, and size structure in relation to salinity, water quality, and other factors.
- Develop models to evaluate the effects of salinity fluctuations upon the species composition, diversity and equitability of seagrass communities.

➢ Determine how changes in a variety of environmental stressors affect benthic filter feeders, and what significance such changes may have on other components of the ecosystem.

➢ What are the effects on local seagrass and hardbottom benthic communities of restoring connectivity through the Keys' passes and what is the spatial extent of these effects?

3.3.2 Other Science Needs

➢ What are the critical requirements (e.g., water quality, depth, sediment characteristics, etc.) needed to sustain a particular benthic habitat?

➢ Has the extent of seagrass coverage in Florida Bay varied widely over the last few hundred years? Is there adequate evidence from existing sediment cores (from different and widely separated locations) to come to consensus on the seagrass coverage in a pre-altered bay?

- What role do sponges and filter feeding mollusk populations play in regulating water quality (e.g., turbidity, algal blooms) and processes such as the nitrogen cycle?

3.4 Higher Trophic Levels

Higher trophic level species potentially include everything from zooplankton to marine mammals. Our strategy will be to focus upon the set of species for which sufficient survey data exists or can be efficiently collected to answer questions about the effect of potential changes in environmental conditions on such parameters as species abundance and community structure.

Advances in understanding higher trophic level responses to restoration require an interdisciplinary approach with input from all the other science themes. For instance, the basic question of "how do changes in stressors affecting the bay affect pathways of higher trophic species' movement within and between FBAMS" requires information from physical processes, water quality, benthic habitats and the mangrove-estuarine transition zone. As many higher trophic level species initially settle in seagrass, hardbottom and mangrove communities, we cannot predict the impact of various stressors on their recruitment without understanding the impact of stressors on juvenile habitat. These nursery areas need to be delineated so that the potential effect of water management changes on salinity patterns, nutrient inputs, seagrass community structure and other conditions in these areas can be predicted. For some species such as gray snapper and sea trout, these nursery areas are within the Florida Bay geographic scope. However, other sought-after gamefish species such as red drum, snook, tarpon and bonefish are found in Florida Bay as pre-adults and adults, but the current nursery grounds of most of their populations are not delineated and are likely located outside of Florida Bay. Linking the higher trophic level theme to the other themes will require complete GIS integration data layers as they become available including salinity, fresh-water flows, benthic communities, and habitat structure and appropriate species distribution and abundance patterns.

3.4.1 Restoration Modeling Needs

- What are the current spatial and quantitative habitat-use patterns of higher trophic level species in Florida Bay? How will these habitat-use patterns change over time with changes to the environment brought on by restoration activities?

    - Determine the effect(s) of salinity on growth and survival of higher trophic level species as well as any effects of salinity on species abundance and community structure and habitat use patterns.

- Determine how changes in water quality, at both micro- and macro-habitat levels, may affect growth and survival of higher trophic level species within Florida Bay.
- Continue to delineate, characterize, quantify, and map important fisheries species nursery areas and habitat use of juveniles.
- Investigate how changes in seagrass diversity affect fish populations and community structure.
- Determine the relationship between density and abundance of bay anchovy to salinity fronts.
- Determine if changes in water management regimes may directly affect waterbird nesting success and overall populations in Florida Bay.
- Determine current mercury concentrations in Florida Bay higher trophic level species and investigate if any changes in concentrations occur with the onset of restoration. Investigate how changes in seagrass diversity affect fish populations and community structure.

➢ What are the movement patterns and temporal trends of higher trophic level species between habitats within Florida Bay? What are the movements, including influx and emigration of higher trophic level species, between Florida Bay and adjacent regions? How will these movement patterns be affected by the onset of restoration?

