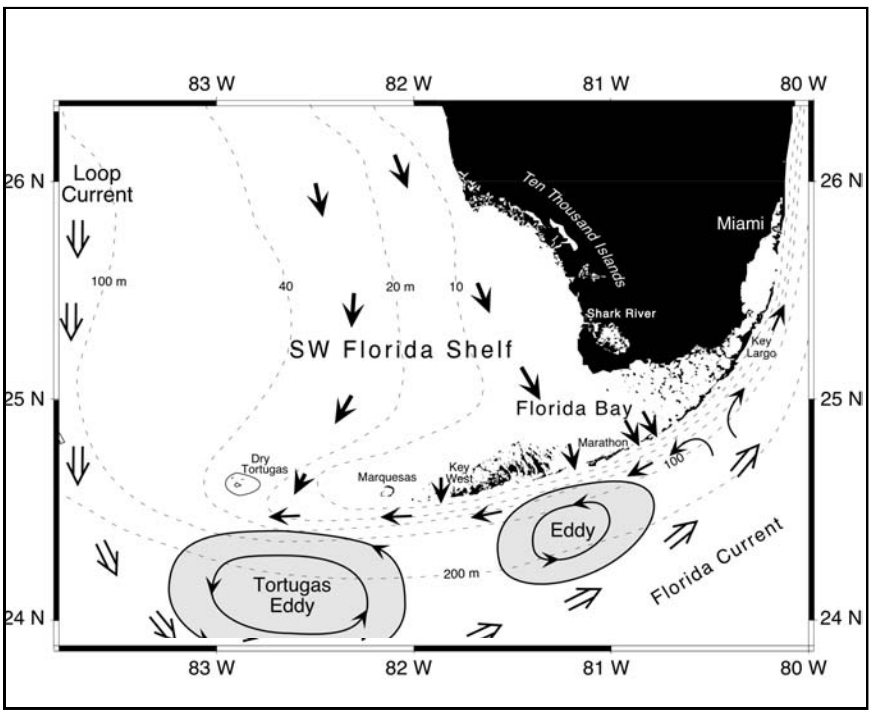
South Florida Ecosystem Restoration:

Scientific Information Needs in the Southern Coastal Areas: Progress and Update

A Report by the Science Coordination Team and the Science Program for Florida Bay and Adjacent Marine Systems

February 2001



Cover Illustration: Schematic representation of the mean coastal circulation that connects the different estuarine and marine subregions of South Florida (courtesy of Dr. Tom Lee, University of Miami).

Executive Summary

This report compiles information on the science information needed for ecosystem restoration in the Southern Coastal Areas of South Florida. In 1996, the Science Subgroup[1] cataloged science information needs for restoration throughout South Florida. Since that time, ecosystem restoration has advanced from planning to implementation; progress in research has satisfied some of the information needs identified in 1996; and resource managers have identified new areas in which scientific information is now needed.

The Science Coordination Team and the Florida Bay Science Program produced this report to document the evolving needs for science information and the progress by research in the Southern Coastal Areas. The Florida Bay Science Program coordinates the interagency/intergovernmental research effort in this subregion, which is centered on Florida Bay. In a parallel effort, the Science Coordination Team and the Florida Bay Science Program briefed the Working Group of the Interagency Task Force on this topic at their meeting on 1 June 2000. A separate document, "Synthesis of Florida Bay Science for Restoration Management," was distributed to the Working Group as part of this briefing.

The information in this report provides an accounting of the science information needs that have been identified by resource managers, i.e. the "charge" given to the science program, and progress by research in meeting those needs. Specifically, this report addresses three main objectives. These are:

- review the scientific needs for Florida Bay and adjacent areas that are identified in the 1996 Science Sub-Group Report[2];
- prepare a report card on the progress towards meeting these needs by the Florida Bay Science Program; and
- revise the statement of scientific information needs to incorporate the needs identified since 1996 and documented in various planning and management documents.

[1] The Science Coordination Team of the Interagency Task Force is the successor to the Science Subgroup.
[2] South Florida Ecosystem Restoration: Scientific Information Needs (Science Subgroup Report to the Working Group – 1996), Available at http://everglades.fiu.edu/taskforce/scineeds/index.html.

Contents:

Acknowledgements:
Members of the joint committee of the Science Coordination Team and Program Management Committee were Joan Browder, Susan Markely Margaret Miller, Bill Nuttle, Peter Ortner, and Bill Perry. Lucy Given provided assistance with compiling information, and both Lucy and Dawn Boyer provided assistance with production of this document.

[1] South Florida Ecosystem Restoration: Scientific Information Needs (Science Subgroup Report to the Working Group – 1996), Available at http://everglades.fiu.edu/taskforce/scineeds/index.html.

Introduction

The Working Group of the Interagency Task Force identifies three overarching goals that guide ecosystem restoration in South Florida. These are 1) get the water right, 2) restore and enhance the natural system, and 3) transform the built environment (Working Group 1998). The most important goal for restoration of Florida Bay and adjacent marine systems is to get the water right. This means providing freshwater flows with the right quality, quantity, timing, and distribution. Determining the “right” quantity, quality, timing, and distribution of freshwater will require certain scientific information. Goals for restoration define the need for scientific information; however the specific information that is needed will change over time as restoration progresses and our understanding of the natural system increases.

This report reviews the scientific information needs that were initially identified for the Southern Coastal Areas, reports progress toward meeting these needs, and compiles a list of scientific information needs identified since 1996. The Southern Coastal Areas includes the Atlantic Coast estuaries from South Biscayne Bay to Barnes Sound, Florida Bay proper and its fringing mangrove habitat, the Florida Keys and associated coral reef tract, and the West Coast estuaries from Whitewater Bay to Rookery Bay with their extensive mangrove habitats. The first compilation of science information needs for restoration of South Florida ecosystems was the 1996 report of the Science Subgroup, i.e. the “1996 Report.” In compiling this list, the Science Subgroup could only anticipate the strategic planning that has been largely completed by the C&SF Project Restudy.

The 1997 report of the Science Subgroup (Science Subgroup 1997) introduces conceptual models as a device for identifying the links between human activities in South Florida and their effects on the ecosystems of the region. The model for marine and estuarine waters (Figure 1) represents the consensus at that time about how changes in quality, quantity, distribution and timing of freshwater flows affect estuarine and marine waters. This knowledge guides restoration efforts; however, some linkages proposed in the model are uncertain. Scientific information is needed to confirm those linkages that are still not understood fully and to construct quantitative models managers require for detailed planning and assessment of restoration projects. Thus, these models serve to guide research as well as restoration.

Review and revision of the science needs identified in 1996 for the Southern Coastal Areas is now timely. With completion of the Restudy and its approval pending restoration is moving toward implementation. A maturing research program in Florida Bay has made tangible progress toward fulfilling many of the identified science needs. And, development of the conceptual models provides a rational approach to organizing scientific knowledge obtained through research and identifying critical information needs.

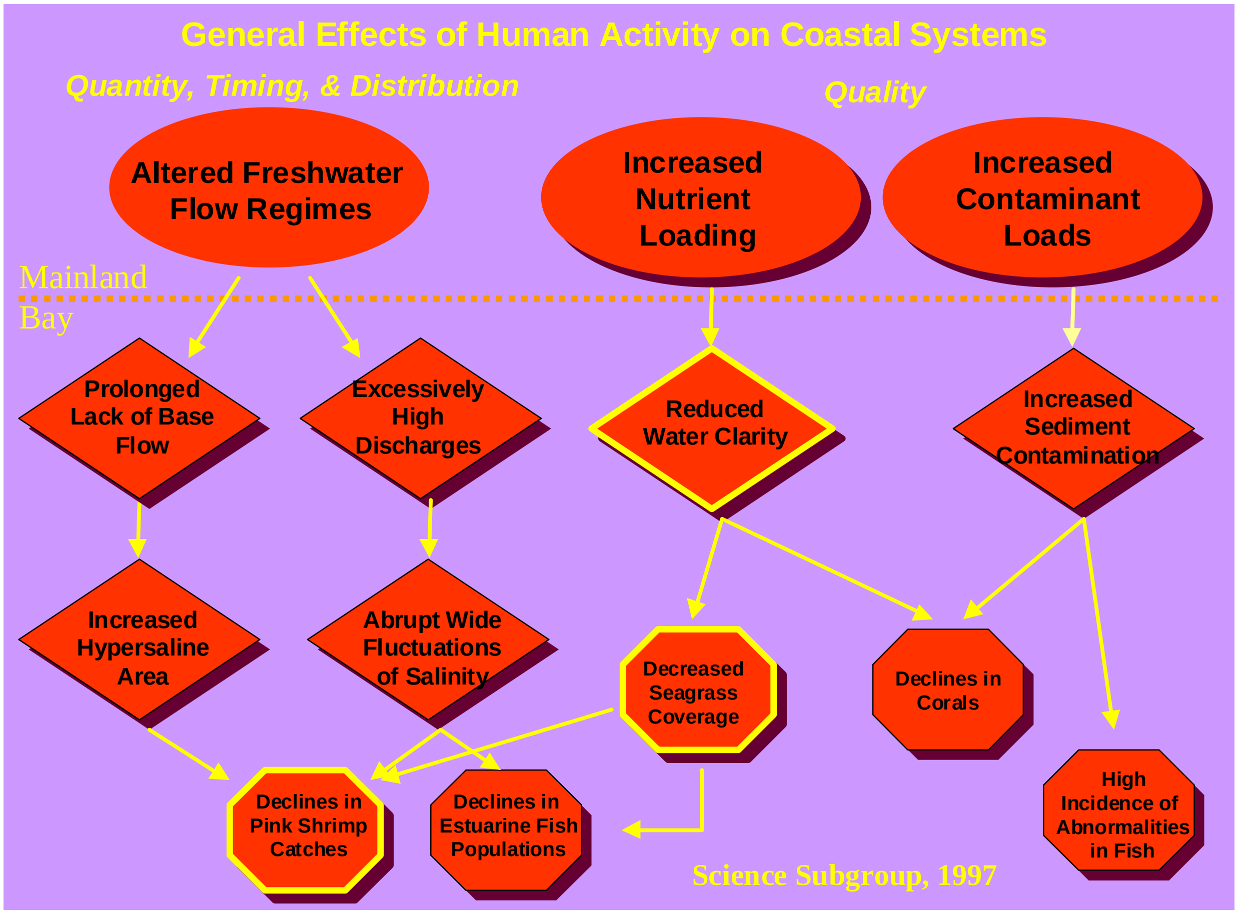


Figure 1: General conceptual model linking quantity, quality, timing and distribution of freshwater flows to observed changes in estuarine and marine systems (Science Subgroup 1997). Yellow outlines highlight changes in Florida Bay that were observed in the late 1980s and early 1990s. Connections in the model diagram represent hypothesized causal links to the environmental effects of human activities, at the top of the diagram, and to consequences elsewhere in the ecosystem, lower in the diagram.

Categories of science information

The 1998 Working Group report identifies four general types of information resource that managers require for science-based decision-making (Working Group 1998, page 12). These are defined below, and they are used throughout this report to organize the discussion of science information needs and information obtained from research.

Reconstruct historical conditions. - Historical conditions are conditions in the ecosystem that pre-date the effects of development in South Florida. In Florida Bay, the biogeochemical analyses of the sediment are an important source of this information.

1) Identify key species, habitat indicators and drivers of the ecosystem. – Key species and habitat indicators are attributes of the ecosystem that can be used to track changes in the ecosystem. Observation and experimentation are used to identify key species and habitat indicators by their roles in the ecosystem as a whole and their links through cause and effect to drivers. Drivers are the major external driving processes that have large-scale influences on the ecosystem. These can be natural processes (e.g. sea level rise) or the result of human activities (e.g. operations of the regional water management system). An attribute is typically a key population, species, guild, or community, but it can also be an aspect of ecosystem structure (e.g. habitat) or process. Attributes are selected to track the known or hypothesized effects of changes in the drivers, and they also include valued aspects of the ecosystem (e.g. endangered species).

