The Florida Bay and Adjacent Marine Systems Science Program:

An effective model for science program management?

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Abstract

Over the past several years there have been indications that the environmental health of Florida Bay may be deteriorating. These indications include but are not limited to the following: 1) a perceived decline in fishing success for many of the commercial and recreational species that depend upon the Bay as a juvenile nursery habitat, 2) atypical algal blooms across much of western Florida Bay, some extending into the Florida Keys, 3) massive seagrass die-offs in western Florida Bay since the summer of 1987, 4) recent reports that mangroves within the Bay are in decline, and 5) sponge mortalities as a result of algal blooms. While the causes of the various problems and the relationships between them are not well understood, there is definite concern that the coastal marine ecosystem of Florida Bay may be in jeopardy.

To generate the requisite scientific information, a group of federal and state agencies have been collaborating in an interagency Florida Bay Science Program. The program is centered around the *Strategic Plan for the Interagency Florida Bay Science Program* to ensure that participating agencies are conducting closely complementary research, monitoring, and modeling projects which, together, should provide the answers to the most critical scientific questions about the Bay ecosystem.

An analysis of the Florida Bay Science Program since inception has shown that considerable progress has been made in understanding many of the previously unanswered questions about the Bay, but further research and monitoring is necessary. In addition, changes to the program's structure, process, and methods of communication are necessary to make it more effective and scientifically consensus based as well as accommodate the changing needs of restoration managers. More specifically, a dedicated effort must be made at providing policy makers timely and reliable scientific information and science-based recommendations before restoration decisions are made.

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Introduction

I. Description

Florida Bay is a triangularly shaped body of water approximately 2200 km^2 in area and is bordered on the north by Everglades National Park, on the east/southeast by the Florida Keys, and on the west by the Gulf of Mexico. Thus, Bay waters are a mixture of freshwater runoff from the Everglades and saltwater entering from the Gulf of Mexico around Cape Sable (see Figure 1). These waters circulate through the west and central portions of Florida Bay before exiting both south through Keys inlets seaward to the coral reef tract and southwest back into the Gulf. Clearly, these environments constitute a closely coupled coastal landscape and cannot be studied in isolation.

The Bay is shallow (<2m) and contains dense seagrass beds, extensive carbonate banks, and hundreds of keys covered primarily with mangroves. These banks and keys act to restrict water flow, increase sedimentation, and offer a transitional environment between marine and terrestrial conditions. Once formed, they self-perpetuate, gradually increasing in size and coalescing with other nearby islands.

II. Environmental Problems

Florida Bay is an extremely unique environment that supports numerous federally protected species including the bottle-nosed dolphin, *Tursiops truncatus*, the American crocodile, *Crocodylus acutus*, and the West Indian manatee, *Trichechus manatus*. It is also a primary inshore nursery for the offshore Tortugas pink shrimp, *Farfantepenaeus duorarum* (Browder et al., 1999).

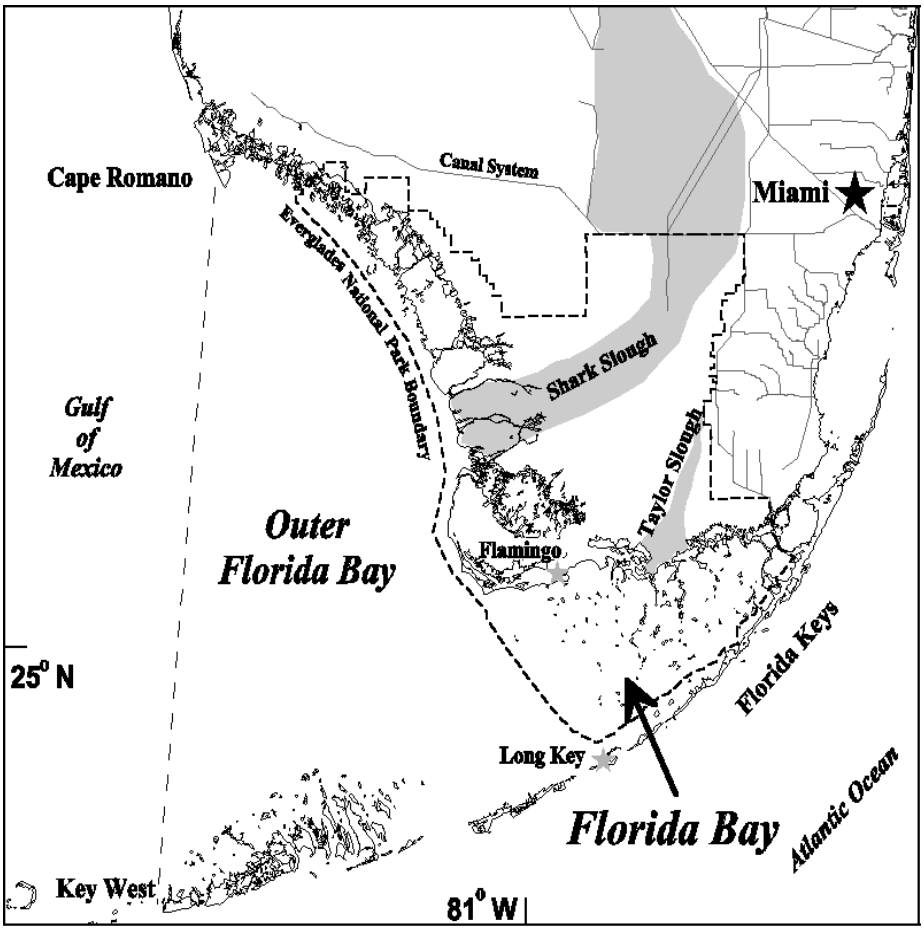

Figure 1. Map of Florida Bay (Fourqurean and Robblee, 1999)

Unfortunately, there are indications that the environmental health of Florida Bay may be deteriorating. In late 1987, massive seagrass die-offs, particularly *Thalassia testudinum*, began occurring in western Florida Bay (Zieman et al., 1988; Robblee et al., 1991; Durako, 1994; Hall et al., 1999; Zieman et al., 1999), a phenomenon not previously observed in this area nor reported in the scientific literature before 1987. Since that time, numerous atypical algal blooms have been observed, most notably in the north-central region of the Bay although some have extended into

the Florida Keys (Phlips et al., 1995; Steidinger et al., 1995; Steidinger, 1996; Boyer et al., 1999). These blooms have resulted in sponge mortalities which may affect lobster recruitment (Butler et al., 1995). In addition, fishing success has declined for the Tortugas Pink Shrimp, a major commercial fishery, suggesting a decline in recruitment into Florida Bay (Browder et al., 1999; Ehrhardt and Legault, 1999). Most recently, mangroves within the Bay are reported to be in decline (Armentano, 1995; Carlson et al., 1995).

Problems can also be seen in the Everglades and areas further north. Presently, 68 plant and animal species within Everglades National Park are listed as threatened or endangered, wading bird populations are down by 90 percent, and invasive exotic species have out-competed native plants in many areas (SFERTF, 1999). In addition, phosphorus (Goforth et al., 1994) and nitrogen (Culotta, 1995) from both urban and agricultural runoff have contaminated the region's waters. There are problems downstream of Florida Bay as well. The incidences of coral disease along the reef tract are 4 times higher now than in 1996 (McManus, 1997) and while the causes are not fully understood, it is generally accepted that Florida Bay most certainly plays a role.

III. Coordinating the Science

Since no one can turn back the clock and South Florida's rapid development will almost certainly continue, a series of compromises and tradeoffs will have to be made in restoring and maintaining a healthy South Florida coastal ecosystem including Florida Bay. It is essential that these decisions be made based on reliable scientific information. To generate the requisite information, a group of federal and state agencies have been collaborating in an interagency Florida Bay Science Program.

Statement of Purpose

The purpose of this Capstone review paper is to provide an overview of the Florida Bay Science Program, compare the initial and existing science plans providing a brief summary of science progress to date, discuss both the program's accomplishments and shortcomings, and offer recommendations that could enhance the overall effectiveness of the program.

Overview

I. Historical Perspective

Before human alteration, the greater Everglades system (Kissimmee-Okeechobee-Everglades) held water within a broad valley defined by an eastern and western coastal ridge. Very subtle decreases in the land's elevation allowed water to move in a sheet-like flow, nearly 40 miles wide, 100 miles long, and in some places up to 2 feet deep, south from central Florida's Chain of Lakes through the Kissimmee River Valley to Lake Okeechobee then onto the Everglades and Florida Bay. Since most of the rain that fell was to the west of the eastern coastal ridge, it was often held within the Everglades where it would seep into the ground and recharge the Biscayne Aquifer. To this day, nearly all of South Florida's water supply is from this aquifer.

Because of Florida's landscape, natural events including hurricanes, drought, fire, and rain kept most development initially centered on the higher areas of the coastal ridges. In fact, computer models now show that the coastal ridges of Florida were the only areas of South Florida where settlement could have occurred naturally (Robinson et al., 1996). It was not until the late 1700s that European colonization took hold and, as a result, the landscape began to change

significantly through deforestation, conversion to agriculture, and removal of natural water systems, particularly in South Florida (Ewel, 1990).