- Determine the mechanisms affecting larval transport and recruitment into Florida Bay. Investigate what processes (physical and biological) are involved in the transport of pre-settlement stages of larval fish and invertebrates across the boundaries and into Florida Bay (eddies and gyres, west bay circulation patterns, Loop Current.
- Determine and map the pathways used by early life stages of offshore spawned higher trophic level species to enter Florida Bay and the degree to which these will be affected by restoring connectivity between Florida Bay and the Atlantic by re-opening Keys' passes.
- Determine the principal factors limiting the abundance of offshore spawned higher trophic level species in the bay interior.
- Investigate and map changes in the movement corridors of higher trophic level species between seagrass, mangrove, and coral reef habitats as a result of restoration.
- Determine if freshwater inflow provides directional cues or otherwise influences the rate of larval immigration from offshore spawning grounds to nearshore nursery grounds in Florida Bay.

3.4.2 Other Science Needs

- What are the impacts of fishing on the population structure(s) of key species?

  - Assess the impacts and tease out influence of fishing pressures on population, movement, and distribution of fish species within Florida Bay and between Florida Bay and adjacent marine ecosystems.

- What are the effects of water quality on survival and growth of higher trophic level species?

  - Develop bioenergetic models.
  - Develop predation mortality models of size-related predation mortality including the effect of salinity on pink shrimp, spotted seatrout, gray snapper, and lobster.

3.5 Mangrove-Estuarine Transition Zone

The Florida Bay mangrove-estuarine transition zone has many important ecological attributes, many of which have been affected by altered freshwater inflow from upstream water management practices. Some of these attributes will likely be affected by restoration activities and respond more quickly than the same attributes within Florida Bay.

3.5.1 Restoration Modeling Needs

- What will be the spatial and temporal salinity patterns in the mangrove-estuarine transition zone with changes in freshwater input from restoration activities and natural rainfall patterns?

  - Complete and/or expand coastal hydrodynamic and hydrologic models to predict salinity patterns in the mangrove-estuarine transition zone.
  - Collect field data needed for the models.
  - Evaluate the need for and feasibility of developing a groundwater model component. Develop a groundwater model if needed and feasible.

- Will freshwater inflow from restoration activities cause ecologically detrimental inputs of nutrients and toxic contaminants to the mangrove-estuarine transition zone?

- Complete or expand the integrated Florida Bay Water Quality Model (or a southern Everglades water quality model) to predict nutrient and toxic contaminant transport to and from the mangrove-estuarine transition zone via freshwater inflow.
- Develop ecological risk assessment models for important toxic contaminants, such as pesticides and mercury.

➢ How will mangrove-estuarine transition zone submerged aquatic vegetation respond to changes in freshwater inflow and nutrient inputs?

- Expand the existing statistical and dynamic submerged aquatic vegetation models to predict submerged aquatic vegetation responses to salinity and other water quality parameters in the mangrove-estuarine transition zone.
- Collect submerged aquatic vegetation and water quality field data needed to support model expansion.

➢ How will mangrove productivity and plant community structure change with changes in freshwater and nutrient input, and relative to sea level rise?

- Develop quantitative relationships and predictive models of mangrove productivity and plant community dynamics relative to freshwater inflow, salinity patterns, nutrient inputs, and sea level rise.
- Develop a landscape model to predict changes in mangrove zone habitat types, especially the white zone, and physiography relative to freshwater inflow and sea level rise

➢ How will transition zone system productivity, nutrient retention, and elevation and change with changing freshwater and nutrient input and sea level rise?

- Develop quantitative relationships of net storage or release of nutrients in soils and plant biomass. Measure rates of soil accretion and subsidence.
- Measure rates of nitrogen transformation (particularly nitrogen fixation and denitrification).
- Incorporate dynamics of transition zone nutrient uptake and release and net ecosystem production in Florida Bay water quality model, such that nutrient export to the bay is predicted.

- How will changing salinity and hydrology in the mangrove-estuarine transition zone affect populations of resident mangrove fishes and their ability to support nesting colonies of wood stork and roseate spoonbill?

    - Develop quantitative relationships and predictive models of resident mangrove fish population density and size structure in relation to estuarine productivity, salinity and hydrology.
    - Develop quantitative relationships and predictive models of the energetic requirements of wood stork and roseate spoonbill nesting colonies in relation to the population density, size structure and seasonal concentration of resident mangrove fishes.