2) Develop (and apply) models to predict and evaluate the effects of human activities. - Models provide a tool for measuring the sensitivity of the ecosystem to human activities. Models are used to evaluate the effects that past activities have had on the ecosystem and to predict how the ecosystem will respond to future activities. Managers will use this information to plan and evaluate projects as restoration progresses.

3) Implement monitoring programs to measure ecosystem attributes. – The data collected in a monitoring program are used to track changes in the ecosystem before and in response to restoration.

Differences between these categories can be understood by their relationship to the conceptual models, e.g. Figure 1. Information on historical conditions provides a baseline for measuring changes in the ecosystem and for setting restoration goals. Information on key species, indicators, and drivers is needed to, first, construct and, later, test and revise the conceptual models. Predictive models translate the conceptual models into quantitative tools that can be used for detailed planning and assessment of restoration projects. Finally, monitoring programs track the response of the whole, interconnected system of physical, chemical and biological components; information that is needed to confirm the success of the restoration.

Scientific Information Needs – Review of the 1996 Report

Table 1 summarizes the science needs identified in the 1996 Report for the Southern Coastal Areas. The emphasis on Florida Bay reflects the attention given to that portion of the Southern Coastal Areas at the time the report was written. The scientific information needs are organized by the categories described above. To do so, the needs identified in the 1996 Report have been reorganized and interpreted to fit in these categories. A transcript of science needs for the Southern Coastal Areas as they appear in the 1996 report is appended to this report.

Table 1: Science Needs Identified in the 1996 Science Subgroup Report

Reconstruct historical conditions

- Quantify historical variations in salinity.
- Determine targets and strategy to recreate natural quantity, timing, quality, and distribution of water using NSM and SFWMM hydrologic models.
- Estimate the effects of hurricanes and other extreme weather on sediments, nutrients, and organic matter in Florida Bay.

Identify key species, habitat indicators and drivers of the ecosystem

- Determine causes of recent ecological shifts in Florida Bay, i.e. dieoff of seagrasses, sponges, and mangroves, occurrence of extensive algae blooms, and high turbidity.
- Identify and describe critical habitats in the Bay and linkages with upland, coastal and reef habitats.
- Identify the effect of loss and fragmentation of habitat on recruitment, growth, survival and distribution of species and communities.
- Determine the effects of vegetation on evaporation and overland flow.
- Map land surface elevations in southwest Florida.
- Determine the response at inland sites to tidal forcing at the coast.
- Estimate recent rates of freshwater discharge into and through the mangrove estuaries.
- Quantify surface conditions across south Florida, i.e. area covered by water, vegetation and different types of land use for input into a regional climate model.
- Determine the initial and boundary conditions in the atmosphere for this model.
- Determine by observation and/or models the boundary conditions (i.e. water levels, fluxes and salinity values) at mangrove, Keys passes and Florida Shelf boundaries of the hydrodynamic model domain.
- Estimate atmospheric exchange of water (rainfall and evaporation) and momentum (wind stress).
- Map bathymetry and benthic communities and other characteristics of the bottom needed to estimate bottom roughness effects on waves and currents.
- Delineate internal flow patterns and determine rates of flow and exchange.
- Identify sources of nutrients and estimate fluxes into the system.
- Estimate rates of nutrient exchange between sediments and water column.
- Identify sources of contaminants, such as pesticides and mercury, to the Bay.

Develop (and apply) models to predict and evaluate the effects of human activities

- Develop and implement the following models:
    - mangrove hydrology model
    - regional climatology model
    - regional (coastal ocean) hydrodynamic model
    - hydrodynamic/salinity model (for interior of Florida Bay and Biscayne Bay)
    - seagrass/water quality model
    - "seascape model," links biotic attributes to changing chemical and physical conditions.
- Quantify effect of management on salinity, hydrology and circulation in Florida Bay and mangroves.
- Evaluate ecosystem impacts of alternative water management strategies on bottom habitat (i.e. seagrass communities) and key higher trophic level species.
- Evaluate the effects of restricted exchange through the Keys passes, shoaling, and reduced freshwater flows on water residence time in Florida Bay.

Implement monitoring programs to measure ecosystem attributes

- Quantify the areal coverage by seagrass communities, and mangroves.
- Quantify the abundance and recruitment of key higher trophic level species.

Progress Towards Addressing the 1996 Scientific Information Needs

Table 2 identifies the research activities undertaken to satisfy the science information needs that are cataloged in the 1996 Report. The Science Program for Florida Bay and Adjacent Marine Systems coordinates research activities of 14 federal and state agencies in the Southern Coastal Areas of Florida. The goal of the Program is to produce data and models essential for understanding Florida Bay as an ecosystem functioning within a regional system that is strongly influenced by human forces. Recent efforts have focused on the factors that control salinity and the effects of salinity on the ecosystem as a whole.

In general, good progress has been made in satisfying the needs cataloged in the 1996 Report. The development and application of predictive models is a notable exception to this. To a certain extent, the work remaining on the models reflects the amount of information and work that they require. For example, development and application of predictive models for higher trophic levels requires both the collection of new information on the response of organisms to environmental change, the development of these models, and the coordinated application of hydrodynamic and water quality models to predict how restoration will affect environmental conditions. However, the problems associated with developing and implementing new models as an interagency effort have also contributed to a lack of progress.

Information obtained through this research confirms some of the causal links hypothesized in the conceptual model proposed in 1997 for Florida Bay (Figure 2). And in the case of these links, research has made measurable progress toward providing the predictive tools that managers need. For example, there is now a good understanding of how changing patterns of high salinity in Florida Bay affect the availability of shrimp in the Dry Tortugas fishery. This understanding is backed by models that can predict shrimp production if given the salinity and temperature in Florida Bay. More work will be needed to develop models capable of linking salinity in the Bay to changes in water management.

In the case of water quality, the available scientific information is less clear about the influence of increased nutrient loading to Florida Bay in runoff from the Everglades. This implies that revisions are needed to the conceptual model for it to accurately represent the links between human activities and the ecosystem (Figure 2). Research into the causes of seagrass dieoff in the late 1980s indicates the dieoff was related to community composition changes associated with long term changes in salinity. Subsequent reductions in water clarity were probably caused by the loss of seagrass, rather than the other way around. Once there is a consensus on a revised conceptual model, restoration efforts can proceed based on the “best available science” even as researchers continue their efforts to resolve the debated issues.

Key to citations listed in Table 2	
[Estuaries]	Florida Bay: A Dynamic Subtropical Estuary. Estuaries vol. 22(2B), June 1999. URL *http://erf.org/journal/journal.html*
[Abstracts]	Program and Abstracts. 1999 Florida Bay and Adjacent Marine Systems Science Conference. November 1-5, 1999, Key Largo, Florida. URL http://www.ifas.ufl.edu/~conferweb/fb_ab.pdf

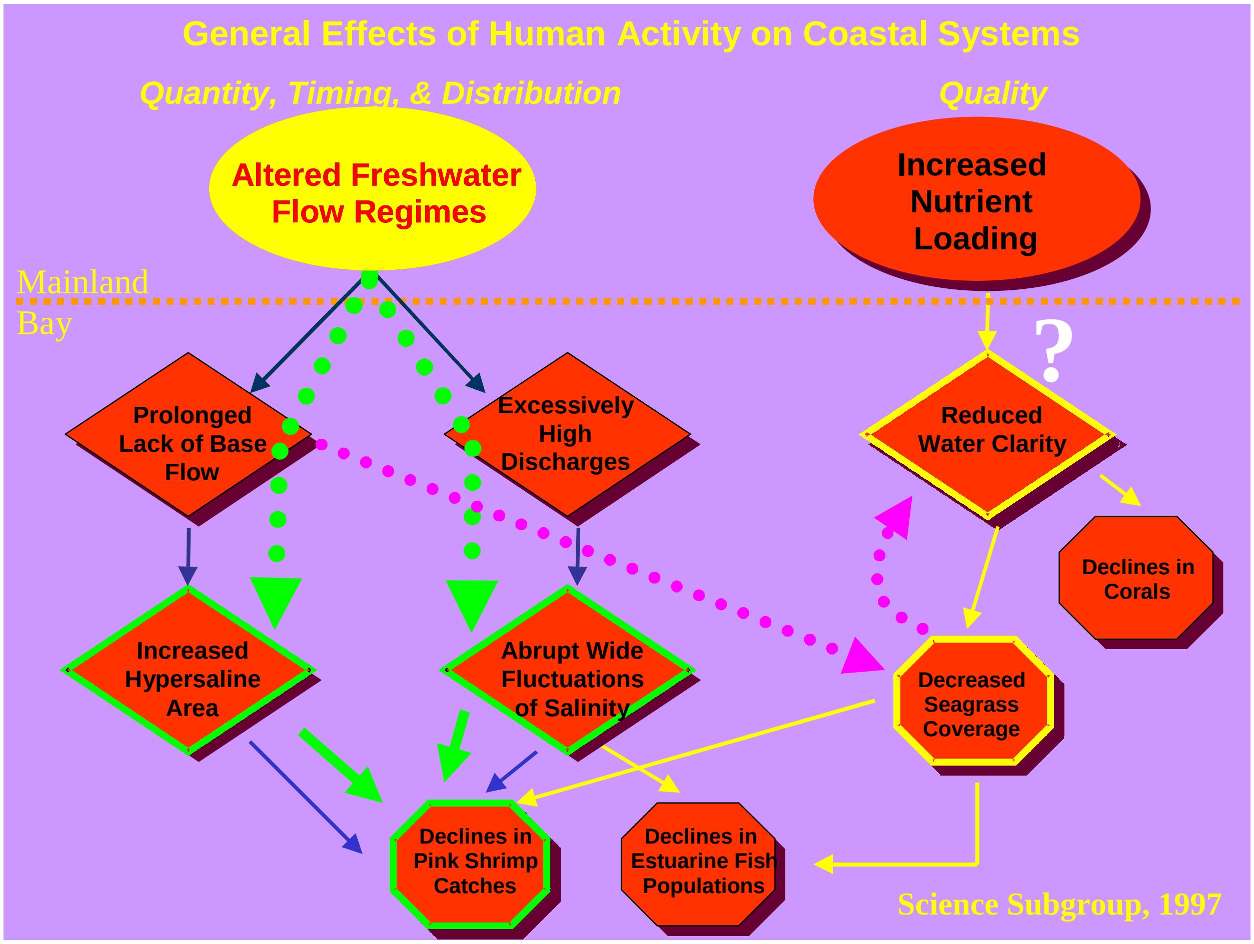


Figure 2: Research results confirm and quantify some of the links (green) in the conceptual model proposed in 1997. In the case of water quality, the available scientific information fails to confirm a strong influence of increased nutrient loading in runoff on water quality in Florida Bay. Other research suggests existence of additional links between long term changes in salinity, seagrass dieoff, and reduced water clarity (purple). Note that the links to increased contaminant loads are omitted from this diagram only for sake of simplicity.