While the construction of canals and dikes that began in the 1880s was initially a private endeavor, the State joined in during the early 1900s by dredging more canals and creating the Tamiami Trail, one of the longest dikes in the world. Following two severe hurricanes in 1926 and 1928 in which water was pushed out of Lake Okeechobee drowning nearly 2,000 people and injuring an additional 2,000, the Hoover Dike was constructed around the entire rim of the lake in 1930. This dike is the largest impediment to free flowing water across South Florida.

After these hydrological modifications were completed, South Florida alternated between not having enough water and having too much. Thus, in 1950, the Army Corps of Engineers (USACE) began a massive water management project, the Central and Southern Florida (C&SF) Project in which more canals, pumping stations, water storage areas, and levees were created. While earlier projects were aimed primarily at flood control, the C&SF Project focused more on storing and moving water and making South Florida less vulnerable to the region's natural water cycle. As a result, billions of gallons of once naturally flowing water into the Everglades was diverted into the Atlantic and the Gulf of Mexico and the water that remained was significantly restricted in flow. Although well intentioned, the USACE's actions destroyed hundreds of thousands of acres of wildlife habitat and severely impacted South Florida's natural water treatment system. Today, the Everglades is less than half of its original size (Davis and Ogden, 1994) and is considered to be one of the most threatened ecosystems in the world.

On its present course, the ecology of South Florida including Florida Bay is not sustainable. The population has grown by nearly 2.4 million people in the last 40 years (BBR, 1996) with more than 6.5 million people residing in the area today (SFERTS, 1999), and the C&SF Project is having to supply water for a population 3 times that which was predicted for the Year 2000. Further, 37 million tourists visit the area annually to experience the region's cultural diversity, pristine beaches, weather, and abundance of recreational activities including boating, diving, and commercial and recreational fishing. Even more sobering are the growth predictions for the future i.e., 12-15 million people by 2050 (USACE and SFWMD, 1999). Clearly, maintaining a healthy ecosystem is now a necessity not only to support wildlife habitat but industry and an ever-increasing population as well.

II. Authority & Responsibility

Decisions about water for South Florida are made by the South Florida Water Management District (SFWMD) whose mandate is to meet the water needs of the public. Unfortunately, this policy has come at a cost to the environment. In 1968, just 18 years after the C&SF Project was begun, research within Everglades National Park (ENP) indicated that not enough water was flowing through ENP to sustain the natural system. Since that time, there has been an explosion of scientific evidence to support those initial claims, and while the full impacts of the USACE's alterations to the natural hydrology may never be known, it is certain that the altered hydrology has affected salinity patterns in Florida Bay, plant and animal biodiversity in both aquatic and terrestrial systems, animal behavior, natural fire regimes, and exotic species. In fact, Florida Bay now receives less than 1/10 of its original amount of water (The Nature Conservancy, 1998).

Water quality, timing, and distribution are important as well. Plants and animals in the Everglades are adapted to natural cycles of wet and dry. Too much water at the wrong time or not enough water at the right time can be extremely damaging. In the past, managers from both the SFWMD and the USACE made little effort to match the timing of water delivery with that of pre-existing patterns of natural hydrology. During times of drought, only small amounts of water were allowed into the Everglades and, subsequently, wildlife dwindled. Then when plenty of water was available, managers allowed too much water into the Everglades flooding crocodile nests, drowning deer, and forcing nesting birds to abandon their hatchlings in search of areas with lower water levels.

III. Restoration

These practices and perspectives began to change sometime between the 1960s and early 1970s when concern for the Everglades and its plant and animal life grew. What was once considered a miserable, bug-infested swamp began to be recognized as a highly valued resource. Ehler (1996) suggests that Marjorie Stoneman Douglas' book, *River of Grass*, may have been the catalyst for this change in perception. While this may be true, a tremendous increase in population coupled with a severe drought in 1971 resulted in numerous conflicts between water users in South Florida. Concurrent with this public concern for the Everglades was criticism of the SFWMD's water management practices and the USACE's extensive C&SF Project. While agriculture had all the water it needed, the ENP was literally drying up and dying.

In 1970, the Water Resource Development Act was established which required an annual minimum water delivery to the ENP. While this was the first step in ensuring that ENP had a

minimum amount of water to meet its needs, it did not solve the problem of quality, timing, and distribution. More attention was brought to the Everglades system in 1983 with the Governor's Save Our Everglades Program, a collaborative effort between governmental agencies and the SFWMD. Since then, other Acts have been established such as the 1987 Florida Surface Water Improvement Act, the 1990 Florida Preservation 2000 Act, and the 1991 Florida Everglades Protection Act but, to date, most of South Florida is designated as a "critical water supply problem area".

The SFWMD predicts more frequent and severe water shortages in the future if no significant changes are made now. But how does the SFWMD meet the growing demands on a limited resource for which there is so much competition? The challenge seems daunting because growth, agriculture, and environmental protection all require water at specific times and places. Meeting the challenge is further complicated because in South Florida the environment is the economy. Major natural areas like Florida Bay, Biscayne Bay, and the Everglades not only support tourism but are a source of jobs as well.

To address these concerns South Florida is now involved in one of the largest restoration efforts ever undertaken. Guiding this restoration effort is the South Florida Ecosystem Restoration Task Force (SFERTF). Initiated in 1993 through a cooperative endeavor, representatives from six federal agencies: 1) Department of Agriculture, 2) Department of Commerce, 3) Department of the Army, 4) Department of the Interior, 5) Environmental Protection Agency, and 6) Department of Justice, established an interagency agreement to facilitate consistent policies and priorities for South Florida restoration. In 1996 as a result of the Water Resources Development

Act, the Task Force expanded and now includes members from state agencies and local tribes and groups as well.

The three primary goals of the Task Force are: 1) restoring a more natural hydrology to the region while still meeting the water needs of growth, development, and agriculture (including flood control); 2) restoring native habitats; and 3) balancing environmental needs with social and economic needs i.e., no more degradation.

Concurrent with and integral to the overall restoration effort has been the USACE's Comprehensive Review Study or 'Restudy' (authorized by the 1992 Water Resources Development Act) of the C&SF Project. The Restudy's primary purpose was to evaluate the current water distribution system and to develop and implement a comprehensive plan to meet the water needs of South Florida through 2050. The evaluation process consisted of nearly 100 specialists from federal, state, regional, local, and tribal groups working together for more than six years to build some type of consensus in formulating goals. While it is impractical to list every agency or group involved, the Restudy included such agencies as the US Fish and Wildlife Service (USFWS), the Environmental Protection Agency (EPA), the US Geological Survey (USGS), Florida Game and Freshwater Fish Commission, The Nature Conservancy (TNC), Florida Department of Agriculture, and the Miccosukee and Seminole Tribes. Other stakeholders such as the Governor's Commission for a Sustainable South Florida and the public were important to the process as well. In July of 1999, the USACE submitted a *Comprehensive Plan* to Congress which recommended specific improvements to the water systems over the next 20 years. The

estimated cost to implement this plan is $7.8 billion, and a response from Congress is expected late summer of 2000.

IV. Florida Bay and Adjacent Marine Systems Science Program

More freshwater alone will not return Florida Bay to its pristine condition. The timing, distribution, and quality of freshwater released to the Bay must also be considered but, at present, there is insufficient scientific knowledge to predict with confidence the consequences of anticipated alterations in freshwater input to Florida Bay.

The Florida Bay and Adjacent Marine Systems Science Program was established to generate the requisite scientific information thereby allowing restoration managers to make informed decisions on how to best restore the Bay to a more naturally functioning ecosystem.

A. Background

The program had its beginnings in 1993 when the ENP, in response to increasing local concern, formed the then Florida Bay Interagency Working Group to focus research objectives in Florida Bay as they applied to restoration. The initial working group consisted of six scientists, one each from the following agencies: 1)ENP, 2) National Biological Survey (NBS), 3) SFWMD, 4) Florida Department of Environmental Protection (FDEP), and two from the 5) National Oceanic and Atmospheric Administration (one representing Oceanic and Atmospheric Research [NOAA/OAR] and the other representing National Marine Fisheries Service [NOAA/NMFS]). While Florida Bay lies entirely within the jurisdiction of either the ENP (ca. 85%) or NOAA (ca.15%), the other agencies were included for either their management responsibilities regarding water delivery or state fisheries i.e., SFWMD and FDEP, respectively, or for their role in

establishing and maintaining a long-term monitoring program which established baseline data on water flows into coastal areas i.e, USGS.

In September of 1993, at the request of the Assistant Secretary of the U.S. Department of the Interior, a panel of experts was convened to review the scientific literature available on the declining ecosystem of Florida Bay. As a result of their findings, the panel recommended a more formal management framework to the Florida Bay Interagency Working Group that included a Program Management Committee (PMC), a Technical Advisory Group (TAG), and a Scientific Review Panel.