3.5.2 Other Science Needs

The other science needs for the mangrove-transition zone overlap with and are incorporated in the other non-geographically based themes.

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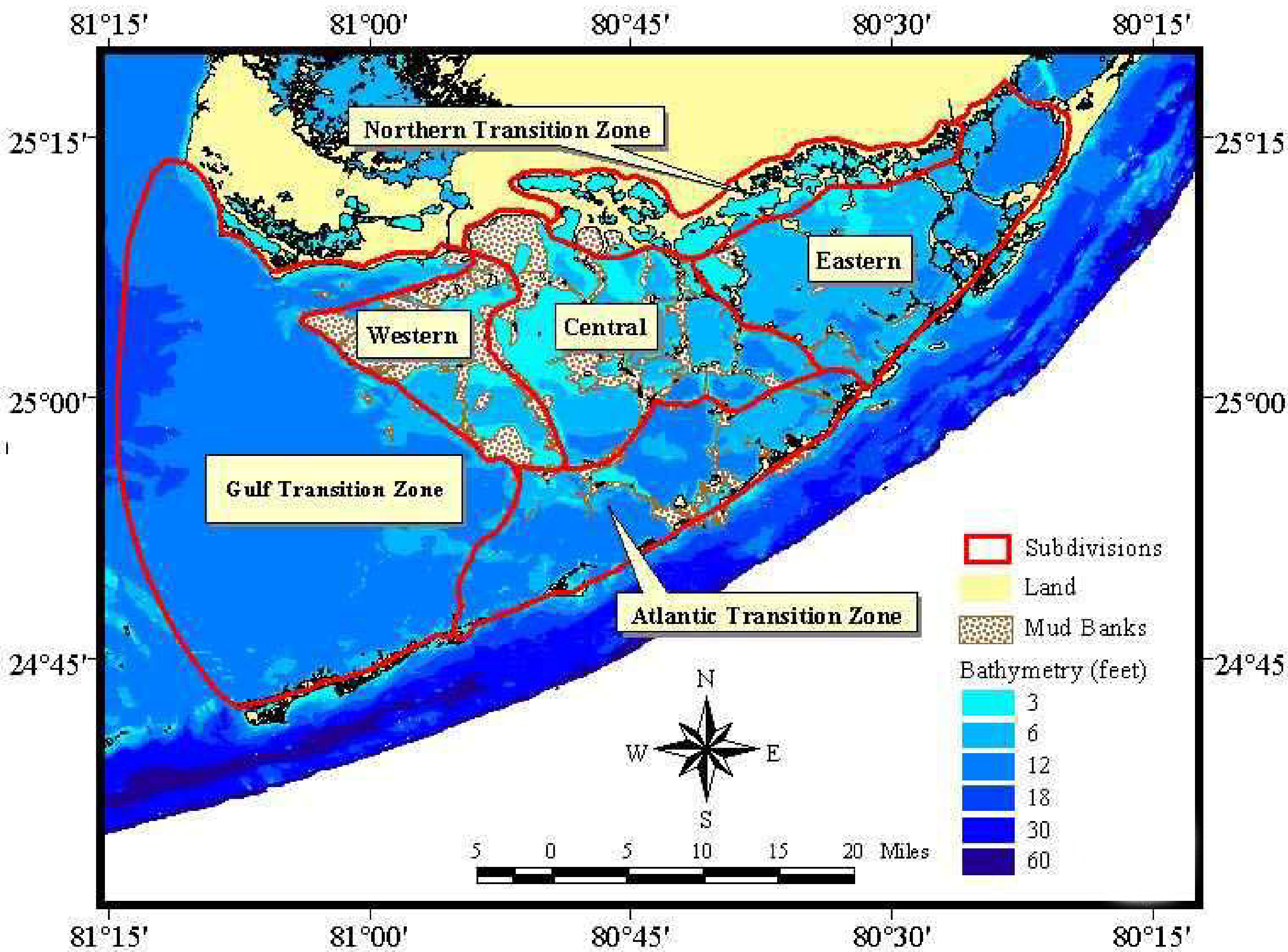
Appendix A: SCIENTIFIC ACCOMPLISHMENTS OF THE FLORIDA BAY AND ADJACENT MARINE SYSTEMS SCIENCE PROGRAM