Table 2: Progress Towards Addressing the 1996 Scientific Information Needs

Reconstruct historical conditions

Quantify historical variations in salinity.	Research on this topic has proceeded along two tracks. The first is an effort to compile historical salinity measurements. The second is to re-assemble historical salinity conditions in the Bay based on paleoecological studies, which use the sedimentary record. Mike Robblee (USGS/BRD) maintains a database of historical salinity measurements assembled from all extant measurements of salinity in Florida Bay. An ongoing project funded by Department of the Interior will make this database available on the Internet in a searchable format. Information on this work can be found at URL http://sofia.usgs.gov/projects/sal_patterns/. Paleoecological studies have produced a wealth of scientific information. These results were summarized in a synthesis presented during the 1999 science conference (Prager [Abstracts]), and they can be briefly summarized as follows: Historically, regional rainfall and climatic events have been the dominant control on salinity variability in Florida Bay. However, in the latter part of the 20th century, changes in land use and water management practices in the region have modified Florida Bay's response to rainfall and climate. The evidence suggests that these human-induced changes led to a more marine ecosystem accompanied by *increases* in spatial coverage by turtlegrass and in the frequency and extent of plankton blooms. Detailed syntheses of the paleoecological work in Florida Bay have been written, and these are in preparation for publication. Results of individual projects are available as Halley and Roulier [Estuaries], Brewster-Wingard and Ishman [Estuaries], Swart et al. [Estuaries], Willard et al. [Abstracts], Holmes et al. [Abstracts], Blackwelder et al. [Abstracts], Brewster-Wingard et al. [Abstracts], Cronin et al [Abstracts], Huvane and Cooper [Abstracts], Nelsen et al. [Abstracts], Orem et al. [Abstracts], Tedesco et al. [Abstracts], and Alvarez-Zarikian [Abstracts]. Summaries of this work are also available at the following URLs: http://www.aoml.noaa.gov/ocd/sferpm/nelsen/nelsendec99.html http://sofia.usgs.gov/projects/eh_fbswc/ http://www.aoml.noaa.gov/flbay/pmcpaleo.html Paleoecological work in Biscayne Bay is described at the below URLs: http://sofia.usgs.gov/metadata/sflwww/metish.html http://sofia.usgs.gov/projects/eh_bbsec/

Reconstruct historical conditions (Cont'd)

Determine targets and strategy to recreate natural quantity, timing, quality, and distribution of water using the NSM and SFWMM hydrologic models.	The NSM and SFWMM hydrologic models do not adequately recreate quantity, timing, and distribution of water flows across the mangrove transition zone and into Florida Bay and adjacent marine areas. The limitations posed by this have only recently become apparent. In response, the Florida Bay Science Program has taken the initiative in defining the science information needs related to the linkage between Everglades hydrology and water quality in Florida Bay. These include a standard data set for Florida Bay that will contain reconstructed flows into the Bay for the period 1995 to mid-2000. The standard data set is needed to improve and verify the capability of both the hydrologic and hydrodynamic models that will eventually provide the scientific information needed to determine targets and strategy for restored flow to coastal marine systems.
Estimate the effects of hurricanes and other extreme weather on sediments, nutrients, and organic matter in Florida Bay.	Hurricanes occur infrequently and opportunities are limited to study their effects on coastal systems while they are present. Fortunately, two hurricanes, Georges and Irene, have visited the Bay in the last few years. During these times, an intensive field effort was in place to study all aspects of the ecosystem and while the studies were not designed specifically to examine the effects of hurricanes, data collected before, during, and after the storms has provided some insight into their effects. Immediately after Hurricane Georges, researchers met to review data collected around the time of the storm and review various hypotheses about the influence of hurricanes on the Bay. A similar meeting is planned to review the effects of Hurricane Irene. Results of the Georges workshop were published as a "Florida Bay Watch Report" and can also be found at URL http://www.aoml.noaa.gov/flbay/hurgeocoverpage.html. The conclusions reached can be summarized as follows: Results so far suggest that Georges was not able to flush a large proportion of water out of Florida Bay and replace it with ocean water, and there was little, if any, change in the banks and channels. It appears that Georges has had a beneficial effect on the seagrass beds. Even though Georges did not completely flush the bay of dissolved nutrients; it did have a cleansing effect by removing older leaves from the seagrass beds and other organic matter that was not well anchored. Organic material that could float to the surface was swept from the bay by wind. Scientists will have to wait to see whether this will have a lasting effect. Some scientists are now reassessing the roles of hurricanes and winter storms in light of these results. In many ways, the effects of hurricane Georges on Florida Bay resembled those of a strong winter storm rather than what many had anticipated from a hurricane. Observations following Georges confirm conclusions reached earlier by scientists studying sediments that the more frequent winter storms are mainly responsible for the slow migration and evolution of the mud banks within the bay. It is still possible that hurricanes can have

Reconstruct historical conditions (Cont'd)

	drastic and persistent effects on the ecosystem of Florida Bay. However, in the aftermath of Georges it appears that this may occur only for the most powerful and least common hurricanes. In addition, sedimentary processes in the Bay are being studied to see what they Can tell us about the effect of past hurricanes. An ongoing USGS project is synthesizing the results of these studies. Information on this work can be seen at URLs: http://sofia.usgs.gov/projects/sed_synth/ http://sofia.usgs.gov/projects/circulation/

Identify key species, habitat indicators and drivers of the ecosystem

Determine the causes of recent ecological shifts in Florida Bay, i.e. dieoff of seagrasses, sponges, and mangroves, occurrence of extensive algae blooms, and high turbidity.	Syntheses of research on these topics, which were presented at the 1999 science conference, can be summarized briefly as follows: **Water Quality** - Florida Bay and adjacent ecosystems form an extensive, interconnected aquatic system. Plankton blooms and increased nutrient concentrations observed between 1991 and 1997 may indicate that broad ecological changes now are occurring here. However, evidence available to date does not support the idea that fresh water inflow from the mainland is responsible. We still lack sufficient knowledge about several other major nutrient sources, such as inputs from the atmosphere and the Florida Shelf, to identify cause(s) of observed changes in water quality with any certainty. Contaminants are found in the sediments and in animals in concentrations high enough to affect reproduction and survival of organisms (pesticides) and to cause regulation of human consumption (mercury in fish). **Seagrass Dieoff and Recovery –** Between 1987 and 1991, dieoffs of turtlegrass denuded 4000 hectares in the West and Central regions of the Bay. It appears that hypoxia and sulfur toxicity caused these dieoffs, possibly in combination with additional stressors such as high salinity and temperature. Since 1995, the overall abundance of seagrass generally has stayed the same, and the diversity of seagrasses found in the Bay has increased. Further changes in the seagrass beds are likely to occur with the restoration of increased freshwater flows, including more localized dieoff events. Quantifying nutrient sources and assessing their impacts has been a major part of the Florida Bay Science Program's work since 1995. The eutrophication hypothesis has not been ignored in this work. The breadth of related research includes nutrient export and cycling in the mangroves near the Florida Bay coast (Rudnick et al. [Estuaries], Rudnick et al. [Abstracts], Childers et al. [Abstracts], Jaffe et al. [Abstracts]), atmospheric sources (Whung et al. [Abstracts and URL http://www.aoml.noaa.gov/ocd/sferpm/whung/whung.html]), benthic flux studies (Carlson, URL

Identify key species, habitat indicators, and drivers of the ecosystem (Cont'd)

	http://www.aoml.noaa.gov/ocd/sferpm/szmant/carlson/carlson.html), nutrient limitation studies (Vargo et al. [Abstracts]), grazing studies (Dagg et al. [Abstracts and URL http://www.aoml.noaa.gov/general/project/ocdpbo1.html]), and transport and circulation studies (Jackson [Abstracts]. Several modeling exercises are underway to attempt an overall integration of the results of these projects (Cerco [Abstracts], Burd and Jackson [Abstracts]). Considerable uncertainty and controversy remain on these topics. In particular, a white paper is currently in circulation that makes a case for eutrophication driven by nutrients in agricultural runoff as the primary cause of algae blooms in the Bay. This paper can be viewed at URL http://www.aoml.noaa.gov/ocd/sferpm/brand/FLBreport.html. A workshop was held in 1996 to review hypotheses about what controls nutrient concentrations and algae blooms in Florida Bay. This workshop was attended by a panel of experts from outside of the region, and their review report can be viewed at URL http://www.aoml.noaa.gov/flbay/pmcnutr.html. Another workshop on this topic is planned for the fall of 2000.
Identify and describe critical habitats in the Bay and linkages with upland, coastal and reef habitats.	Research to identify and map critical habitats is described under "Quantify the areal coverage by seagrass communities, and mangroves." A long-term monitoring program is in place to provide information on coastal oceanography, exchanges between the coastal ocean and Florida Bay, and currents within the Bay. Results of this work can be viewed at the following URLs: http://mpo.rsmas.miami.edu/flabay http://www.aoml.noaa.gov/ocd/sferpm/nsmith/smithcover.html.
Identify the effect of loss and fragmentation of habitat on recruitment, growth, survival and distribution of species and communities.	The effects of habitat loss and fragmentation have not yet been investigated in great detail. Current work on this topic is related to the development of the "seascape" model.
Determine the effects of vegetation on evaporation and overland flow.	Results on the effect of vegetation on flow can be viewed at URL http://sofia.usgs.gov/projects/vege_resist. Results of the effect of vegetation on evaporation can be viewed at URL http://sofia.usgs.gov/projects/evapotrans.
Map land surface elevations in southwest Florida.	Results of efforts to refined elevation measurements can be seen at URL http://sofia.usgs.gov/projects/elev_data.
Determine the response at inland sites to tidal forcing at the coast.	The USGS program investigating the influence of tides, sea level and hydrology on the hydrology of the Everglades and coastal mangroves can be viewed at URL http://sofia.usgs.gov/projects/time. This work also makes use of the results of studies on vegetative resistance and evaporation.

Identify key species, habitat indicators and drivers of the ecosystem (Cont'd)

<table>
<tr><td>Estimate recent rates of freshwater discharge into and through the mangrove estuaries.</td><td>Research on this topic can be viewed at URLs:
http://sofia.usgs.gov/projects/nutrient_load
http://sofia.usgs.gov/projects/freshwtr_flow

The Florida Bay Science Program recognizes the need to assemble these data into a standard data set. Assembly of this data set has just begun. When finished, this data set will provide the "best" reconstruction of conditions affecting the Bay during the period 1995 through 2000.</td></tr>
<tr><td>Quantify surface conditions across south Florida, i.e. area covered by water, vegetation and different types of land use for input into a regional climate model.</td><td rowspan="2">This work has been accomplished, and the results have been incorporated into a regional climate model. Results obtained by this model are described elsewhere in this report card, Mattocks et al. [Abstracts] and can be viewed at URL http://www.aoml.noaa.gov/ocd/sferpm/mattocks/mattocks_cover.html.</td></tr>
<tr><td>Determine the initial and boundary conditions in the atmosphere for this model.</td></tr>
<tr><td>Determine by observation and/or models the boundary conditions (i.e. water levels, fluxes and salinity values) at mangrove, Keys passes and Florida Shelf boundaries of the hydrodynamic model domain.</td><td rowspan="2">This has been accomplished, and the results were incorporated into model runs that were reported by Kim et al. [Abstracts] and Cosby et al. [Abstracts].

The Florida Bay Science Program recognizes the need to assemble these data into a standard data set. Assembly of this data set has just begun. When finished, this data set will provide the "best" reconstruction of conditions affecting the Bay during the period 1995 through 2000.</td></tr>
<tr><td>Estimate atmospheric ex-change of water (rainfall and evaporation) and momentum (wind stress).</td></tr>
<tr><td>Map bathymetry and benthic communities and other characteristics of the bottom needed to estimate bottom roughness effects on waves and currents.</td><td>Work to provide an up-to-date bathymetry of Florida Bay is described at URL http://sofia.usgs.gov/projects/bathymetry.

Results of research to map bottom types related to hydrodynamic friction factors are described at URL http://sofia.usgs.gov/projects/sed_trans.</td></tr>
<tr><td>Delineate internal flow patterns and determine rates of flow and exchange.</td><td>Research in this area continues with greater emphasis being given to rates of internal exchange and residence times within Florida Bay in new projects that begin this year.