Based on these recommendations, in April of 1994 the Florida Bay Interagency Working Group changed their name to the Program Management Committee (PMC) and developed the first science plan for the Florida Bay region i.e., the *Florida Bay Science Plan*. Although not well organized, this initial plan was truly the basis for the program and included such information as management responsibilities and research activities, management framework, scientific goals and objectives, and research approach. More specifically, the plan identified 14 questions encompassing 72 specific associated tasks of varying urgency that should be addressed to further our understanding of the Florida Bay ecosystem. In addition, the plan formally established the PMC's presence in Florida Bay and provided the framework for the creation of the Florida Bay Scientific Review Panel (now called the Science Oversight Panel [SOP]) as recommended by the Department of the Interior's appointed panel of experts.

Over the next several years, the PMC expanded to include representatives from the EPA, the USACE, the USFWS, and the US Geologic Survey's Geologic Division (USGS/GD). The

NBS, already represented on the PMC, became part of the US Geologic Survey's Biological Research Division (USGS/BRD). In 1997, at the request of the Science Oversight Panel (formerly established as the Scientific Review Panel), the *Florida Bay Science Plan* was rewritten and renamed the *Strategic Plan for the Interagency Florida Bay Science Program* (SSP). Whereas the initial plan focused on developing and describing the program process as well as generic information/research needs, the new plan was organized around five central questions that defined working hypotheses and conceptual models (Ortner, 2000; Thompson, 2000). The new plan also defined program elements needed, some of which were in progress at the time the plan was rewritten, to address these five central questions:

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?

B. Current Structure

As stated previously, the science program is centered around the *Strategic Plan for the Interagency Florida Bay Science Program* (SSP). This helps to ensure that participating agencies on the PMC are conducting closely complementary research, monitoring, and modeling activities. Other components of the program include: 1) specific research, monitoring, and modeling activities, 2) research teams, 3) topical workshops, 4) annual science conferences, 5) communications, 6) program management, and 7) technical oversight How most of these components are intended to work together is shown in Figure 2.

Methodology

Since the science plans have been the basis for the overall program, I compared the most recent plan (Armentano et al., 1997) with the initial plan (Armentano et al., 1994) to determine the degree to which specific tasks identified in 1994 had been accomplished. Each of the 14 questions as well as the 72 tasks associated with those questions of the 1994 plan were analyzed and, based on various reports, abstract booklets, conversations with managers and scientists, and personal knowledge, a **very brief overview** of the program's research progress since 1994 is given below. Major Research Topic Areas, their associated questions, and representative samples of the specific 72 associated tasks identified in the 1994 plan are also included to provide a basis for comparison.

Results

<u>Major Research Topic Area:</u> Water Budgets, Circulation Dynamics, and Salinity

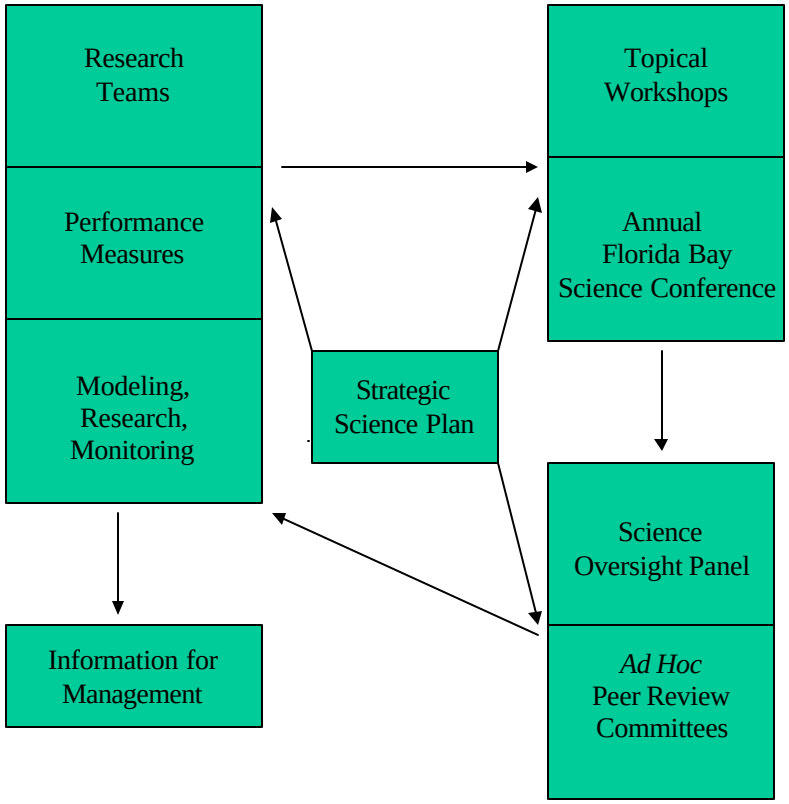

Figure 2. The Florida Bay Science Program Process

1. *What has been the relationship of surface water and groundwater flows through the Everglades to the salinity of Florida Bay? How has this relationship changed in the past, and how is it expected to change with future management plans?*

   - Determine the rates and effects of freshwater flows through Taylor Slough and channels and the canals and adjacent panhandle area on water quality in Florida Bay.
   - Determine the linkage between Shark River Slough discharges and Florida Bay.
   - Determine evaporation rates from the Bay and surrounding areas.

- Improve monitoring of rainfall.
- Develop a circulation dynamics model for Florida Bay.
- Integrate the circulation models of Florida Bay with larger-scale physical oceanographic, hydrological, and meteorological models that provide boundary conditions and forcing functions.

Progress from 1994 to 1997

Minor accomplishments were made both in regards to determining rates and effects of freshwater flows through Taylor Slough and channels (Johnson and Fennema, 1995; Patino 1995) as well as determining linkages between Shark River Slough discharges and Florida Bay (Swain and Patino, 1996). Results of salinity surveys, however, may provide answers to the dynamics of the freshwater plume from the Shark River. There was no work done on evaporation rates, but rainfall evaluation began in limited areas of South Florida (Willis, 1995; Willis et al, 1996). In the summer of 1995, several groups began collecting field data to define circulation for use in the hydrodynamic model (Lee and Johns, 1995; Patino, 1995; Smith 1995). A series of models were initiated in 1994 and 1995. USACE Waterways Experiment Station (WES) initiated a hydrodynamic model i.e., RMA2 (now RMA10) (Roig 1995; Roig 1996). Florida International University (FIU) and University of Virginia (UVA) initiated the FATHOM mass balance model for salinity (Nuttle et al., 1995). NOAA initiated a regional 2D model to establish barotropic boundary conditions for Florida Bay, and an atmospheric model for simulating local weather regimes (Mattocks et al., 1995; Mattocks et al., 1996). Other efforts included the ongoing monitoring of meteorological and oceanographic parameters (Vargo et al., 1995).

Progress from 1997 to Present

Although some instrumentation was installed to determine rates and effects of freshwater flows through Taylor Slough and channels, etc., the connection between canal flows and overland flow to the actual input to the Bay is still missing. Nothing more has been accomplished in regards to the linkage between Shark River Slough discharges and Florida Bay although the intended findings are to be part of the hydrodynamic model for Florida Bay. There is still no funded project for establishing evaporation rates despite the fact that this project was shown to be critical to our understanding of this major research topic. Major progress has been made regarding rainfall estimation, and the SOP has recommended that this project be made operational (Hobbie et al., 2000). Field data collection regarding circulation continues. The existing circulation models i.e,. RMA10 and FATHOM have been shown to be marginally useful and have, in fact, been recommended to be discontinued by the SOP (Hobbie et al., 2000).

2. *What is the effect of the relative lack of storms over the past three decades on the buildup of sediments, nutrients, and organic material in the Bay?*

- Conduct detailed bathymetry of the Bay.
- Determine the main components of sediment budget.
- Determine the physical and chemical composition of sediments and their variability across the Bay.
- Determine the historical pattern of sediment accumulation and composition.

Progress from 1994 to 1997

Sediment elevation data and high resolution bathymetric surveys began in 1995 (Prager et al.,

1996). Sediment cores were in the process of being dated and analyzed to provide a historical reconstruction of environmental changes in the past 100-200 years (Halley and Roulier, 1995; Wanless et al., 1995;Wingard et al., 1995; Winkler et al., 1995; Brewster-Wingard et al., 1996; Nelsen et al., 1996) .

Progress from 1997 to Present

Bathymetry surveys were completed and a map of bottom types was produced in 1998 (Prager and Halley, 1998). Several groups continue to analyze cores (Brewster-Wingard et al., 1999; Cronin et al., 1999; Huvane and Cooper, 1999; Nelsen et al., 1999; Willard et al., 1999). One group has completed their analyses of Florida Bay paleo-salinity (Nelsen et al., in press), and their work will be published in a chapter of *Linkages Between Ecosystems in the South Florida Hydroscape: The River of Grass Continues* (Porter and Porter, in press). However, a draft synthesis of their work with that of other agencies (USGS) is needed because some of the information seems contradictory and is not at the level that restoration managers can understand.

3. *What have been the effects in Florida Bay of increased residence time of water caused by restricted water flow through channels between the Keys, shoaling, and reduced freshwater inflows?*
    - Determine the effect on circulation of shoaling caused by sediment accretion on the mudbanks.
    - Determine the relative importance of tides, winds, and altered freshwater inflows on flushing rates and exchanges with adjacent water bodies.