Since the program's inception ten years ago, a great deal of progress has been made in understanding the physical, biological and chemical factors that regulate change and stability within the Florida Bay environment. Highlights from the synthesis document (PMC [in press]) in regards to Ecosystem History, Physical Processes, Nutrient Dynamics, Plankton Blooms, Seagrass Ecology and Higher Trophic Levels are given below and follow the 1997 PMC established nomenclature of zonation within Florida Bay (see Fig. A-1).

Figure A-1. Florida Bay Zones



Ecosystem History: While quantitative observations on the state of the Florida Bay ecosystem date back to the 1950s, they are not sufficient to provide an accurate representation of the bay's natural state. Major changes had already occurred in the hydrology of the Everglades by the time these studies were initiated. Fortunately, through analysis of coral and sediment cores we can learn about the history of the Florida Bay ecosystem over the past 150 years or so. These analyses indicate that:

- The sediment record of epiphytal ostracods and mollusks suggests that seagrass has been more abundant in the last 50 years compared with the first half of the 20th century. These data suggest that dense and abundant seagrass beds may not have been the long-term stable state of the ecosystem.
- Benthic macroalgae may have increased in recent decades.
- Blooms have occurred sporadically in central Florida Bay over the sediment record and along the western margin since at least the 1970's.
- Sediments from limited cores in northeast Florida Bay show evidence of recent organic and nutrient (i.e., carbon, nitrogen, and phosphorous) enrichment (1980 to present).
- Northeast Florida Bay appears to be a source of phosphorus to the mangrove zone at the southern end of Taylor Slough. Taylor Slough does not appear to be a significant phosphorus source to northeast Florida Bay. This is consistent with present water column phosphate concentrations which are higher in Florida Bay than in Taylor Slough or the Everglades wetlands.
- Geochemical changes recorded in coral bands suggest that construction of the Flagler Railroad and Overseas Highway altered local exchange with the Atlantic by blocking passes between the Keys.

Physical Processes. Research on physical processes aims to identify the main external factors that control the movement of water and solutes within Florida Bay and their exchange with the Everglades and adjacent marine systems. Two physical characteristics of Florida Bay that distinguish it from most other estuaries in the U.S. are the restricted exchange across the shallow but otherwise open boundary with the Florida Shelf and the relatively small amount of terrestrial freshwater discharge to the bay.

- Florida Bay salinity is directly related to the net flux of fresh water from the combined influence of evaporation, precipitation, and runoff. Evaporation is approximately equal to precipitation, while runoff is roughly ten percent of either. Historical salinity data and salinity proxy data show that Florida Bay salinity has commonly undergone large salinity changes on time scales of seasonal, interannual (ENSO), decadal (NAO) and even longer periods that are not understood.

- For the past several decades, Florida Bay has behaved as a marine lagoon with salinity reaching 70 ppt in the central region during the drought years 1989 and 1990. Bay salinities have since declined under the influence of increased precipitation.
- Shallow bank configurations that restrict water exchange tend to separate the bay's interior into three distinct regions with differing salinity regimes. The northeast region is the most isolated from oceanic influences, receives most of the surface runoff and has the largest seasonal cycle of salinity; the central region receives little runoff and has the maximum salinity; and the basins in the western region have the greatest oceanic/Gulf of Mexico exchange and the smallest seasonal change in salinity.
- Stable isotopic markers indicate that runoff from the Everglades is the dominant source of fresh water to the northeast region of Florida Bay; whereas for the western region precipitation dominates. In the central region a mixture of runoff and precipitation provides the fresh water.
- Since 1985, freshwater discharges from Taylor Slough and the C-111 canal have increased as a consequence of changes in water management. Trout Creek conveys the largest volume of fresh water to northeast Florida Bay. Negative flows can occur during the dry season and during storm events.
- Groundwater inflows are believed to be most influential along the northern boundary of the bay. However, estimates for the rate of groundwater discharge are highly uncertain, ranging over four orders of magnitude depending upon the methodology applied.
- Seasonal cycles in local wind forcing produce distinct seasonal patterns in internal circulation.
- South Florida coastal current systems provide seasonal pathways for local larval recruitment and opportunities for recruitment from remote sources.