Research aimed at characterizing condition in the adjacent coastal ocean and patterns and rates of exchange with Florida Bay are available at URLs:
http://mpo.rsmas.miami.edu/flabay
http://www.aoml.noaa.gov/ocd/sferpm/nsmith/smithcover.html</td></tr>
<tr><td>Identify sources of nutrients and estimate fluxes into the system.</td><td>This research is described above under "Determine causes of recent ecological shifts…"</td></tr>
</table>

Identify key species, habitat indicators and drivers of the ecosystem (Cont'd)

	Rudnick et al. [Estuaries] provides the most current estimates of regional fluxes for N and P.
Estimate rates of nutrient exchange between sediments and water column.	Research has shown 1) that Florida Bay sediment nutrients might play a major role in initiating and supporting Florida Bay phytoplankton blooms. Because sediment quality is as important as water quality in controlling phytoplankton blooms and promoting seagrass regrowth in Florida Bay, any restoration efforts in Florida Bay will require information on the amounts and flux rates of nutrients supporting these persistent blooms. This project measured spatial and seasonal variation in Florida Bay sediment nutrient pools and fluxes. Spatial variation in total sediment porosity, grain size, and carbon, nitrogen, phosphorous, and silica concentrations, as well as dissolved and solid-phase forms of nitrogen and phosphorous and microalgal abundance were measured at 24 sites across Florida Bay in July-August 1997 and again in January-February 1998. Sediment-water nutrient fluxes were measured quarterly at four sites in Florida Bay using four large, acrylic chambers in situ. Details of this research were reported by Yarbro and Carlson [Abstracts] and they can be viewed at URL http://www.aoml.noaa.gov/ocd/sferpm/szmant/carlson/carlson.html.
Identify sources of contaminants, such as pesticides and mercury, to the Bay.	Contaminants are currently being monitored in sediments, mollusks, and fish. Result of this work were presented at the 1999 science conference (Evans and Crumley [Abstracts], Lewis et al [Abstracts], Macauly and Goodman [Abstracts], Cantillo et al. [Abstracts], Rand et al. [Abstracts] and can be viewed at the following URLs: http://sofia.usgs.gov/projects/merc_speciation http://sofia.usgs.gov/projects/synth_hgcycl/

Develop (and apply) models to predict and evaluate the effects of human activities

Develop and implement the following models: - mangrove hydrology model - regional climatology model - regional (coastal ocean) hydrodynamic model - hydrodynamic/salinity model (for interior of Florida Bay and Biscayne Bay) - seagrass/water quality model - "seascape model," links biotic attributes to changing chemical and physical conditions.	**Summary:** Much has been accomplished on the development and implementation of models in the Southern Coastal Areas, as reported below. However, lack of coordination and of a plan for application of the models threatens the loss of much effort. In general, development of the models has proceeded piecemeal, with different agencies taking the lead with models of different parts of the regional hydrologic/hydraulic system. The Florida Bay Science Program has attempted to provide needed coordination and oversight (workshops) but these efforts have not always been effective. Also, agency efforts to develop and implement models generally have not been matched by a commitment of resources, i.e. staff, needed to eventually apply the models to the analysis of restoration alternatives. Without this commitment, agencies are threatened with the loss of the progress that has been made. **Mangrove hydrology model:** Work in this area has proceeded on at least three different projects. First, the Corps of Engineers has sponsored work to implement a combined surface water and groundwater hydrologic model covering the entire South Florida peninsula. Information on this work can be viewed at URL http://sofia.usgs.gov/sfrsf/rooms/hydrology/modeling/.

Develop (and apply) models to predict and evaluate the effects of human activities (Cont'd)

	Second, the USGS/WRD has implemented a surface water hydrology code in a domain that straddles the mangrove coast of Florida Bay. Results of this work can be viewed at URL http://sofia.usgs.gov/projects/sheet_flow. This model synthesizes results from several related process studies (see above) and new topographic surveys. Third, Robert Twilley et al. have constructed a simple mangrove hydrology model for use in investigating the influence of changing hydrology and sea level on the structure and dynamics of the mangrove forests along the west coast of Everglades National Park. Results of this work can be viewed at URL http://www.ucs.usl.edu/~rrt4630/mangrove-restudy.htm. **Regional climatology model:** A regional climatology model has been successfully implemented for South Florida. Results reported at the 1999 science conference (Mattocks et al. [Abstracts]) show that the model successfully capture the spatial development of convective storms, which account for the majority of rainfall in the region. Further, model results make a strong argument for the case that changes in land use over the last few decades are responsible for persistent and discernable changes in the both the spatial distribution and the seasonal amount of rainfall (decrease). These results are supported by other modeling studies and by the rainfall record. Although the trend is total rainfall is small, it is large enough to have a major effect on net water supply unless evaporation has undergone a similar change. More information on this project can be found at URL http://www.aoml.noaa.gov/ocd/sferpm/mattocks/mattocks_cover.html. **Regional (coastal ocean) hydrodynamic model:** A coastal ocean model has been implemented by NOAA. This model has been used to provide seaward boundary conditions for the RMA-10 hydrodynamic model, which covers a portion of the Florida Shelf, the interior of Florida Bay and the reef tract. More information on this project can be found at URL http://www.aoml.noaa.gov/ocd/sferpm/aikman/aikmancover.html. **Hydrodynamic/salinity model:** Research and development efforts in Florida Bay have pursued two radically different approaches to salinity prediction. These are the detailed representation of tide and wind-driven water movements in a hydrodynamic model, i.e. the RMA-10 model, and the relatively coarse, tidally averaged representation by a mass-balance model, i.e. FATHOM. Both models are operational and can be used to calculate salinity values within Florida Bay. Progress was reported at the 1999 science conference (Kim et al. [Abstracts], Cosby et al. [Abstracts]). However, more work is needed to document the predictive capability of the models. Currently, neither model has the confidence of the technical community. This is the main conclusion of a technical review of the models and from the experience in applying these models to simulate the response of Florida Bay salinity based on hydrologic scenarios from the Restudy Project. Confidence of the technical community is a prerequisite for the application of models in the planning and assessment of restoration activities. Technical reviews of these models can be viewed at URL http://www.aoml.noaa.gov/flbay/modelreview_web.html.

Develop (and apply) models to predict and evaluate the effects of human activities (Cont'd)

	In Biscayne Bay, at least two hydrodynamic salinity models are under development. One is an implementation by the Corps of Engineers of the same code, RMA-10, that they are using for Florida Bay. Information on the Biscayne Bay Feasibility Study can be viewed at URL http://www.restudy.org/biscayne.htm. A second model has been implemented by John Wang (Wang et al. [Abstracts]). This model has been applied to predict the dispersal and distribution of fish and shrimp in Biscayne Bay and south along the reef tract. **Seagrass/water quality model:** The Corps of Engineers has supported implementation of a water quality model of Florida Bay that has a seagrass component. Most attention has been paid to working out problems related to the exchange of information with the hydrodynamic model, which provides essential information on water movement, and on parameterizing nutrient fluxes and transformation rates for Florida Bay. Results of this work were reported at the 1999 science conference (Cerco et al. [Abstracts]) Although the water quality model (above) includes seagrass as a component, development of a detailed seagrass model is being pursued as a separate research effort. This modeling effort is more focussed on understanding the dynamics of the seagrass community, including the dieoff phenomenon, on the scale at which it is being studied in the field. This modeling effort is just now getting underway, and no results have been reported. The intent is that, after about 2 years of development, the model(s) developed here will substitute for the rudimentary seagrass model currently contained in the water quality model. **Seascape model:** There is now a long history of research aimed at constructing models to predict shrimp catch in the Dry Tortugas fishery based on environmental conditions, i.e. hydrology in the Everglades. Building on these results, Browder et al. [Estuaries] have both refined the empirical approach and constructed alternative models based on detailed measurement of post larval growth and survival based on ambient salinity and temperature in the Bay. These new models have been successful in relating fishery yield to changing conditions within Florida Bay, and they show promise as diagnostic tools for restoration. Progress on this work was reported by Browder et al [Abstracts] and Browder [Abstracts]. Beginning in 1999, several research projects in Florida Bay have focused directly on the expanding this approach to include the seagrass community and fish species other than shrimp. Specifically, progress on models of seagrass distribution (Fourqurean et al. [Abstracts]), juvenile recruitment of lobster (Butler [Abstracts]), molluscan communities, and communities of prey fish (Johnson [Abstracts]) was reported in several papers presented at the 1999 science conference. Work conducted since the conference continues the development of the empirical seagrass model and expands the approach to single fish species, such as seatrout.
Quantify effect of management on salinity, hydrology and circulation in	Evaluation of the effects of restricted exchange and altered hydrology depends on successful validation of the salinity model(s). During 1999, the Florida Bay Science Program coordinated a scenario analysis exercise as a test of the salinity

Develop (and apply) models to predict and evaluate the effects of human activities (Cont'd)

Florida Bay and mangroves.	models under development for Florida Bay. Model results were reviewed at a workshop by ecologists and physical scientists and reported at the 1999 science conference (Kim et al [Abstracts]). One of the main results of this exercise was a greater appreciation of the problems faced by modelers in validating salinity models once they are constructed. This is essential to gaining the confidence of the scientific community, and the models will not be used otherwise. As a result, the Program has undertaken an initiative t o define and assemble a standard data set for Florida Bay. One use for such a data set will be the validation of salinity models. A long-term monitoring program is in place to provide information on coastal oceanography, exchanges between the coastal ocean and Florida Bay, and currents within the Bay. Results of this work can be viewed at the following URLs: http://mpo.rsmas.miami.edu/flabay http://www.aoml.noaa.gov/ocd/sferpm/nsmith/smithcover.html
Evaluate ecosystem impacts of alternative water management strategies on bottom habitat (i.e. seagrass communities) and key higher trophic level species.	Application of higher trophic level models, i.e. the seascape model, to evaluate ecosystem impacts of alternative water management strategies must await the development and validation of salinity models for the associated coastal water bodies.
Evaluate the effects of restricted exchange through the Keys passes, shoaling, and reduced freshwater flows on water residence time in Florida Bay.	(See comments above on "Quantify the effect of management…")

Implement monitoring programs to measure ecosystem attributes

Quantify the areal coverage by seagrass communities, and mangroves.	The areal coverage of seagrass communities is being monitored in 9 basins within Florida Bay as part of the Fisheries Habitat Assessment Program (FHAP). This project has been devised to provide an assessment of the distribution and status of vegetated fisheries habitats (seagrasses and macroalgae) in Florida Bay. Status and trends data gathered during this study are necessary to be able to separate natural ecosystem fluctuations from changes that result from anthropogenic activities. This study will provide baseline data to evaluate the response of the macrophyte community to future management or restoration activities, e.g. proposed modifications to freshwater delivery into Florida Bay. Results were reported at the 1999 science conference by Durako et al [Abstracts]. More information on this project can be obtained at URL http://www.fmri.usf.edu/seagrass/monitor.htm. Seagrass communities in the Florida Keys National Marine Sanctuary have been mapped by the Southeast Environmental Research Center, Florida International University. Results of this work were reported by Fourqurean et al. [Abstracts]. Miam-Dade Department of Environment Resources Management (DERM) monitors seagrass communities in the coastal bays along the north coast of Florida Bay. A document describing the methods and results obtained in the regional monitoring effort, including the Miami-Dade DERM program, can be

Implement monitoring programs to measure ecosystem attributes (Cont'd)

	found at URL http://www.fiu.edu/~seagrass/. Seagrass cover has also been mapped from satellite imagery; Stumpf et al [Abstracts], Stumpf et al. [Estuaries]. A synthesis of long-term trends in seagrass communities in Florida Bay, based on the work described above, was presented at the 1999 science conference by Hall et al. [Estuaries] and Zieman et al. [Abstracts]. The mangrove communities of Everglades National Park and Biscayne National Park were mapped as part of a comprehensive vegetation-mapping project in 1995. Vegetation of Big Cypress Preserve was also mapped. This project was carried out by the Center for Remote Sensing and Mapping, University of Georgia, using satellite imagery from the period following Hurricane Andrew. More information on this project can be found at URL http://www.ovpr.uga.edu/rcd/95su/everglad.html.
Quantify the abundance and recruitment of key higher trophic level species.	Research ongoing in this area in the southern coastal area includes work on the following species: *Roseate spoonbill* (Lorenz et al. [Abstracts]); *American crocodile* (Mazzotti [Estuaries]); *Pink shrimp* (Browder et al [Estuaries], Ehrhardt et al. [Estuaries]); *Bottlenose dolphin* (URL http://species.sefsc.noaa.gov/photoid/biscaynebay.htm); *sport fish* (Johnson et al. [Abstracts], Eklund et al. [Abstracts], Ault et al. [Abstracts], Bohnsack et al. [Abstracts]; *prey fish* (Lorenz [Estuaries], Thayer et al. [Estuaries], Matheson et al. [Estuaries], Thayer et al. [Abstracts]); and *lobster* (Butler [Abstracts]). More information on the project Fish Recruitment, Growth, and Habitat Use in Florida Bay can be viewed at URL http://www.aoml.noaa.gov/ocd/sferpm/hoss/hosscover.html. In general, work on communities and individual species seeks to document their response to changing environmental conditions, both in the water column (e.g. salinity), and benthic habitat (Johnson et al. [Abstracts], Butler [Abstracts]). The Higher Trophic Level Team of the Florida Bay Science Program provides overall coordination with the objective of formulating models of these responses, i.e. performance measures, so that this information is accessible to resource managers. (See section on the "seascape model.")