Progress from 1994 to 1997

While flow measurements were taken, they were not used to look at effects but rather calibrate models. Major channels discharging flows into northern Florida Bay were being instrumented with acoustic doppler current profilers, water level recorders, etc.

Progress from 1997 to Present

Both of the above are still ongoing. Questions 1 - 3 above were condensed and focused in the 1997 Strategic Science Plan becoming Central Question #1: *How and at what rates do storms, changing freshwater flows, sea level rise, and local evaporation/precipitation patterns influence circulation and salinity patterns within Florida Bay and outflows from the Bay to adjacent waters?* That aside, there has been good overall progress under this major research topic area in understanding the hydrography of Florida Bay. Unfortunately, big problems still exist with the USACE's RMA10 hydrodynamic model (one of the main components of the science program) and UVA's FATHOM mass balance model. It is not clear how the program will progress in this regard.

<u>Major Research Topic Area</u>: Water Quality and Nutrient Cycling

1. *What are the sources, quantities, and ecological effects of "external" nutrients introduced into Florida Bay?*
    - Measure the deposition of wet and dry nutrients into the Bay and, if important, determine their sources and estimate their historical variability.
    - Estimate nutrient flux by measuring surface and groundwater flows and concentrations.

- Continue and extend the water quality monitoring to include western Florida Bay and the southwestern coastal waters.
- Monitor the flow of water, organic and inorganic nutrients through Keys passes and estimate the input of anthropogenic nutrients from the Keys.
- If the budget suggests that Gulf waters are an important nutrient source, investigate the import and export of nutrients through mangroves and estimate their historical variability.

Progress from 1994 to 1997

The sources were identified i.e., canal inputs into Taylor Slough, but the connection between the canal and Bay with overland flow through the mangroves was still not known although there had been some work on nutrient input flux through the mangroves (Rudnick et al., 1996). There was also some work on atmospheric inputs and exchanges with the western boundary. These inputs could be a large component but they are estimated and the possibility of error is large. Water quality monitoring continued and was expanded to include the Southwest Florida Shelf and the Florida Keys National Marine Sanctuary (Fourqurean et al., 1995). USACE's Waterways Experiment Station (WES) initiated a water quality model for Florida Bay (Dortch, 1996).

Progress from 1997 to Present

Currently, groundwater inputs have been shown to be negligible (Corbett et al., 1999), but see Top et al. (1999). Water quality monitoring continues (Boyer and Jones, *In Press*; Jones and Boyer, 1999; Keller, 1999) . Sewage inputs from the Keys have been identified as a potential nutrient source (Bayside) in groundwater (Dillon et al., 1998). Estimates and preliminary

measurements have been made. There has been major progress in WES's water quality model (Cerco et al., 1999). However, in the 1999 Report of the Florida Bay Science Oversight Panel (Hobbie et al., 2000), the SOP recommended that the water quality project be put on hold until the hydrodynamic model problems get worked out i.e., the water quality model is dependent on the physical model.

2. *What are the rates of nutrient exchange between the sediment and water column within Florida Bay, and what controls the magnitude and direction of these fluxes?*

- Measure net fluxes in benthic chambers and sediment cores.
- Measure rates of detrital decomposition in seagrass stands.
- Investigate the processes by which seagrasses assimilate nutrients from sediments.
- Investigate chemical and microbial processes that mobilize or immobilize nutrients in the sediments.
- Develop a model of the benthic subsystem that includes seagrass population and nutrient pools and pathways in nutrient cycle.
- Determine contribution of nutrients from tidal pumping subsurface water from permeable limestone floor to water column.
- Obtain and date sediment cores, estimate rates of sediment and nutrient accumulation.

Progress from 1994 to 1997

Some measurements of benthic flux were made in the northeastern boundary of Florida Bay (Rudnick et al., 1996).

Progress from 1997 to Present

The benthic flux measurements are continuing (Rudnick et al., 1999; Solomon and Koch, 1999; Yarbro and Carlson, 1999). Investigations of chemical and microbial processes that mobilize or immobilize nutrients in sediments were conducted (Chambers et al., 1999). Results showed that phosphorus binding to iron-rich sediments decreases phosphorus in the water column, thereby, decreasing the amount of phosphorus available to stimulate nuisance algal blooms. Sediment cores and nutrient accumulation were investigated (Orem et al., 1998). Results suggest that nutrification has occurred across eastern and central Florida Bay beginning in the early to mid 1980's.

3. *What are the rates of nutrient assimilation by phytoplankton in the Bay, and what limits the growth of the phytoplankton assemblage?*

- Monitor the distribution, biomass, productivity and composition of the phytoplankton community.
- Monitor light distribution in the water column and determine photosynthesis versus light extinction curves for the dominant phytoplankton species.
- Measure nutrient uptake kinetics of the dominant phytoplankton species and conduct experiments to study phytoplankton nutrient limitation.
- Measure zooplankton biomass and grazing rate.
- Measure benthic filter feeder biomass and grazing rates.
- Estimate or use the sediment record to determine the effect of sediment resuspension upon light and nutrient availability in the water column.

- Develop a model of water column processes that is coupled to the benthic model and that incorporates both pelagic nutrient dynamics and grazing losses.

Progress from 1994 to 1997

Aerial surveys were initiated to visually map phytoplankton blooms and their extent (Sargent et al., 1995). Productivity estimates were made (Tomas, 1996) and some taxonomic surveys were conducted (Steidinger and Phlips, 1996). Zooplankton grazing rate studies were initiated (Dagg and Ortner, 1996).

Progress from 1997 to Present

When the Strategic Science Plan was updated in 1997, the questions and tasks focused on phytoplankton above were considered important enough to become one of the five central questions of the new plan i.e., Central Question #3: *What regulates the onset, persistence and fate of planktonic algal blooms in Florida Bay?* Since 1997, the aerial surveys and productivity studies have been discontinued. Some taxonomy work continues (Steidinger et al., 1998). Nutrient assays to determining limiting factors to growth i.e., N and P, were initiated (Richardson, 1998; Brand and Suzuki, 1999: Lavrentyev et al., 1999). Phytoplankton has been incorporated into the Water Quality model (Cerco et al., 1999) but, again, this model has been recommended to be put on hold pending physical model solutions or deletion. Zooplankton grazing rate studies continue and bloom experiments were initiated and continue to date (Ortner et al., 1998; Brenner and Dagg, 1999).

4. *What are the sources, quantities, and effects of toxic pollutants introduced into the Florida Bay ecosystem?*

- Monitor tissue concentrations of fish and upper trophic organisms.
- Monitor water column mercury concentrations and chemical forms.
- Measure atmospheric mercury inputs.
- Monitor mercury concentrations in canals and surface and groundwater.
- Relate actual pesticide application to potentially critical areas and periods within the Bay i.e., .life history, recruitment.

Progress from 1994 to 1997

In the spring of 1995, monitoring activities in Florida Bay were initiated (Summers et al., 1995).

Progress from 1997 to Present

A survey of contaminants in the sediments, water, and fish from the lower C-111 was conducted in 1997 (Goodman et al., 1998; Macauley and Goodman, 1999). More specifically, Evans and Crumley (1999) investigated mercury concentrations in fish. In addition, the role of particulates and dissolved organic carbon and their influences on the fate and transport of mercury compounds was investigated (Cai et al., 1998). Although the topic of contaminants has been repeatedly pointed out by the Task Force as being important to address, very few research projects have been funded to date. In fact, this area of research was completely dropped from the science plan when it was updated.

5. *What is the cause of turbidity in the Bay, and what is its effect on Bay water quality?*

- Determine the biological components of turbidity.
- Determine the contribution of resuspended sediments to turbidity.

Progress from 1994 to 1997

Initial work on remote sensing and turbidity was begun (Stumpf and Frayer, 1996).

Progress from 1997 to Present

The work on remote sensing and turbidity continues (Stumpf et al., 1999). However, there have been technical problems discriminating between turbidity and the Bay bottom. The water quality monitoring continues as mentioned previously (Jones and Boyer, 1999). Questions 3 and 5 of this Major Research Topic Area were repackaged under Central Question #3 of the new (1997) science plan (see Page 25). Question 4 above was dropped entirely from the program, and Questions 1 and 2 above were repackaged in the new (1997) science plan under Central Question #2: *What is the relative importance of the advection of exogenous nutrients, internal nutrient cycling including exchange between water column and sedimentary nutrient sources, and nitrogen fixation in determining the nutrient budget of Florida Bay?*

While good overall progress has been made in this major research topic area e.g., continued water quality monitoring, establishment of nutrient budgets for the Bay, WES water quality model, much more work is needed.

<u>Major Research Topic Area</u>: Seagrass, Mangrove, and Hardbottom Habitats

1. *What environmental factors explain the observed distribution of seagrasses within the Bay and caused the recent die-off?*

    - Determine current seagrass distributions, abundances, and biomasses and the effects of salinity, light, temperature, and nutrient concentrations on their distribution, productivity, etc.