Nutrient Dynamics. In contrast to water movement and salinity, both external and internal processes combine to determine characteristics of water quality. The historical sources of nutrients have proven difficult to quantify, thus, making it difficult to resolve the question of whether the seagrass die-off and subsequent plankton blooms were triggered by the onset of eutrophication of Florida Bay.

- Temporal trends over the last 13-years show bay-wide declines in total phosphorus, total nitrogen, and chlorophyll *a* with an overall increase in turbidity.
- Objective analysis shows that northeast, central, and western Florida Bay exhibit significant differences in water quality characteristics due to nutrient inputs, tidal advection, and water residence time. In general, phosphorus concentrations increase while nitrogen decreases from east to west resulting in a shift from potential phosphorous limitation to nitrogen limitation.

- Atmospheric input of nitrogen is presently large relative to the other sources.
- Terrestrial nutrient loading fluctuates in phase with freshwater flow; however, flow weighted concentrations decrease with increasing flow.
- High rates of organic carbon and nitrogen fluxes occur, both into and out of sediments, over diel cycles. Benthic denitrification is higher than predicted from nitrogen-loading rates.
- Sediment flux of ammonium decreases with increase in sediment chlorophyll *a* concentration indicating that the microphytobenthos is important in regulating water column nitrogen concentrations.
- There is very little, if any, inorganic phosphorous flux out of the sediments with the exception of the western bay/Shelf area where it can be made available through resuspension.

<u>Plankton Blooms</u>. Research on plankton blooms in Florida Bay has been directed at describing the combination of internal and external conditions associated with the onset, persistence and fate of blooms in this ecosystem. On a mechanistic level, plankton blooms form whenever plankton growth exceeds the combined effect of grazing and dispersion. Research to date indicates that there are three ecologically distinct bloom regions in the Florida Bay ecosystem – the northeast region, central region, and west region.

Northeast Region:

- Algal blooms are largely absent from the northeast region of Florida Bay. The phytoplankton community of the northeast region is a diverse mixture of cyanobacteria, dinoflagellates, diatoms and microflagellates, none of which form blooms.
- The lack of algal blooms in the northeast region of Florida Bay is largely attributable to severe phosphorus limitation. Despite significant water inflows to the region from the Everglades, the very low phosphorus levels in these inputs and strong binding with calcium carbonate particulates result in nutrient-limited conditions.

Central Region:

- Large algal blooms have been a common feature of the central region since at least 1992. The greatest bloom activity is generally in the summer and early fall. Blooms originating in the north central region are pushed southward by prevailing wind-driven circulation into the south central region and Atlantic Transition Zone, where they can spread out into the Atlantic reef tract through passes between the Florida Keys. The dominant bloom-forming alga in the central region is the picoplanktonic cyanobacterium *Synechococcus elongatus*, although several species of diatom and dinoflagellate do occasionally occur in bloom proportions.

- Nutrient limitation of phytoplankton growth in the central region appears to alternate between phosphorus and nitrogen. Potential nutrient sources include: 1) benthic flux (internal cycling) (N); 2) groundwater (P); 3) tidal exchange with the Gulf of Mexico or northeast region (N or P); and 4) atmospheric deposition (N). These sources are not mutually exclusive; all or several may be operating simultaneously.
- The dominance of *Synechococcus elongatus* is attributable to the unique ecophysiological characteristics of this species of cyanobacterium. These characteristics include: 1) wide tolerance to salinity; 2) superior ability to compete for phosphorus at low concentrations; 3) ability to regulate buoyancy and, thereby, take advantage of nutrients available in the sediments; 4) lower susceptibility to grazing losses; and 5) ability of local isolated strains to store nutrients (N and P) during periods of low availability.