References

Florida Bay: A Dynamic Subtropical Estuary. Estuaries vol. 22(2B), June 1999. Available at http://erf.org/journal/journal.html

Program and Abstracts. 1999 Florida Bay and Adjacent Marine Systems Science Conference. November 1-5, 1999, Key Largo, Florida. Available at http://www.ifas.ufl.edu/~conferweb/fb_ab.pdf

Science Subgroup. 1997. Ecologic and Precursor Success Criteria for South Florida Ecosystem Restoration. Report to the Working Group of the South Florida Ecosystem Restoration Task Force. Available at http://everglades.fiu.edu/taskforce/precursor/toc.html

Science Subgroup. 1996. South Florida Ecosystem Restoration: Scientific Information Needs. Report to the Working Group of the South Florida Ecosystem Restoration Task Force. Available at http://everglades.fiu.edu/taskforce/scineeds/index.html

Working Group. 1998. Success in the Making: An Integrated Plan for South Florida Ecosystem Restoration and Sustainability. South Florida Ecosystem Restoration Task Force. Available at http://www.sfrestore.org/documents/success/01.htm

Appendix 1: Scientific Information Identified in the 1996 Report

Models

Models are essential tools for understanding and managing complex systems. One major use of models will be as assessment tools to evaluate proposed plans by predicting how the ecosystem and its various components will respond to the changes. Five general classes of models – hydrologic, hydrodynamic, meteorological, ecological, and water quality/transport – will be used. Figure 7 shows how these models are connected and how they will provide information needed by other models and, in turn, use data generated by other models. Here is summarized the scientific information about the Southern Coastal Areas that is needed to construct and apply this suite of predictive models.

Characterize the ecosystem, drivers, and attributes.
- input data for regional climatological model (areas of surface water, land use and cover, atmospheric boundary and initial conditions)
- input data for hydrologic/salinity models for mangrove coast (vegetation effects on ET and flow rate parameters, discharges rates for calibration, elevations in SW Florida, tide amplitude and phase lag along transect perpendicular to coast)
- habitat requirements for native species (for purpose of GAP analysis)
- salinity requirements of species
- internal flow paths, exchange rates
- volume flux through Keys passes, banks
- freshwater inflow (to Florida Bay)
- groundwater inputs (to Florida Bay)
- boundary fluctuations of salinity, water level
- forcing from West Florida shelf waves
- wind fields and wind-generated surface waves
- bottom community maps
- precipitation and evaporation (in Florida Bay)

Reconstruct historical conditions.
- salinity patterns
- determine targets and strategy to recreate natural quantity, timing, quality, and distribution of water using natural and water management hydrologic models (NSM, SFWMM)

Measure ecosystem attributes.
- area of various plant communities

Evaluate and predict the effects of human activities.
- determine linkage between water management and rainfall with meteorological model linked to hydrologic models (SFARPS)
- quantify water management effects on salinity, water depths and water flow in mangrove zone using hydrologic-salinity model

- evaluate ecosystem impacts of alternative water management strategies using linked trophic-level models
- determine abundance and diversity of native flora and fauna on the basis of available habitat using GAP
- determine acreage of favorable estuarine habitat in terms of salinity and bottom features using a seascape model linked to hydrologic models
- determine how water management affects salinity and circulation in Florida Bay using hydrodynamic models

Subregion 8: Southern Coastal Areas

The Southern Coastal Areas includes the Atlantic Coast estuaries from South Biscayne Bay to Barnes Sound, Florida Bay proper and its fringing mangrove habitat, the Florida Keys and associated coral reef tract, and the West Coast estuaries from Whitewater Bay to Rookery Bay with their extensive mangrove habitats. Restoration in this area will be largely dependent on getting the water right, i.e. restoring the quality, quantity, timing and distribution of freshwater flows from the Greater Everglades and adjacent developed areas into the coastal estuaries. Restoration efforts are focused on redirecting fresh water into Biscayne Bay, Card Sound, and Barnes Sound via the C-111 system and restoring flow into northern Florida Bay via Taylor Slough and Shark Slough. A review of existing management plans was completed in 1996. Critical gaps in information considered essential for management decisions supporting restoration in this region were identified and are highlighted in Figure 16 along with objectives for Subregion 8.

Characterize the ecosystem, drivers, and attributes.
- Quantitative data on inputs and outputs for nutrient budget.
- Nutrient exchanges rates between sediment, water column, and plants.
- Controls on magnitude and flux directions.
- Phytoplankton, macroaglae, and coral nutrient assimilation rates.
- Principal environmental factors that explain observed distribution and recent die-off of seagrasses, corals, sponges, and mangroves.
- Critical habitat.
- Linkages between upland, coastal and reef habitat.
- Sources, quantities and effects of toxic pollutants.
- Cause of turbidity in Florida Bay and relation to water quality.
- Impacts of fragmentation on populations and processes.
- Impacts of fragmentation.
- Relationship of recruitment to habitat variation in estuaries and reef tract.
- Relationship between altered conditions and growth and survival.
- Relationship between habitat degradation/loss and fisheries productivity
- Relationship between Florida Bay habitat changes and changes in coral reefs and southern coastal areas.

Reconstruct historical conditions.

- Historical relationship of surface and groundwater flows through Everglades, flow restriction through Keys channels, and Florida Bay salinity.
- Effects of climate extremes on accumulation of sediments, nutrients, and organic matter in Florida Bay.

Measure ecosystem attributes.

- Data necessary for recovery of endangered and threatened species.

Evaluate and predict the effects of human activities.

- Effects of increased water residence time in Florida Bay caused by restricted Keys channel flow, shoaling, and reduced freshwater inflows.

Other issues/needs identified

The 1996 Scientific Information Needs report identifies a number of issues/needs that pertain to the Southern Coastal Area but which are not identified in the report specifically as science needs in the section devoted to the southern coastal areas. These issues/needs are summarized here.

- How will hydrologic changes, both in quality and quantity of fresh, estuarine, and oceanic waters from all boundaries, impact coastal waters and associated habitats from Barnes Sound to Charlotte Harbor?
- How will sea level rise impact the area and interact with anthropogenic changes?
- How does water quality from upstream subregions impact Subregion 8 (southern coastal areas)?
- How will the hydrology of South Florida be affected by continued development in Monroe, Dade and Collier counties?
- What are the main land-sea human interactions with the area?
- A major issue is that 37 plant and animal species in Subregion 8 are Federally listed as endangered or threatened, or are under review for listing, under the endangered Species Act of 1973. All 21 species currently listed either have recovery plans completed or in the process of completion.
- Each agency needs to develop an implementation plan, relative to their jurisdictional responsibilities, that addresses the scientific information needs outlined in Figure 16.
- A complete biological inventory of Subregion 8 must be completed by the agency with primary jurisdictional responsibility for each area with the subregion.
- The FWS needs to develop a comprehensive strategic plan that includes all wildlife refuges as a whole, within the subregion and perhaps within the State. A science implementation plan must also be developed that includes impacts of continued development on habitat, especially as related to endangered species.
- Linkages between upland influences relative to coastal habitat need to be better defined and identified in all existing plans.

Appendix 2: Scientific Information Needs Identified Since the 1996 Report

This section compiles science information needs identified for the Southern Coastal Areas since 1996. These are derived from resource management plans, other management documents and documents arising from a review of the Science Program in Florida Bay, Table 3. All of these documents were written after the 1996 Science Subgroup report. A few of the consulted documents were only available as draft documents; therefore the science needs identified in them are subject to possible revision. However, these are included here because they represent important new management initiatives that will have an effect on the direction of research in the Southern Coastal Areas.

Peer review of research provides science with a mechanism of self-regulation. Left alone, this process will pursue a path of increasing understanding of ecosystem processes. However, resource managers, who support and rely on scientific information to guide their decisions, must intervene to assure that the path of research also serves managers' evolving needs. The information assembled here provides that direction to research in the Southern Coastal Areas.

Each new science need added to the list, Table 4, corresponds to a need explicitly identified in one of these documents. A few key documents, such as the Multispecies Recovery Plan and the planning documents for the Florida Key National Marine Sanctuary contribute the bulk of the newly identified science needs. Other documents consulted are primarily reviews of existing science information and did not contribute to identifying new science needs. The detailed statements of science needs found each document are attached as Appendix 2 to this report.

Table A.2.1: Source documents consulted in updating the statement of science needs for Southern Coastal Areas

Organization	Source Documents	doc #
Science Program for Florida Bay and Adjacent Marine Systems	• PMC 1998. letter to Mr. Stuart Appelbaum, Project Manager, C&SF Project Restudy, U.S. Army Corps of Engineers.	**1**
	• PMC, 1997. Strategic Plan for the Interagency Florida Bay Science Program.	**2**
	• Hobbie, J.E. et al. 2000. Perspectives from the 1999 Florida Bay Science Conference. Report of the Florida Bay Science Oversight Panel	**3**
	• Boesch et al. 1998. Annual Report of the Florida Bay Science Oversight Panel: Perspectives from the 1998 Florida Bay Science Conference.	**4**
	• Boesch, D.F. et al. 1997. Annual Report of the Florida Bay Science Oversight Panel: Perspectives from the 1996 Florida Bay Science Conference and Review of the Strategic Plan.	**5**
Department of the Interior	• CESI 2000. Priorities for coastal and marine science in Critical Ecosystem Studies Initiative	**6**
	• VanLent et al. 1999. An examination of the Modified Water Deliveries Project, the C111 Project, and the Experimental Water Deliveries Project: Hydrologic analyses and effects on endangered species.	**7**
Department of Commerce (NOAA)	• Schmidt et al. 1999. Site Characterization for the Dry Tortugas Region: Fisheries and Essential Habitat. report of project supported by NOAA and NPS.	**8**
	• NOAA 1998. South Florida Ecosystem Monitoring Integration Project Implementation Plan	**9**
	• The Nature Conservancy Florida and Caribbean Marine Conservation Science Center 1996. Site Characterization for the Florida Keys National Marine Sanctuary and Environs. report prepared under contract to NOAA.	**10**
	• NOAA 1996. Florida Keys National Marine Sanctuary Final Management Plan/Environmental Impact Statement	**11**
Environmental Protection Agency	• Kruczynski 1999. Water Quality Concerns in the Florida Keys: Sources, Effects, and Solutions	**12**
U.S. Fish and Wildlife Service	• FWS 1999. South Florida Multi-species Recovery Plan	**13**
South Florida Water Management District	• Rudnick et al. 1999. Sufficiency Review of Information Needed to Establish Minimum Flows and Levels for Florida Bay (draft)	**14**
	• South Florida Water Management District 1999. 2000 Everglades Consolidated Report	**15**
	• Ogden and Davis 1999. Conceptual models documents for Florida Bay and mangrove coast (draft)	**16**

Table A.2.2: Science Needs for the Southern Coastal Areas Identified after 1996
(Numbers in brackets refer to the corresponding source document listed in Table 3.)