- Conduct surveys of benthic and epiphytic macroalgae to assess eutrophication and possible competitive effects upon the seagrasses.
- Determine etiology of seagrass die-off in situ in Florida Bay.
- Determine age structure and mortality and reproduction patterns in seagrasses.
- Develop spatially couple physical-biological models linking experimentally verified causes of die-off to distribution of seagrasses.

Progress from 1994 to 1997

Monitoring of seagrass distribution and abundance was conducted (Durako et al., 1995, Fourqurean et al., 1995; Hefty, 1995, Zieman et al., 1995; Durako et al., 1996). The influence of salinity on submerged aquatic vegetation was also investigated (Montague, 1995; Montague, 1996). Some disease work was initiated on *Labyrinthula* (Landsberg and Blakesley, 1995; Landsberg et al, 1996), and seagrass was incorporated into WES's water quality model.

Progress from 1997 to Present

Monitoring continues (Durako et al., 1998, Durako et al., 1999), the disease work is ongoing (Blakesley et al., 1998; Blakesley et al., 1999), and the influences of salinity and water quality continue to be investigated (Jones et al., 1998). Simulations were run on the water quality model but, again, this model has been recommended to be put on hold. A conceptual model of Florida Bay seagrass mortality (Carlson et al., 1999) was initiated as was a predictive statistical model using water quality and sediment type to predict seagrass distribution and community structure (Fourqurean et al, 1999). Research in genetic variation in *Thalassia testudinum* was also conducted (Cutler et al., 1998).

2. *What environmental factors explain the pattern of mangrove die-back within the FB ecosystem?*

- Monitor mangrove community composition and coverage.
- Determine the effects of tidal inundation patterns, freshwater flow alteration, and nutrient availability on mangrove growth, physiology and reproduction.
- Determine relationship of past, present, and future freshwater flow patterns.
- Continue assessment of Hurricane Andrew's impacts on mangroves.
- Model mangrove population dynamics in Florida Bay.
- Incorporate the mangrove community into an overall ecosystem model.
- Monitor salinity of ground water on islands in relation to mangrove die-off.

Progress from 1994 to 1997

Low level aerial surveys were conducted in 1995 (Armentano, 1995), and the role of climate and porewater salinity in relation to mangrove mortality was investigated (Carlson et al., 1995). Biogeochemical properties of mangroves were also investigated (Twilley et al., 1996).

Progress from 1997 to 2000

Little, if any, progress has been made since 1996 regarding mangroves and, in fact, this question was dropped entirely when the new plan was written i.e., it wasn't included in any of the five central questions.

3. *What has been the cause and consequences of sponge die-off and the subsequent alteration of hardbottom communities?*

- Determine mechanisms for sponge mortality.

- Incorporate hardbottom communities into a biological monitoring program.

Progress from 1994 to 1997

Initial studies to look at distribution of sponges as they relate to lobster recruitment were conducted i.e., researchers quantified sponge die-off in relation to bloom events (Herrnkind et al., 1995). Sponge biomass estimates were also made in limited areas of Florida Bay (Stevely and Sweat, 1995).

Progress from 1997 to Present

Stevely and Sweat (1998) continued their investigation through summer of 1998. No other sponge work has occurred since the plan was rewritten. Again, Question 2 above was eliminated from the 1997 plan, and Questions 1 and 3 above were repackaged in the 1997 plan as Central Question #4: *What are the causes and mechanisms for the observed changes in seagrasses and the hard bottom community in Florida Bay? What is the effect of changing salinity, light, and nutrient regimes on these communities?*

Major Research Topic Area: Living Resources

1. *Has recruitment into Florida Bay been affected by habitat changes in Florida Bay, and have altered environmental conditions affected growth and survival of animals in Florida Bay?*

    - Develop a Bay-wide faunal monitoring program.
    - Conduct comprehensive life history studies of selected species.
    - Conduct manipulative field experiments testing the impacts of change in critical habitats of selected species.

- Conduct laboratory-based physiological and behavioral experiments in conjunction with the above study.
- Develop models linking experimental data to life histories, habitat changes, etc.

Progress from 1994 to 1997

Field sampling for FDEP's statewide marine Fisheries-Independent Monitoring Program which began in September of 1993 continued (Colvocoresses and McMichael, 1995). Age, growth, mortality, and fecundity investigations of Spotted Seatrout, *Cynoscion nebulosus*, were initiated (Elledge and Brock, 1995). A Pink Shrimp, *Penaeus duorarum*, study was initiated in 1994 (Browder et al., 1995) as were other investigations of fish species in relation to habitat change (Hoss and Thayer, 1995; Lorenz and Harrington, 1995; Matheson et al., 1995). Benthic assemblages were also mapped using mollusks (Lyons, 1995), and an investigation on the effects of changing juvenile habitat on spiny lobster recruitment was initiated (Herrnkind et al., 1995).

Progress from 1997 to Present

The pink shrimp and mollusk work is ongoing (Browder et al., 1999, and Lyons, W.G., 1999, respectively), and both the pink shrimp group (Browder et al., 1999) and the lobster group (Butler, 1999) have developed models describing recruitment dynamics. Thayer et al. (1999) continue their investigation of fish recruitment, composition, growth, and habitat use in Florida Bay. A new study on settlement stages of fish, shrimp, and lobster into Florida Bay was initiated in July of 1997 (Richards et al., 1999)

2. *Has habitat degradation or loss caused a reduction in fishery productivity in the Bay?*

- Collect unbiased information on life-history states of select indicator species.
- Focus on habitat-based research.
- Develop a model that relates cohorts on nursery grounds to cohorts in the Tortugas fishery landings for Pink Shrimp.
- Measure impacts of habitat change via tissue analysis and stomach content analyses.
- Conduct laboratory physiological research on early life-history stages of key species to evaluate changes in habitat on coastal resources.

Progress from 1994 to 1997

Besides the work accomplished for Question 1 above, an analysis of catch/harvest data to evaluate trends in abundance of red drum, spotted seatrout, gray snapper, and snook was conducted by Schmidt (1995).

Progress from 1997 to Present

Schmidt's work continues (Schmidt and Delgado, 1999). See Question 1 above, *Progress from 1997 to Present*, for further progress since Questions 1 and 2 of this Major Research Topic Area overlap.

3. *Have environmental and habitat changes in the Bay affected the distribution and reproductive success of upper-tropic-level consumers?*

This question was further subdivided into three groups i.e., predatory birds, crocodiles, and sea turtles. A sample of the representative tasks for each is group is included below.

For Predatory Birds:

- Monitor abundance and distribution of key species and determine the relative importance of specific areas for nesting, feeding, etc.
- Analyze stomach contents to gather information on feeding and habitat preferences.
- Sample nests for egg and hatchling productivity.
- Monitor.

For Crocodiles:

- Conduct nest censuses.

For Sea Turtles:

- Combine netting studies with tagging.
- Integrate existing data on distribution, abundance, habitat characterization and environmental parameter
- Conduct studies on fibropapilloma disease.

Progress from 1994 to 1997

An aerial survey of wading birds and other large water birds was conducted (Browder et al., 1995). An American crocodile monitoring program was initiated in 1994 (Mazzottii and Brandt, 1995). Finally, an intense investigation of sea turtle species composition, population structure, sex ratio, health and status, etc., was initiated (Schroeder et al., 1995).

Progress from 1997 to Present

Other than Lorenz et al. (1999) investigating nesting patterns of roseate spoonbills, I found no further research results on other wading birds, the American crocodile, or sea turtles. I am confident, however, that other investigations continue on these species, but the work is either

funded by agencies and institutions outside the Florida Bay and Adjacent Marine Systems Science Program or it is not being reported at the annual science conferences by the appropriate investigators.

Discussion

As stated earlier, the Florida Bay Science Program is just one component of the overall restoration effort. The formal Task Force structure is depicted in Figure 3. The individual Project Coordination Teams (PCTs) and the areas they cover geographically are depicted in Figure 4. Although the Florida Bay Science Program falls primarily within PCT 3, it was established before PCT 3 was formed and, therefore, functions independently.

In early 1999, the Florida Bay Science Program was formally asked by the Science Coordination Team (SCT) to expand its area of coverage to waters adjacent to Florida Bay. This expansion included parts of PCTs 4 and 5 and all of PCT 6 i.e., Biscayne Bay, Rookery Bay, and the Florida Keys, respectively (see Figure 4). The purpose of the expansion as stated by the SCT was for the PMC to act as an advisory body to these adjacent areas.