West Region:

- The diatom-dominated blooms in the west region are composed mainly of *Rhizosolenia* spp. *Chaetoceros* spp. and pennates. Diatom blooms in the west region typically begin in late summer and are advected into the western bay from shallow coastal waters off Cape Sable.
- The diatom blooms are generally nitrogen limited. The onset of diatom blooms appears to be associated with enhanced riverine outflow from the Shark River and associated inputs of nitrogen and silicate.

<u>Seagrass Ecology.</u> Seagrasses account for a major portion of the primary production in the Florida Bay ecosystem and are a critical habitat feature for higher trophic level organisms. Therefore, it is particularly important to understand the mechanism for the die-off observed in the late 1980s and the relation of this event to the algal blooms that occurred subsequently. The loss of seagrass observed in other estuaries has been explained as a consequence of eutrophication increasing algal growth and reducing the amount of light available to the seagrasses. The seagrass die-off in Florida Bay did not follow this pattern, and its cause may be unique to Florida Bay.

- Geographic variation in patterns of seagrass loss suggests multiple causes and requires a distinction between primary die-off and secondary mortality. There is a high spatial coincidence among the distribution of *Thalassia* loss, *Labyrinthula* abundance, high sediment sulfide levels, and turbidity. Determining the relative contributions of these factors to die-off versus secondary mortality has been problematic.

- Primary die-off is associated with high-density *Thalassia* beds. High-density beds result in conditions that increase stress on *Thalassia*: high sediment sulfide levels; self-shading of shoots; night-time/early morning anoxia/hypoxia in meristems; and increased susceptibility for leaf-to-leaf transmission of the *Labyrinthula* disease organism.
- Recent bay-scale changes in seagrass distribution and abundance following the region-scale primary seagrass die-off (1987-1991) are largely due to secondary mortality of *Thalassia* associated with areas of chronic turbidity (since 1994) in the west region.
- There has been little net change in seagrass distribution and abundance since 1995 in central basins that are periodically subjected to low salinities. Low salinity may provide refugia from disease since *Labyrinthula* has never been observed in Florida Bay in salinities below 15 psu.

Higher Trophic Level Species. Florida Bay supports many ecologically and commercially important animal species. Research on these species has focused upon the influence of physical circulation, water quality, and benthic habitat on the growth and survival of individuals, populations, and communities. A key objective has been to formulate models that can predict how valued species can be expected to respond to changes in water quality, habitat structure and the supply of freshwater.

- Salinity patterns and variability directly affect recruitment, survival and growth of many animals that live in and use Florida Bay as a nursery ground. We have sufficient information on about a dozen key species to predict how they will respond to future salinity conditions that might arise from altered freshwater inflow into Florida Bay.
- Analysis of historical data indicates that water management activities can affect the productive capacity of Florida Bay. This information has been used to predict the annual catch of pink shrimp in the Dry Tortugas fishery based on upstream hydrologic conditions in the Everglades.
- Seagrass diversity may determine faunal density; many faunal species have affinities to certain seagrass community types. No faunal species is favored by monospecific *Thalassia*.
- Characteristics of shoreline habitats affect abundance and community composition in the bay. Mangrove prop root habitat in the northeast region has significantly more fish larvae than nearby open water sites or nearshore areas without mangroves.
- Fishing affects fish populations. Recreational fishing in Everglades National Park affects the size structure of gray snapper. Evidence of overfishing is seen in gray snapper and other species on the reef tract.
- Postlarval shrimp enter the bay preferentially where tidal flows are greatest. Peak

concentrations of postlarval pink shrimp are roughly an order of magnitude greater in passes leading into the west region from the Gulf of Mexico than in channels to Florida Bay through the Florida Keys.