Reconstruct Historical Conditions

- A review of existing paleoecology projects indicates a number of significant gaps that should be addressed. 1) The consistency in Pb-210 and C-14 dating by atomic mass spectrometry must be established before pre-1940 records can be reliably dated to define the natural state of the Bay. 2) The spatial and temporal natural variability must be established to a higher degree of confidence to support resource and restoration decisions. 3) Other environmental proxies should be considered with the 80 yr rainfall record at Homestead, such as tree rings to tease out annual rainfall and evaporation variability across the Bay. [3]

- It should be a priority of the Paleoecology Research Team to produce a consensus reconstruction of salinity trends and variability in Florida Bay as they relate to climatic variability and water management practices. [4]

- New paleoecological approaches involving chemical, sedimentological, or biological indicators reflecting past seagrass abundance and algal blooms should be attempted to establish whether the recent crisis in Florida Bay is simply another episode in a naturally occurring cycle or is unique to contemporary conditions. [5]

- Because the appropriate record of observation and measurement is not available to document the sequence and spatial extent of the changing nutrient inputs and plant communities within Florida Bay, the paleoecology research team should explore all approaches that might give meaningful information about the changing trophic conditions of Florida Bay, including the organic components (pigments, biomarkers) and biotic communities (including indicator species) of the sediment record. [5]

- Biscayne Bay: Define pre-drainage conditions for central and southern Biscayne Bay, to the extent possible, salinity regimes in the bay, coastal morphology, surface and groundwater hydrology, and biota that characterized the bay before the C&SF Project. [6]

- Strategy Z.2, Z.3, Z.5 – Conduct baseline surveys in the designated ecological reserves, sanctuary preservation areas, and special use areas. [11]

- W.24 – Conduct an historical assessment of Everglades/Florida Bay/Florida Keys hydrology as it has affected water quality and biological communities in the Sanctuary. [11]

- Identify historical and geological trends in mangrove distribution relative to hydrology and sea-level in the mangrove communities of South Florida. [13]

Identify key species, habitats indicators, and drivers of the ecosystem

- Basin-scale studies are clearly needed in the eastern and central parts of the Bay. Vital questions include: how long are residency times of water masses; how much communication is there between adjacent basins; and what is the evaporation across the Bay? Earlier plans to carry out intensive monitoring of some basins should be implemented. Focus on inter-basin flow, tidal and freshwater effects, salinity and nutrient balances, and evaporation leading to hypersalinity. [3]

- The development of a canonical data set is needed in which are described basic forcing functions, boundary conditions, and response variables. This will serve the need for a calibration data set for models. As well, these data will become the point of reference in discussions of what constitutes a “wet year” or “long residence time.” The data should include bathymetry, meteorology, freshwater and wastewater inflow, circulation, salinity, water quality, benthic conditions, and biological resources both seasonally and synoptically. Forcing functions such as climate cycle (ENSO), Loop Current position, Gulf Stream eddies (seaward of Keys), and hurricane events should be readily available. [3]

- Efforts should be undertaken to examine the vertical flow structure over the central portion of Bay.[4]

- Efforts should be undertaken to address nutrient input and export across the entire western boundary, particularly across the banks and channels separating the Gulf Transition Zone and Western Florida Bay. [4]

- An attempt to measure spatial structure of evaporation should be made. [4]

- Nutrient input estimates (including atmospheric) are sparse and should be expanded. [4]

- A cooperative effort should be taken by modelers and field scientists to address the question of flow over mudbanks during high tide. [4]

- There is a need to integrate hydrographic measurements (UM), water quality data (FIU) and oceanographic observations to clearly describe the physical regime inside/outside of Florida Bay proper. [4]

- Attention should be paid to the question of the use of organically bound nutrients by microbes and algae and to what degree do these nutrients transverse the Bay through channels and mudbanks. [4]

- Both laboratory and field experiments using carbonate sediments from the natural system should go forth to provide essential geochemical information. [4]

- Rate measurements of nutrient recycling by algae throughout the Bay are needed. [4]

- Process studies leading to a full understanding of the formation and persistence of algal blooms in Florida Bay remains lacking. [4]

- A special focus on the causes and interrelationships of seagrass die-off, algal blooms and pelagic and benthic grazing needs to be undertaken. [4]

- Understanding nutrient dynamics and their relationships to phytoplankton production is of central importance in evaluating whether there has been an ecosystem shift, and if so, what the causes are.[4]

- It is imperative that high quality data assessing the single and combined effects of salinity and temperature on seagrass survival and growth become available soon. [4]

- The extent to which *Labyrinthula* causes seagrass mortality under various field conditions, or whether it was a causative agent in the initial or subsequent seagrass die-off should be addressed ASAP. [4]

- Expanded study of the dynamics of the “urchin outbreak” on *Syringodium* and the significance of this event are needed ASAP. [4]

- A retrospective analysis, which takes into account other supportive long-term knowledge of pink shrimp, should be assessed. [4]

- Bay and basin-wide detailed nutrient balances are needed to address algal blooms, management of wastes from the Florida Keys, and assessments of C-111, Taylor Slough, and Shark River impacts.[5]

- Additional drilling and geochemical monitoring of groundwater test wells are needed to determine whether or not the contribution of subsurface seepage plays a major role in the overall composition of Florida Bay waters.[5]

- The PMC should support a group of investigators to resolve key questions in the “River of Sand” such as conductance, residence time, nutrient concentrations, recharge areas and surface effluent zones.[5]

- Atmospheric deposition of nutrients to the Bay remains unquantified and should be addressed.[5]

- The lability of organic matter needs to be calibrated in order to assess the effects of defoliation and death of mangroves from Hurricane Andrew and the contribution of increased seagrass detritus to initiating plankton blooms.[5]

- Attention should be focused on empirical measurements of diagenetic rates to determine the role of the sediments in nutrient cycles in the Bay.[5]

- It is necessary to determine the rate of *Labyrinthula* transmission in the field.[5]

- It is critical to determine whether the pathogen can initiate a seagrass die-off without concomitant physiological stress.[5]

- Identification of other seagrass pathogens should be pursued.[5]

- A GIS map depicting algal blooms, sediment plume distribution, light transmittance, temperature, salinity, and seagrass distribution should be produced.[5]

- Data collection and research on potential grazers of epiphytes, such as mesoherbivores, scarids, and other macroherbivores, should be pursued.[5]

- Seagrass transplantation into unvegetated, declining, and other areas would serve as a valuable research tool as well as act as a living indicator of water quality and sediment stabilization.[5]

- Experiments addressing the interaction of light, salinity, and temperature on seagrass restoration should be undertaken.[5]

- Mesocosm experiments, combined with field manipulations and transplantation, will become critical in evaluating seagrass physiology. Site visits to mesocosm facilities by scientists familiar with mesocosm problems and seagrasses should occur.[5]

- Information on higher trophic level distribution and production needs to be scaled to the whole system, not described site by site.[5]

- Links to circulation, water quality, and seagrass models to predict areas of high and low fish and shell-fish production based on physiological and habitat requirements of individual species should be undertaken. The predictions from the models could be tested against actual measurements of growth or production.[5]

- More work needs to be done on the processes of growth, recruitment, and mortality; and less on standing stock.[5]

- Strategy F.3 – Assess existing research on the impacts of stocking on the genetic integrity of native stocks. Conduct research on natural stock recovery and its role in maintaining genetic integrity.[11]

- Strategy F.7 – Conduct research on the impacts of artificial reefs on fish and invertebrate populations for long-term management.[11]

- Strategy F.10, F.11, F.14, F.15 – Conduct research on fishery harvesting methods to provide information for programs to evaluate, reduce or eliminate adverse impacts.[11]

- Strategy B.2 – Conduct research to develop information needed to plan, direct and monitor habitat restoration efforts.[11]

- Strategy R.5 – Conduct a program to study and implement carrying-capacity limits for recreational activities.[11]

- Strategy W.24 – Conduct studies of the circulation (present-day, long-term net transport and episodic transport) from Florida Bay to the Sanctuary and studies to document the ecological impacts, if any, of Florida Bay waters on Sanctuary communities.[11]

- Strategy W.22 – Conduct special studies to 1) establish pollutant loading thresholds, 2) detect the presence of waste-water pollutants and determine relative contribution from various sources, 3) document transport and severity and extent of ecological impacts.[11]

- Strategy W.23 – Conduct special studies to document the fate and impacts of non-wastewater pollutants, develop innovative monitoring tools, and examine the effects of global climate change on organisms and ecosystems of the Keys.[11]

- Support research on the physiology, life history, and ecology of the manatee. Studies of physiology, life history, and ecology are needed for understanding population status and trends, and to help assess what habitats are most important to manatees and why. Collect additional biological information on number of individuals, age-class structure, habitat use, reproductive viability, food use and availability, and threats.[13]

- Conduct research on the biology and life history of crocodiles. Although basic information on the biology of the American crocodile has been collected, more detailed information is needed to determine the status of the crocodile population in South Florida.[13]

- Conduct research on the habitat relationships of the American crocodile. Much of the habitat-based research needed for the recovery of the American crocodile is currently addressed in one or more research projects dealing with the maintenance and recovery of the Florida Bay ecosystem. However, specific research information on the relationship of American crocodiles to salinity regimes, exotic species, and adjacent land uses will be critical to the design of future management actions for the American crocodile.[13]

- Continue to gather information on green turtle, hawksbill sea turtle, Leatherback sea turtle, and Loggerhead sea turtle species and population biology.[13]

- Conduct research to evaluate the relationship of sand characteristics (including aragonite) and green turtle, hawksbill sea turtle, Leatherback sea turtle, and Loggerhead sea turtle nesting behavior, nesting success, hatching success, hatchling emerging success, hatchling fitness, and sex ratios.[13]

- Identify the extent of mangrove habitat. Although the existing GIS information, aerial photography, and ground-truthed land cover information are available for this community throughout South Florida, a comprehensive regional analysis has not been conducted. [13]

- Continue and update studies on the utilization of mangrove communities by endemic and wide-ranging species, including the development of landscape-scale management recommendations for the recovery of these species in South Florida. [13]

- Perform a hydrologic study of the flood attenuation and storm buffering potential of mangrove habitat under natural sheetflow conditions. [13]

- Examine the population dynamics by invasive exotics in the understory of mangrove habitat. [13]

- Examine the habitat value of buttonwood forests in South Florida. [13]

- Identify and characterize the extent of remaining salt marsh habitat. Salt marshes are found throughout most of South Florida, but specific information on community types and extent is not known. [13]

- Conduct research on salt marshes in South Florida by examining their structure, composition, and ecological processes. Very little is known about the ecological processes of South Florida salt marshes. Additional information is needed to help restore and preserve these habitats. [13]

- Characterize the importance of salt marshes to other flora and fauna, especially less-known taxa like insects and marine invertebrates. [13]

- Investigate the effects of hydrologic alterations on salt marsh processes. [13]

- Investigate salt marsh nursery grounds. [13]

- Continue to conduct genetic research of salt marsh vegetation. [13]

- Investigate the effects of non-native species on salt marshes. [13]

- Compare the ecology of marshes in different regions of South Florida, especially to the Keys. [13]

- Compare restored marshes to natural marshes. [13]

- Compare and evaluate salt marsh restoration techniques to determine the ability of different techniques to replace the structure, composition, and ecological processes of natural marshes. [13]

- Determine the relationship between light and water quality to seagrasses. Increases in turbidity and nutrients occur both in short pulses and over long periods of time. In order to determine the effects to South Florida's estuaries from episodic events, measurements (*i.e.* monitoring) of photosynthetically active radiation, water quality, and seagrass cover and abundance need to be taken at the fixed transect sites. Implement site-specific monitoring protocols to identify causes of seagrass decline. Integrating these measurements should identify the effects light and water quality have on seagrasses. [13]

- Because of the problems experienced by Florida Bay, the effect of extensive phytoplankton blooms (*i.e.*, light availability, and nutrient regimes) as well as slime mold disease (*i.e.*, *Labyrinthula*) on seagrass communities should continue to be investigated. In addition, the effects of freshwater flows (*i.e.*, quality, quantity, timing, distribution) on seagrasses should be investigated further. [13]

- 3a) Primary producers – Measure the primary production of seagrasses, algae, and mangroves during wet and dry seasons using techniques that establish reference conditions. Correlate variance around the reference condition with environmental variables such as water quality and quantity.[14]

- 3b) Secondary producers - Initiate a program to review and examine the growth requirements[, i.e. environmental conditions] of economically, ecologically and legally important animals. [14]

- 4) – Investigate nutrient cycles, transport and availability in response to freshwater flows by
  1) evaluating sediment accretion and erosion across marsh-mangrove and basin-bank ecotones;
  2) measuring water and nutrient fluxes across sediment-water interfaces and mangrove-bay transects and determine the effects of high salinity on nutrient retention by sediments and soils; and
  3) conduct wetting/drying studies across marsh-mangrove ecotone. [14]

Develop (and apply) models to predict and evaluate the effects of human activities.