While it is important to coordinate research between adjacent areas of Florida Bay, 'advising' these areas may not be the appropriate mandate. The Florida Keys are entirely within NOAA's jurisdiction under the National Marine Sanctuary Protection Act and, as such, have quite an extensive management process already in place. Rookery Bay is part of the highly recognized National Estuary Program and has been functioning quite effectively with its management structure for a number of years. Finally, Biscayne Bay has recently received substantial funding from the State of Florida legislature under the Biscayne Bay Partnership Initiative to establish an integrated

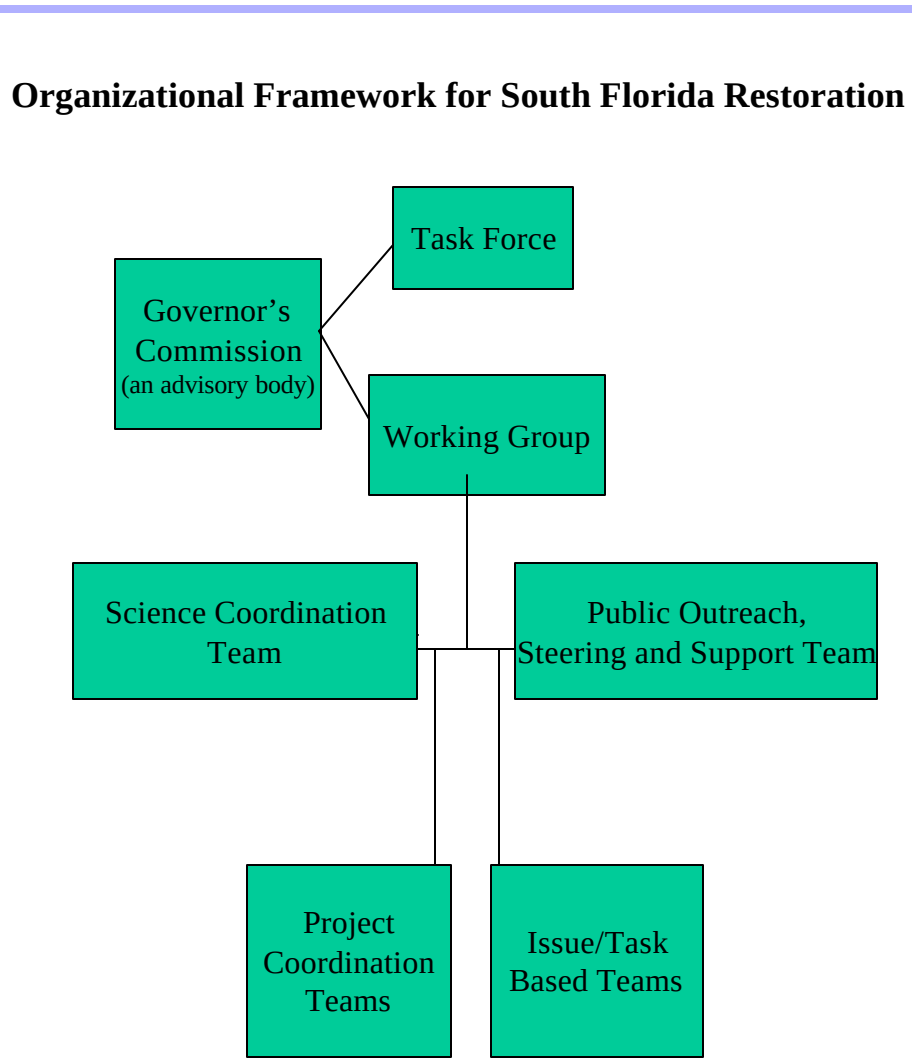

Figure 3. Organizational Framework for South Florida Restoration (SFERTF, 1999)

program of science, management, and economics. Concurrent with the kickoff of several workshops in support of this Initiative, a subgroup of the Florida Bay PMC decided to formally form a Biscayne Bay Program Management Committee as requested to do months earlier by the SCT. It is unclear at this time how this group will fit into the Biscayne Bay Partnership Initiative. Nevertheless, the Florida Bay Science Program has officially changed its name to the Florida Bay

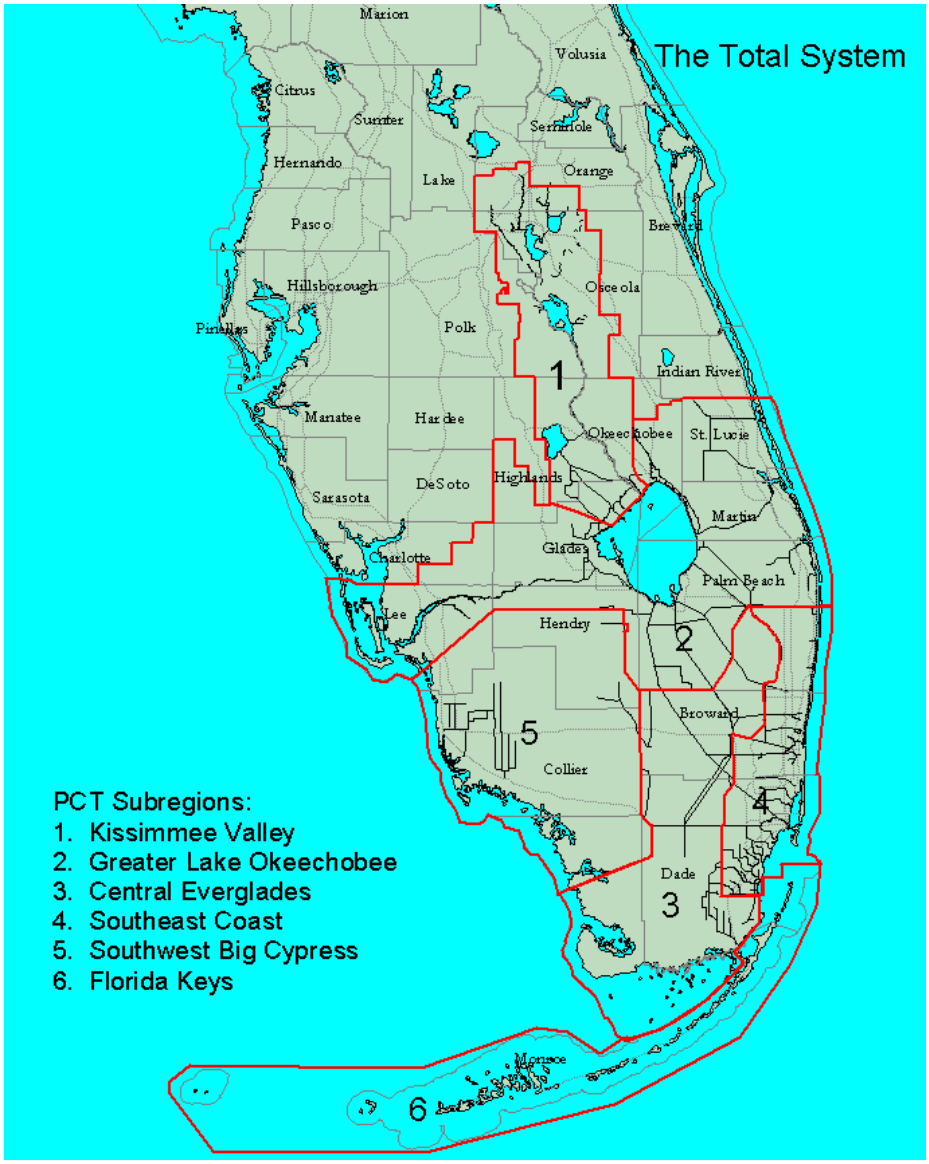

Figure 4. Subregions as Designated by the Science Subgroup (SFERTF, 1999)

and Adjacent Marine Systems Science Program and representatives from the aforementioned PCTs have been invited to participate on the PMC as they see fit.

I. Accomplishments

The fact that there is a program in place with so many federal and state agencies working together is the most obvious accomplishment to date, especially given that each agency is governed by it own policies and agenda. In addition, this program has far exceeded the progress of the six PCTs designated by the SCT.

In general, with the technical oversight provided by the Florida Bay Science Oversight Panel (SOP) and the research as set forth in the *Strategic Plan for the Interagency Florida Bay Science Program* (SSP), the program appears to be moving forward. Numerous workshops have been conducted since the program's inception. These workshops have focused on: 1) Florida Bay Nutrients, 2) Seagrass Modeling, 3) Water Quality Modeling, 4) Higher Trophic Levels, 5) Hurricane Georges Retrospective, 6) Paleoecology and Ecosystem History, 7) Circulation Modeling, 8) Florida Bay Salinity Modeling, and 9) Overall Modeling Integration. In addition, five research teams, one for each of the five Central Questions, have been established. Communication amongst researchers has improved through the program's Annual Science Conference, electronic list servers, and the program web site located at http://www.aoml.noaa.gov/flbay/ .

The program has also been enhanced by the appointment of an Executive Officer to the PMC in 1998. This position is the only paid position i.e., all members of the PMC are representatives from federal and state agencies who meet on a monthly basis. The Executive Officer's purpose is to: 1) develop ecological performance measures, 2) conduct synthesis activities, 3) manage the development and application of predictive models, and 4) communicate results to resource managers. Although in position for only 1.5 years, the Executive Officer has made significant

progress in numbers 2 and 3 and initial progress in numbers 1 and 4. The Executive Officer has made progress in other areas as well including the compilation of several documents: 1) a *Draft Implementation Plan* (unpublished) for the program, 2) *Predictive Models for Florida Bay, Florida Keys and Southwest Coast: Program Assessment and Status - February 1999* (unpublished), and 3) coordination of a *Summary of Research on Florida Bay* (unpublished). All documents are available on the program web site.

II. Shortcomings

Shortcomings in the program appear to center around coordination and oversight, process, and communications.