- The food web exhibits the same regional structure as seen in the variation of circulation, salinity, and water quality. Based on stable isotope analyses, the central region has a strongly seagrass-based trophic structure; whereas the northwestern and eastern bay have a more plankton dominated trophic structure. The trophic structure of the southwestern bay is based on macroalgae. Contrary to speculation in the mid 1990's, there is no indication of a general shift from seagrass/benthic to plankton/pelagic structures.
- Temporal variation in recruitment strength of spiny lobster, gray snapper, and pink shrimp is related to regional oceanographic processes, especially the Tortugas gyres.
- Sources of elevated mercury concentrations in fish from northeast Florida Bay include (1) methylmercury in runoff from the Everglades and (2) *in situ* mercury methylation in sediments from both the mangrove transition zone and the open bay itself.
- Loss of benthic filtering sponges in the early 1990s may have reduced overall water clarity in parts of Florida Bay.
- Sponge population recovery since the early 1990s dieoff has been extremely slow.

Appendix B: ORGANIZATIONAL STRUCTURE OF THE FLORIDA BAY AND ADJACENT MARINE SYSTEMS SCIENCE PROGRAM

Program Management Committee:

Guiding the science program are representatives from each of the 10 federal and state agencies with regulatory, management, or other responsibilities in Florida Bay and its surrounding marine ecosystems. Members of the Program Management Committee (PMC), each of whom typically have programmatic responsibilities within their respective agencies, meet on a monthly basis to discuss restoration and natural resource management issues and needs and to coordinate science activities relevant to the geographic scope of the program.

The PMC establishes direction and priorities for science activities through:

- a strategic plan;
- recommendations to participating agencies;
- peer review of research proposals (at request of agencies);
- facilitating synthesis of scientific information to assess/identify critical issues;
- making recommendations to CERP and participating agencies on research, monitoring and modeling; and
- nurturing development of regional science programs focused on adjacent areas.

More specifically, the PMC:

- helps to evaluate and provide scientific basis for ecological targets and performance measures;
- oversees and facilitates development of credible predictive tools;
- interprets status and trends and predictions;
- oversees activities of science teams;
- sponsors topical workshops and science conferences; and
- communicates results to other scientists, reviewers, managers and the public.

The continued viability of the PMC with its many federal and state agencies working together to ensure the best and most efficient use of limited resources (both financial and other) while continuing to deliver quality science remains a fundamental challenge given each agency's unique mandates and very different internal procedures and budget processes.

Science Teams:

Functioning science teams add immeasurable value to the program. Unfortunately, agency constraints combined with lack of sufficient funding, make it impossible to maintain them at this time. Regardless, the PMC is committed to reinitiating the teams should funding become available and, therefore, they have been included as an essential component within the program's organizational structure.

To date, these teams have been organized around the 1997 strategic plan's five central questions with the primary objective being to develop scientific knowledge of Florida Bay through coordinated research, modeling, and monitoring activities. However, given the maturation of the program and the needs to evolve with and respond to new demands from the implementation of restoration, the topical emphasis of these teams if reinitiated would have to be revised.

Although the PMC recognizes the need for integration across ecosystem type and region to answer restoration and natural resource management issues, arranging multiple science teams in this manner would create a tremendous organizational problem. Therefore, science teams will be organized into five topical/model themes (i.e., physical processes [hydrodynamics], water quality, benthic habitats, higher trophic levels, and the mangrove-estuarine transition zone), and one model integration team. The integration team will consist of the five topical/model team chairs and their respective PMC leads and will be charged with ensuring that the physical modeling supported will address the ecological and water quality needs and water quality modeling will be sufficient for ecological uses and other cross-disciplinary requirements. This holistic ecosystem approach is seen as especially critical (Hobbie et al. 2003 and 2001). Another responsibility of this team will be to ensure that modeling efforts are sufficient to accommodate natural variability (e.g. sea level rise) that could mask or modify the ability to predict restoration-related changes in system state.