- Existing hydrologic models must be refined so that they provide more reliable predictions of volume and location of flows into Florida Bay, Biscayne Bay and across the southwest Florida coast. [1]

- The regression equations relating salinity at coastal locations to water levels at P33 are neither robust nor reliable measures of ecological conditions in Florida Bay. Therefore, managers should not rely on these in the detailed planning leading to implementation of restoration. [1]

- NOAA's Princeton Ocean Model is critical to providing oceanographic and boundary conditions and forcing to the Bay circulation model and must include measures of uncertainty for water levels, velocities, and fluxes. [5]

- Shinn (USGS) should perform a simple Darcy's Law calculation of the potential flux and these water-flux calculations can be contrasted with inlet-flux measurements by the COE and others. [5]

- It is essential that a conceptual model of higher trophic levels in Florida Bay be developed. [5]

- Florida Bay: Develop a practical model of effects of freshwater inflows on salinity patterns in the bay to permit evaluation of the ecological effects of changes in South Florida water management. [6]

- Florida Bay: Develop a model of water circulation in the bay that will permit evaluation of the ecological effects of changes in South Florida water management. [6]

- Strategy W.21 – Develop phased hydrodynamic/water quality models and coupled, landscape-level ecological models to predict and evaluate the outcome of in-place and proposed water quality management strategies. [11]

- Develop predictive models that link light attenuation to water quality and to nutrient loadings and epiphyte abundance. The most critical factor affecting seagrass distribution and abundance is light availability, which is a function of water quality. Hence, identifying the water quality constituents regulating light availability in the water column is an initial step. Understanding how nutrients and epiphytes affect light availability is just as crucial. These predictive models will be linked to identify pollutant load reduction goals for specific estuaries or specific segments within estuaries. [13]

- 5a) Statistical models – Use statistical approaches to explore cause and effect relationships and design experiments. [14]

- 5b) Hydrodynamic models – Use hydrodynamic models to predict exchange rates and residence times for zones and sub-basins within the Bay and to predict the salinity distribution in the Bay for a given rate and distribution of freshwater input.[14]

- 5c) Water quality models – Use water quality models to evaluate the spatial effects of MFL policy on water quality. [14]

- 5d) Vegetation models and 5e) Higher trophic level models – Use models to integrate results from growth and scope studies (higher trophic level), mesocosm experiments (on physiological responses), studies of primary productivity, and analysis of biogeochemical processes. This needs to be done in order to understand the long-term responses of a plant community or plant species to freshwater delivery schedules related to setting MFLs.[14]

Implement monitoring programs to measure ecosystem attributes

- There is need for a plan designed to detect future trends in water quality and biological resources. The plan should consider the impacts of oil spills, drought, and El Nino/La Nina. The oil spill simulations conducted for the west Florida shelf in the early to mid-1990s by Florida State University should be investigated to see what Florida Bay resources might be at risk. These resources (e.g. the western grass beds) should be adequately defined before a spill occurs to ensure adequate damage assessment. Quantifying the effects of drought and resulting hypersalinity or the effects of an El Nino/La Nina will be difficult. The long-term monitoring programs must measure the best parameters frequently enough at critical locations. There should be flexibility so as to be able to change the monitoring frequency and intensity from year to year.[3]

- While there is no need to make measurements during or immediately after a large hurricane, a plan must define exactly the priorities of what to be measured and when and where. A plan should be in place or updated before the 2000 hurricane season.[3]

Biological Strategy[9]

- B.1 – Standardize bloom-monitoring methods, establish a core monitoring group, and integrate remote sensing.
- B.2 – (none)
- B.3 – Coordinate and supplement current seagrass monitoring programs.
- B.4 – Establish a strategy for rapid assessment of the effects of natural and anthropogenic events.
- B.5 – Assess nutrient enrichment/limitation on primary productivity.
- B.6 – Coordinate monitoring and assessment of coral reef change.
- B.7 – Monitor habitat changes due to invasion of exotic plants.
- B.8 – Establish monitoring of animal and plant diseases.

Chemical Strategy[9]

- C.1 – Establish comprehensive monitoring of nutrient sources, sinks and transformation in the water column and sediments.
- C.2. – Establish comprehensive monitoring of contaminant sources, sinks and transformation in the water column, sediments and food chain.

Human Activities Strategy[9]

- H.1 – Measure population growth and its impact on the environment.
- H.2 – (none)
- H.3 – (none)
- H.4 – Determine extent of wetland, mangrove and forest losses.
- H.5 – Monitor harvest of fish, shellfish in recreational and commercial fisheries.

Physical Strategy[9]

- P.1 – Monitor changes in light attenuation in the water column.
- P.2 – Monitor circulation and exchange between coastal water bodies.
- P.3 – Monitor changes in salinity and related hydrologic fluxes of rainfall and evaporation.

- Strategy F.6 – Evaluate and enhance existing fisheries sampling programs. Initiate a fishery pre-recruitment monitoring effort.[11]
- Strategy W.33 – Develop and implement a Sanctuary-wide program to monitor the status of various biological and ecological indicators to discern the effects of human and natural disturbances and assess the overall health of the Sanctuary. [11]
- Strategy W.5 – Develop and evaluate biochemical and ecological measures to provide early warning of widespread ecological problems. Develop water quality standards appropriate to coral and seagrasses. [11]

- Strategy W.20 – Provide long-term, comprehensive information about the status and trends of water quality parameters and biological resources in the Sanctuary; and evaluate the effectiveness of remedial actions taken to reduce water pollution. [11]

- Support the investigation of the distribution and status of the manatee and its habitat in South Florida by continuing flying synoptic statewide aerial surveys. Aerial survey sighting data have provided and continue to provide useful data on manatee distribution and, in some situations, relative abundance. When combined with telemetry data, certain types of aerial sightings provide a sound basis for determining habitat use patterns. Aerial sightings also provide useful information on the proportion of calves. Because of uncertainty in the number of animals not seen in turbid water, uncertainty as to the proportion of the population within a survey area, and other problems, however, aerial sighting data generally do not permit scientists to estimate or detect trends in population size.[13]

- Support the monitoring of manatee populations in South Florida. The success of efforts to develop and implement measures to minimize manatee injury and mortality and to protect manatee habitat will depend on the accuracy and completeness of data on manatee life history and ecology, population status, and habitat condition. [13]

- Develop and implement a manatee habitat monitoring program. In addition to efforts to monitor the status of manatee populations, work should be undertaken to monitor the condition and status of manatee habitat. Information from such a program could provide an early warning of future threats to manatee populations and help explain observed manatee population trends. Presently, there is no systematic approach to monitoring the condition of key manatee habitats. [13]

- Conduct surveys to determine the current distribution and abundance of American crocodiles. Survey all remaining suitable habitats in South Florida for American crocodiles. Most knowledge about the current distribution of crocodiles comes from surveys conducted within Everglades NP, the upper Florida Keys, and areas surrounding Turkey Point in Miami-Dade County. These areas correspond to locations with the highest known crocodile densities, but do not represent the entire range of the American crocodile. Surveys for crocodiles have not been conducted in large portions of South Florida; for example, American crocodiles have been observed in increasing numbers on the southwest coast of Florida, north to the J.N. Ding Darling NWR. These areas should be surveyed in order to determine the size and distribution of the American crocodile population and should include occurrence of individuals and nesting effort. [13]

- Monitor the South Florida crocodile population. Long-term monitoring is essential to the assessment of the status of the crocodile population. [13]

- Continue to monitor crocodile habitat. [13]

- Continue standardized surveys of nesting beaches to determine if Kemp's Ridley sea turtles nest in South Florida. [13]

- Continue standardized surveys of green turtle, hawksbill sea turtle, Leatherback sea turtle, and Loggerhead sea turtle nesting beaches. Nesting surveys are undertaken on the majority of nesting beaches. In the past, beach coverage varied from year to year, as did the frequency of surveys, experience and training of surveyors, and data reporting. Consequently, no determination of nesting population trends had been possible with any degree of certainty. However, in 1989, to better assess trends in nesting, DEP, in cooperation with FWS, initiated an Index Nesting Beach Survey (INBS) program to collect nesting data that can be used to statistically and scientifically analyze population trends. The INBS program should continue to gather a long-term database on nesting activities in Florida that can be used as an index of nesting population trends. [13]

- Monitor trends in green turtle, hawksbill sea turtle, Leatherback sea turtle, and Loggerhead sea turtle nesting activity. DEP and FWS should continue to refine standardized nest survey criteria, identify additional index survey beaches to be monitored, and continue to conduct training workshops for surveyors. Consequently, DEP and FWS should ensure that routine monitoring of nesting beaches is done on at least a weekly basis during the time that green turtles, hawksbill sea turtle are nesting, including the timeframes of any nesting that occurs outside of the regular survey period.[13]

- Update the GIS database for mangroves to monitor cumulative impacts. As areas of mangroves are converted to other land uses, changes should be mapped to identify and analyze trends in habitat loss. [13]

- Monitor mangrove communities to evaluate biodiversity. Monitor community- level processes, structure, and composition, including rare and imperiled species. Improve reference information for community composition, biodiversity, and site-to-site variability[13]

- Develop a long-term monitoring plan to evaluate status of salt marshes. Monitor the extent of salt marsh habitat by updating the loss or change of habitat due to residential or commercial construction through GIS databases. [13]

- Identify the extent of seagrass habitat. Using existing GIS databases, satellite/thematic images and aerial photographs (scales =1:12,000; 1:24,000; or 1:48,000) coupled with ground-truthing efforts, produce maps of seagrass distribution and abundance as an initial step in evaluating the extent of seagrasses in South Florida. Many of the region's estuaries have already been mapped or are currently being mapped for seagrasses (*e.g.*, Indian River Lagoon, Biscayne Bay, Florida Bay, and the Florida Keys). [13]

- Assess the status and condition of existing seagrass habitat. Monitoring selected areas within the region will be used to determine if seagrass beds are healthy or stressed and whether conditions are stable, improving, or declining and to what degree. [13]