A. Coordination and Oversight

The formal management framework for the Florida Bay program as recommended by the panel of experts convened in 1993 called for formation of both a Program Management Committee (PMC) and a Technical Advisory Group (TAG) with each having very specific purposes.

Program Management Committee. The primary role of the PMC was to ensure that their respective agencies drafted Florida Bay implementation plans which, when completed, were to be reviewed by the PMC to ensure consistency with the *Florida Bay Science Plan*. In addition, it was assumed that agency representatives sitting on the PMC would communicate program recommendations to their agencies' superiors who would then see that the recommendations were incorporated into individual agency implementation plans. To date, NOAA has been the only agency to bring an implementation plan to the PMC for review.

The PMC also functions without any real accountability or management (unlike technical) oversight (see page 34, paragraph 1). While two members of the PMC sit on the Working Group's Science Coordination Team (SCT), these members sit on the SCT not as PMC representatives reporting thereto but as representatives for their individual agencies. And while information about PMC activities may be shared on occasion, there is no official mechanism in place which requires the PMC to report its activities to the Working Group (via the SCT) as part of the greater South Florida ecosystem restoration effort. This lack of accountability is further compounded because the Florida Bay program (and its PMC) is often referred to, particularly by the SCT, as the "model" for science program management. Since many of the SCT's Project Coordination Teams are still trying to discern their mission (SFERTF, 1999), the SCT may be referring to the Florida Bay program by default simply because it is in place and functioning. Whether or not the program is effective or how it operates is never questioned. Clearly, the issue of accountability and management oversight is difficult to address.

In addition, since the majority of funds available to support the program come from many federal and state agencies' base funds rather than from a single source, it is even more unclear as to whom the PMC should be accountable to. Not only do PMC members have a responsibility to the Florida Bay and Adjacent Marine Systems Science Program, but they have a responsibility to their respective agencies to ensure that agency funds are being used appropriately and that agency mandates are being met as required. This is yet another reason why implementation plans are so important. The plans would provide, at least to some degree, accountability to individual agencies.

Technical Advisory Group. The TAG, composed of scientists funded by the different agencies of the PMC, whose purpose was to assure "scientific quality" of research and to advise the PMC on technical issues, was never established. Instead, the PMC decided to fulfill this role as well. This is, by far, one of the biggest flaws within the program. While each member of the PMC may, in fact, be an expert within a particular discipline, having the PMC (a supposed program management/coordination committee) make a technical decision or recommendation about a particular issue based on the opinion of a small subset of its fellow members does not represent a true consensus of the best science. In essence, it is possible that one individual makes a group decision. Further, personal prejudices may influence decisions of the other committee members who are less knowledgeable about the subject in question. This inappropriate decision making process undermines the effectiveness and quality of the program as well as trust in the PMC. More often than not, the PMC seems unwilling to accept outside comment or opinion unless it comes from the Florida Bay Science Oversight Panel (SOP) although there has been progress in this area with the appointment of the Executive Officer.

Model Evaluation Group. A Model Evaluation Group (MEG) was formed in 1996 for the purpose of providing outside expert review/guidance on the development of models for research and prediction in Florida Bay. To date, the MEG has met on two occasions, October of 1996 and May of 1998. Since that time, there has been substantial money and effort spent on further developing and refining the program's modeling effort, in particular USACE's RMA10 hydrodynamic model and water quality model and UVA's and FIU's FATHOM salinity box model. To date, the two models developed to run salinity scenarios, RMA10 and FATHOM,

have failed to perform as needed for Florida Bay. In fact, as a result of both information presented at the November 1999 Florida Bay and Adjacent Marine Systems Science Conference and a review of the two models conducted by the Physical Science Team, the Science Oversight Panel (SOP) has recommended that 1) the FATHOM modeling effort be dropped completely, 2) the USACE consider other models until the problems with RMA10 are remedied, and 3) the water quality model be put on hold until a hydrodynamic model is in place and implemented.

Although both models had internal problems, they may have been elucidated earlier on had the PMC kept the MEG engaged during their modeling effort. Again, the MEG was established specifically to advise the PMC on modeling, providing technical expertise as needed.

B. Process

Research Teams. Several of the research teams, a key component of the science program process (see Figure 2) are continuing to have difficulty getting organized and functioning, but progress overall varies depending upon the team. Presently, two of the five teams have PMC members acting as the team leaders, with one of those two teams still remaining to be fully established. The other three teams have non-PMC members as team leaders and are experiencing little, if any, leadership and organizational problems.

Science Plan. The current science plan needs to be revised and better integrated with the SFERTF's new strategic plan for South Florida restoration (in development) to ensure continued funding of critical research, monitoring, and modeling projects.

Data Management. The program lacks easily accessible data on the research being conducted in Florida Bay. While it is unreasonable to expect a centralized data management component for raw data given that each federal or state agency represented on the PMC has different rules and regulations when it comes to data management, metadata (verses raw results data) would be extremely useful and easy to generate for a centralized database. Unfortunately, the program has made no progress in this regard even though both science plans specifically discuss this issue and state that compatible data-management plans and procedures will be implemented. At one point, NOAA took the lead in gathering information from various data managers, in working with specific agencies regarding proposals to manage the PMC's data effort, and in submitting a draft data management/implementation plan. After months of effort and little, if any, commitment or response from the PMC, NOAA ceased their efforts.

Public Information. While the program does have an education and outreach component to relay scientific information, minutes of the monthly PMC meetings have never been made available on the program's web site. In fact, they are not even recorded. The PMC's unwillingness to take minutes and make them public also undermines their credibility, specifically amongst researchers in the community.

C. Communications

Problems with communications can be broken down into three general areas: 1) mechanism, 2) style, and 3) perception.

Mechanism. No effective mechanism exists for getting research information to restoration managers i.e., those that make decisions about how restoration will proceed. This activity is

mentioned throughout the current science plan as one of the primary purposes of the program and, more specifically, a purpose of the PMC but does not necessarily occur. As stated earlier, it was intended that PMC representatives forward important findings and recommendations to agency superiors who would, in turn, incorporate this information into their implementation plans. It is likely that this information is being passed up the chain in some agencies, but it's obvious that it's not occurring in all agencies (see next paragraph), particularly those that are making critical decisions about how ecosystem restoration will proceed i.e., SFWMD, USACE, ENP.

During the most recent Florida Bay and Adjacent Marine Systems Science Conference (November of 1999), the first special session was held to provide science managers of several federal and state agencies the opportunity to speak directly with restoration managers and vice versa. The most notable observation made during this session was that restoration managers were not getting timely, science-based information in a way that they could understand i.e., no formal mechanism existed. Although unfair, much blame was directed towards the scientists for failing to communicate effectively. In truth, no one group is at fault (see Mechanism [above] and Style [below]). Nevertheless, it should be the responsibility of the PMC, not the individual researchers, to ensure that restoration managers get timely, science-based information in a non-technical format.

Style. Another problem is communication style. A manager is expected to make timely decisions and, therefore, wants quick answers based on what we know at the moment. A typical scientist, regardless of how much information he knows, is not comfortable passing this information along until he is 100% certain about it. In addition, a scientist's approach is often very focused, while restoration and the decisions being made in support of it are more broad based and system-

wide. Finally, restoration managers aren't asking specific questions of scientists and, again, the information that restoration managers do receive is too technical.

Perception. The problem with perception is two-fold. First, there may not be any scientific basis for a perceived problem, but if the public feels there is a problem, then it has to be addressed as such. Second is the program's lack of investment in studies that support the social science issues.

An example of a perceived problem may be the following: Much of the available public literature on Florida Bay mentions a decline in commercial and recreational fish stocks that utilize the Bay as a juvenile nursery habitat. However, pink shrimp appears to be the only commercial species that heavily utilizes the Bay as juveniles and spotted sea trout appears to be the only recreational species that utilizes the Bay. While pink shrimp has shown declines, spotted sea trout numbers have been steady over the last ten years. In addition, most of the popular gamefish species, such as snook and red drum, don't appear to use the Bay at all as early juveniles (Colvocoresses, 2000). Unfortunately, whether a problem truly exists or not is besides the point. If the public perception is that it does, then it does. Although many scientists and administrators are unwilling to accept this, the reality is that decisions are ultimately made by the public and the politicians (Orbach, 1999).

The Florida Bay program does have an education and outreach component in place, the Florida Bay Education Project, but since its inception, the project has had numerous internal problems. Further, it has been a constant struggle to provide the financial support to keep the project going. While education and outreach is generally viewed as important by the PMC,

support for it quickly falls aside when dollars are tight. Research will not be jeopardized to support education and outreach.

III. Recommendations

A. Coordination and Oversight

Although the science program has been functional and progress made, I recommend a clear separation of the technical aspects of the program from the management/coordination functions. The Executive Officer would act as liaison and coordinator between the two (see Figure 5). This would entail restructuring the PMC membership, creation of a formal mechanism for communication with resource managers i.e., the Restoration Group (RG), and a realignment of the research teams (see *B. Science Process* below). Figure 5 is not a hierarchy *per se* but rather a proposed structure to facilitate better communication and overall program function.