Specific functions of all teams will be to:

- facilitate communication among scientists,
- coordinate field work at common sites,
- standardize data collection methods,
- assemble key data sets,
- develop conceptual and predictive models, and
- interpret and synthesize results of science activities.

Science Oversight Panel:

Independent, expert review is an integral component of the program as well. This need will continue to be served by the Science Oversight Panel (SOP), which provides technical and management review of the quality of the research, modeling, and monitoring activities in Florida Bay and the scientific results and inferences from these activities. The SOP also provides guidance to the PMC on strategies for program development. Members of the SOP participate in science conferences by formally leading question and answer sessions and by providing written reports to the PMC presenting critical review and recommendations for advancing the program (most recently, Hobbie et al., 2003). Additionally, at the request of the PMC, the SOP participates in *ad hoc* advisory panels of experts for specialized technical workshops e.g., circulation modeling.

The present SOP consists of six senior scientists with significant experience in major estuarine restoration programs but without involvement in Florida Bay projects. Although the geographical scope of the FBAMS Science Program goes beyond the geographical area Florida Bay and this strategic plan, the SOP has specifically declined the opportunity to expand its role to address any of the existing or planned scientific activities in adjacent marine systems (e.g. Biscayne Bay or waters of the Florida Keys). To address this issue, the PMC is considering an explicit oversight sub panel or additional panel for Biscayne Bay and a link to the Florida Keys National Marine Sanctuary Technical Advisory Committee. The PMC also feels that, while the expertise of the existing panel members covers the breath of our program, it may be advantageous to invite an additional panel member with expertise in applied science/adaptive management given that science information from our program so strongly supports the CERP adaptive management framework.

Science Conference:

The first science conference was held in 1995 and, since that time, conferences have been an integral part of the FBAMS Science Program. The science conference is intended to: 1) facilitate interagency and agency/academia collaboration and exchange of scientific information, 2) update the Florida Bay Science Oversight Panel so they can recommend necessary programmatic changes to the PMC, and 3) publicize preliminary research results prior to publication since some are relevant to ongoing restoration management decisions. To date, six conferences have been held, the latest (April, 2003) being a Joint Conference with Greater Everglades Ecosystem Restoration. The next conference is tentatively scheduled for late November/early December 2005.

Topical Workshops:

To seek resolution to and establish consensus on high profile scientific issues (e.g., nutrients) or simply to gain a better understanding of a particular topic, the PMC sponsors workshops. Some of these workshops include ad hoc advisory panels and most lead to written recommendations that the PMC accepts as guidance in coordinating the interagency program. Nearly all of these workshops have some form of documentation available on the program's web site at http://www.aoml.noaa.gov/flbay/pmcrschtms.html .

Appendix C. ON-LINE RESOURCES

A Synthesis of Research on Florida Bay
http://www.aoml.noaa.gov/flbay/draft/wkn_contents.pdf

An Adaptive Assessment Strategy for the Comprehensive Everglades Restoration Plan
http://www.evergladesplan.org/pm/recover/recover_docs/aat/032700_aat_strategy.pdf

Biscayne Bay Strategic Science Plan
http://www.aoml.noaa.gov/ocd/sferpm/bbscienceplandraft.pdf

Comprehensive Everglades Restoration Plan (CERP)
http://www.evergladesplan.org

Coordinating Success: Strategy for Restoration of the South Florida Ecosystem.
http://www.sfrestore.org/documents/isp/sfweb/sfindex.htm

Florida Bay and Adjacent Marine Systems Science Program
http://www.aoml.noaa.gov/flbay/

Florida Bay/Florida Keys Feasibility Study
http://www.evergladesplan.org/pm/studies/fl_bay.cfm

Recommendations for Interim Goals and Interim Targets for the Comprehensive Everglades Restoration Plan: Indicators and Prediction Methods
http://www.evergladesplan.org/pm/recover/recover_docs/rlg/013004_rlg_ig_it_report.pdf

South Florida Ecosystem Restoration Task Force
http://www.sferstore.org