Program Management Committee. The Program Management Committee (PMC) should re-examine its membership. To be most effective, all members on the PMC should have a fairly high level of authority within their respective agencies or at least frequent access to those that do. In the best scenario, members of the PMC would have individual funding authority within their agencies. While some individuals that presently serve on the PMC would remain, many would be different.

The PMC would function strictly in a program management (versus technical) capacity ensuring that the needs in the science plan are being addressed as their agencies' expertise and scientific research programs allow. The PMC would continue to guide the overall progress of the program but would have no authority to make technical decisions without the consensus of the

Proposed Communication Structure for the Florida Bay and Adjacent Marine Systems Science Program

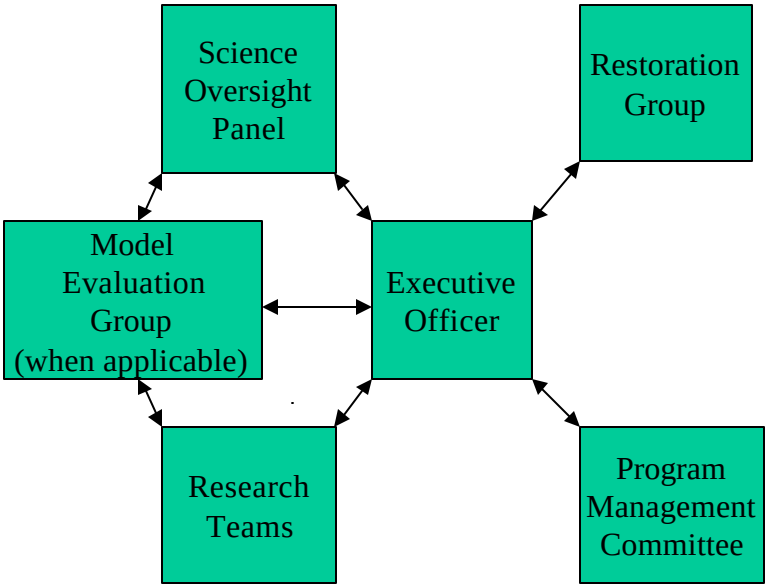

Figure 5. Proposed Communication Structure for the Florida Bay and Adjacent Marine Systems Science Program

appropriate technical research team. Finally, the PMC would ensure that the science program is well represented in the greater South Florida ecosystem restoration effort by participating in various teams and workshops sponsored by components of the formal Task Force structure.

Restoration Group. A formal mechanism for communicating with restoration managers should be created. This does not involve forming another management group *per se*. It does imply, however, that an explicit commitment exists from an appropriately identified number of restoration managers, most of whom already sit on SFERTF's Working Group, to formally meet with science

program representatives at least two times per year. These meetings would involve the PMC, Executive Officer, and research team leaders. Their purpose would be to discuss both science needs as identified by restoration managers and science information learned to date. The Restoration Group should include the Superintendents of both Everglades and Biscayne National Parks and the Florida Keys National Marine Sanctuary, the USACE's District Engineer, the Chairman of the SFWMD's Governing Board, the Executive Director of the South Florida Ecosystem Restoration Task Force, the Florida Keys coordinator for the EPA, and an appropriate member from Rookery Bay National Estuarine Research Reserve.

Science Oversight Panel. The Science Oversight Panel (SOP) would continue on as they have in the past, providing independent expert review of the program's strategies and of the scientific quality of research, monitoring, and modeling activities. The SOP currently consists of seven senior scientists with significant experience in major estuarine restoration programs but without involvement in Florida Bay projects. The SOP would continue to participate in annual conferences by leading question and answer sessions and by providing written reports to the PMC with both critical review and recommendations.

Model Evaluation Group. Every effort should be made to re-engage the Modeling Evaluation Group (MEG) in the program's modeling effort, and either the entire MEG or representatives thereof should be included in all meetings and workshops related to modeling. There are presently several documents available to provide background information on the program's activities during the past two years. The MEG should be in close contact with the Science Oversight Panel so as not to provide contradictory advice to the program and its research teams. As suggested in the

Report of the Florida Bay Science Oversight Panel: Perspectives from the 1999 Florida Bay Science Conference (Hobbie et al., 2000), a member of the Science Oversight Panel should also be a member of the MEG.

Executive Officer. The Executive Officer would continue in much the same role as he does currently. He would report to the PMC but his primary role would be to oversee and coordinate the research teams, act as liaison between the Science Oversight Panel and the research teams, and communicate with the PMC and Restoration Group (RG). Specifically he would ensure that all groups (PMC, RG, SOP, and research teams) are meeting as needed and that the science plan is kept up-to-date. The Executive Officer should have a minimum of one, preferably two, support personnel. In addition, the Education and Outreach component of the program should report directly to the Executive Officer. Finally, the Executive Officer appointment should be made into a more permanent position verses the current two-year term appointment.

B. Science Process

Research Teams. Although the Technical Advisory Group, as recommended by the 1993 Interior's Advisory Panel, was never established, the research teams, in effect, could address this need. However to do so, all teams must become more organized and functional. First, the position of team leader must be given to a non-PMC member. PMC members who are also scientists in the respective disciplines should be welcomed and encouraged to participate on the teams but, again, responsibility and authority for the team rests with the team leader. The Executive Officer would have the responsibility of ensuring that the teams are meeting on a regular basis, that technical information is being communicated to the PMC as needed, and that programmatic

information is being communicated to the research teams as needed. Again, the PMC would have no authority to make technical decisions without consensus of the appropriate research team.

In addition, expanding the membership of existing teams should be strongly encouraged. Representatives should include, but not be limited to, scientists funded by the participating agencies of the PMC. Many institutions/researchers not funded by current PMC agencies participate in the program by providing technical expertise, data analysis, and participation in meetings, yet they are not fairly represented in the decision making process. The success of the Florida Bay program clearly depends on these institutions/researchers as well. Finally, in coordination with the Executive Officer, the research teams would be responsible for writing the technical aspect of the program's science plan.

Science Plan. The current science plan should be revised. It should clearly state the goals and objectives of the program at the beginning and, at a minimum, should include the following: 1) a clear discussion of structure, process, authority, and accountability; 2) a synthesis of research thus far and how that information relates to the restoration decisions being made; 3) a discussion of mechanisms for communication, particularly to restoration managers; 4) a discussion of research goals for the future and the implications of not being able to meet these goals, as they relate to restoration, due to a lack of or delay in funding; 5) a GANTT chart or timetable of deliverables; 6) performance measures; and 7) the need for studies in the social sciences as they relate to stakeholders, economics, and restoration decisions. The revised science plan should clearly show the relationship between the Florida Bay and Adjacent Marine Systems Science Program and the

goals, subgoals, and indicators stated in the SFERTF's new strategic plan, due to Congress on July 31, 2000.

Data Management. The program should commit to having a centralized database for metadata of the research being conducted in and around Florida Bay. In fact, USGS currently has funds available to do just this. The current USGS representative on the PMC should take the lead in this respect and ensure that a line of communication is created between the two groups to collaborate on this issue.

Public Information. The PMC is officially part of the South Florida Ecosystem Restoration effort and is, therefore, exempt from the Federal Advisory Committee Act (FACA). However, it should meet the Sunshine Law requirements as do the SCT, Working Group, and Task Force and, as such, should make minutes of the monthly PMC meetings available to the public on the program's web site.

C. Communication

Specific recommendations to improve communications include the following: 1) Establish a Restoration Group (see *A. Coordination and Oversight* above) that meets no less than two times per year with the Executive Officer, PMC, and research team leaders, to discuss upcoming restoration plans (both short-term and long-term), formulate specific questions that need to be addressed, assess the progress of the research, etc.; 2) Restoration managers need to ask scientists specific questions now to address long-term/future changes; 3) Scientists need to be willing to provide best guesses with information that is available at the time; 4) These best guesses must be relayed to restoration managers in a way that they can understand; and 5) Agency science program

managers need to understand and accept that the social sciences are equally important and play a significant role in driving restoration (Milon et at., 1997). Therefore, more commitment is needed to allocate portions of their program funds both to support studies of the social sciences and to support education and outreach.

Conclusion

While many of the tasks and objectives stated in the science plans have not been completed, the comparison does show that progress in research has been made and, subsequently, our understanding of the Florida Bay ecosystem has increased. Given that research was occurring in the Bay before the science program was established, it is likely that some portion of this understanding would have occurred without the program. Clearly, however, the science program and its plans have helped to focus the research effort and facilitate communication amongst researchers. Further, having so many federal and state agencies and researchers working together affords a legitimacy to the science program both in the higher levels of the South Florida Ecosystem Restoration effort and in the individual agencies at the Washington D.C. level. This legitimacy, in turn, has helped to secure funding both through these individual agencies as well as from SFERTF's Critical Ecosystems Studies Initiative (CESI). As a result, there has an increase in research specifically because of the Florida Bay and Adjacent Marine Systems Science Program.

While overall progress is being made, particularly by the researchers and the Executive Officer, the program could be more efficient by reassessing its present structure, solving the elements of the program that are not working as intended i.e., the MEG and the research teams, addressing the issues of communication, implementing a centralized metadata data management

program, and revising the science plan to better reflect the current direction and goals of the program and how they tie into restoration decisions being made.

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