- 2a) Hydrologic conditions – Quantify water flow and exchange around the Bay's boundaries, including creeks and marshes draining mangrove wetlands, inlets along the Florida Keys, and across the wide Gulf of Mexico boundary. As well, quantify precipitation, evaporation, surface water and groundwater flow within the Bay, including flow among its banks, channels and basins. [14]

- 2b) Water quality – Continue operation of the water quality-monitoring network established in 1991. This network tracks salinity, temperature, dissolved oxygen, pH, chlorophyll and nutrients. [14]

- 2c) Soil and sediments – Monitor sediment and porewater geochemistry in various regions, including [mangroves and] several seagrass communities to document the effects of salinity fluctuations on sediments and ecosystem health. [14]

- 2d) Flora – Monitor seagrass, its productivity, distribution and health, and algal blooms, their composition, magnitude, and distribution, in the Bay. Also expand existing monitoring of the macrophytes and periphyton in and near the transition zone between the Bay and the freshwater Everglades. [14]

- 2e) Fauna and 2f) Endangered &threatened species – Quantify health, reproduction, abundance, spatial distribution, and variability of upper trophic resources of the Bay. Resources to be monitored include not only designated endangered and threatened species, important game fish, shrimp, and lobster, but also the basic components of the food web on which they depend. [14]

Appendix 3: Notes on the Scientific Information Needs Identified Since 1996

Table A.3: Source documents consulted in updating the statement of science needs for Southern Coastal Areas

Organization	Source Documents	Doc. #
Science Program for Florida Bay and Adjacent Marine Systems	PMC 1998. letter to Mr. Stuart Appelbaum, Project Manager, C&SF Project Restudy, U.S. Army Corps of Engineers	**1**
	PMC, 1997. Strategic Plan for the Interagency Florida Bay Science Program.	**2**
	Hobbie, J.E. et al. 2000. Perspectives from the 1999 Florida Bay Science Conference. Report of the Florida Bay Science Oversight Panel	**3**
	Boesch et al. 1998. Annual Report of the Florida Bay Science Oversight Panel: Perspectives from the 1998 Florida Bay Science Conference.	**4**
	Boesch, D.F. et al. 1997. Annual Report of the Florida Bay Science Oversight Panel: Perspectives from the 1996 Florida Bay Science Conference and Review of the Strategic Plan.	**5**
Department of the Interior	CESI 2000. Priorities for coastal and marine science in Critical Ecosystem Studies Initiative	**6**
	VanLent et al. 1999. An examination of the Modified Water Deliveries Project, the C111 Project, and the Experimental Water Deliveries Project: Hydrologic analyses and effects on endangered species.	**7**
Department of Commerce (NOAA)	Schmidt et al. 1999. Site Characterization for the Dry Tortugas Region: Fisheries and Essential Habitat. report of project supported by NOAA and NPS.	**8**
	NOAA 1998. South Florida Ecosystem Monitoring Integration Project Implementation Plan	**9**

	The Nature Conservancy Florida and Caribbean Marine Conservation Science Center 1996. Site Characterization for the Florida Keys National Marine Sanctuary and Environs. report prepared under contract to NOAA. NOAA 1996. Florida Keys National Marine Sanctuary Final Management Plan/Environmental Impact Statement	**10** **11**
Environmental Protection Agency	Kruczynski 1999. Water Quality Concerns in the Florida Keys: Sources, Effects, and Solutions	**12**
U.S. Fish and Wildlife Service	FWS 1999. South Florida Multi-species Recovery Plan	**13**
South Florida Water Management District	Rudnick et al. 1999. Sufficiency Review of Information Needed to Establish Minimum Flows and Levels for Florida Bay (draft) South Florida Water Management District 1999. 2000 Everglades Consolidated Report Ogden and Davis 1999. Conceptual models documents for Florida Bay and mangrove coast (draft)	**14** **15** **16**

***Document 1*:** PMC, 1998. letter to Mr. Stuart Appelbaum, Project Manager, C&SF Project Restudy, U.S. Army Corps of Engineers

Synopsis

This letter provides the PMC's comments on the anticipated benefits for Florida Bay of the hydrological restoration described in the draft report on the Central and South Florida Project Comprehensive Review Study (Restudy). The comments identify gaps in understanding the links between marine ecosystems in south Florida and hydrologic conditions and water quality in the southern Everglades. These limit our ability to predict with confidence the ecological benefits that will accrue from hydrological restoration.

Develop (and apply) models to predict and evaluate the effects of human activities

- Existing hydrologic models must be refined so that they provide more reliable predictions of volume and location of flows into Florida Bay, Biscayne Bay and across the southwest Florida coast.

- The regression equations relating salinity at coastal locations to water levels at P33 are neither robust nor reliable measures of ecological conditions in Florida Bay. Therefore, managers should not rely on these in the detailed planning leading to implementation of restoration.

Document 2: PMC, 1997. Strategic Plan for the Interagency Florida Bay Science Program.

Synopsis
In general, the Strategic Plan functions to coordinate specific research projects toward satisfying the science needs established by the cooperating agencies and on recommendation of the Science Oversight Panel. The Interagency Science Program for Florida Bay coordinates activities of cooperating agencies toward the goal of producing data and models essential to understanding the Bay as an ecosystem functioning within a regional system that is strongly influenced by human activities. This requires complementary and closely integrated modeling, empirical studies, monitoring and historical data analysis, which is the focus of the Program.

The Strategic Plan is built around the following five central questions:
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?
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?
3. What regulates the onset, persistence and fate of planktonic algal blooms in Florida Bay?
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?
5. What is the relationship between environmental and habitat change and the recruitment, growth and survivorship of animals in Florida Bay?

This document describes the general themes of research related to each of the strategic questions, the role of models as an agency for integration of the research results, and the administrative and review processes that operate in the program. The strategic plan does not attempt to catalog detailed science information needs. Instead, identification of emerging and/or unmet science needs is one function of the Science Oversight Panel.

Document 3: Hobbie, J.E. et al. 2000. Perspectives from the 1999 Florida Bay Science Conference. Report of the Florida Bay Science Oversight Panel

Synopsis
This is a report to the Program Management Committee by the Science Oversight Panel of the Florida Bay Science Program.

Reconstruct historical conditions
- A review of existing paleoecology projects indicates a number of significant gaps that should be addressed. 1) The consistency in Pb-210 and C-14 dating by atomic mass spectrometry must be established before pre-1940 records can be reliably dated to define the natural state

of the Bay. 2) The spatial and temporal natural variability must be established to a higher degree of confidence to support resource and restoration decisions. 3) Other environmental proxies should be considered with the 80 yr rainfall record at Homestead, such as tree rings to tease out annual rainfall and evaporation variability across the Bay.

Identify key species, habitat indicators and drivers of the ecosystem

- Basin-scale studies are clearly needed in the eastern and central parts of the Bay. Vital questions include: how long are residency times of water masses; how much communication is there between adjacent basins; and what is the evaporation across the Bay? Earlier plans to carry out intensive monitoring of some basins should be implemented. Focus on inter-basin flow, tidal and freshwater effects, salinity and nutrient balances, and evaporation leading to hypersalinity.

- The development of a canonical data set is needed in which are described basic forcing functions, boundary conditions, and response variables. This will serve the need for a calibration data set for models. As well, these data will become the point of reference in discussions of what constitutes a "wet year" or "long residence time." The data should include bathymetry, meteorology, freshwater and wastewater inflow, circulation, salinity, water quality, benthic conditions, and biological resources both seasonally and synoptically. Forcing functions such as climate cycle (ENSO), Loop Current position, Gulf Stream eddies (seaward of the Keys), and hurricane events should be readily available.

Implement monitoring programs to measure ecosystem attributes

- There is need for a plan designed to detect future trends in water quality and biological resources. The plan should consider the impacts of oil spills, drought, and El Nino/La Nina. The oil spill simulations conducted for the west Florida shelf in the early to mid-1990s by Florida State University should be investigated to see what Florida Bay resources might be at risk. These resources (e.g. the western grass beds) should be adequately defined before a spill occurs to ensure adequate damage assessment. Quantifying the effects of drought and resulting hypersalinity or the effects of an El Nino/La Nina will be difficult. The long-term monitoring programs must measure the best parameters frequently enough at critical locations. There should be flexibility so as to be able to change the monitoring frequency and intensity from year to year.

- While there is no need to make measurements during or immediately after a large hurricane, a plan must define exactly the priorities of what to be measured and when and where. A plan should be in place or updated before the 2000 hurricane season.

Document 4: Boesch et al. 1998. Annual Report of the Florida Bay Science Oversight Panel: Perspectives from the 1998 Florida Bay Science Conference.

Synopsis

This is a report to the Program Management Committee by the Science Oversight Panel of the Florida Bay Science Program.

Reconstruct historical conditions

- It should be a priority of the Paleoecology Research Team to produce a consensus reconstruction of salinity trends and variability in Florida Bay as they relate to climatic variability and water management practices.

Identify key species, habitat indicators and drivers of the ecosystem

- Efforts should be undertaken to examine the vertical flow structure over the central portion of the Bay.

- Efforts should be undertaken to address nutrient input and export across the entire western boundary, particularly across the banks and channels separating the Gulf Transition Zone and Western Florida Bay.

- An attempt to measure spatial structure of evaporation should be made.

- Nutrient input estimates (including atmospheric) are sparse and should be expanded.

- A cooperative effort should be taken by modelers and field scientists to address the question of flow over mudbanks during high tide.

- There is a need to integrate hydrographic measurements (UM), water quality data (FIU) and oceanographic observations to clearly describe the physical regime inside/outside of Florida Bay proper.

- Attention should be paid to the question of the use of organically bound nutrients by microbes and algae and to what degree do these nutrients transverse the Bay through channels and mudbanks.

- Both laboratory and field experiments using carbonate sediments from the natural system should go forth to provide essential geochemical information.

- Rate measurements of nutrient recycling by algae throughout the Bay are needed.

- Process studies leading to a full understanding of the formation and persistence of algal blooms in Florida Bay remains lacking.

- A special focus on the causes and interrelationships of seagrass die-off, algal blooms and pelagic and benthic grazing needs to be undertaken.

- Understanding nutrient dynamics and their relationships to phytoplankton production is of central importance in evaluating whether there has been an ecosystem shift, and if so, what the causes are.

- It is imperative that high quality data assessing the single and combined effects of salinity and temperature on seagrass survival and growth become available soon.

- The extent to which *Labyrinthula* causes seagrass mortality under various field conditions, or whether it was a causative agent in the initial or subsequent seagrass die-off should be addressed ASAP.

- Expanded study of the dynamics of the "urchin outbreak" on *Syringodium* and the significance of this event are needed ASAP.

- A retrospective analysis, which takes into account other supportive long-term knowledge of pink shrimp, should be assessed.

Document 5: Boesch, D.F. et al. 1997. Annual Report of the Florida Bay Science Oversight Panel: Perspectives from the 1996 Florida Bay Science Conference and Review of the Strategic Plan.

Synopsis
This is a report to the Program Management Committee by the Science Oversight Panel of the Florida Bay Science Program.

Reconstruct historical conditions

- New paleoecological approaches involving chemical, sedimentological, or biological indicators reflecting past seagrass abundance and algal blooms should be attempted to establish whether the recent crisis in Florida Bay is simply another episode in a naturally occurring cycle or is unique to contemporary conditions.

- Because the appropriate record of observation and measurement is not available to document the sequence and spatial extent of the changing nutrient inputs and plant communities within Florida Bay, the paleoecology research team should explore all approaches that might give meaningful information about the changing trophic conditions of Florida Bay, including the organic components (pigments, biomarkers) and biotic communities (including indicator species) of the sediment record.

Identify key species, habitat indicators and drivers of the ecosystem

- Bay and basin-wide detailed nutrient balances are needed to address algal blooms, management of wastes from the Florida Keys, and assessments of C-111, Taylor Slough, and Shark River impacts.

- Additional drilling and geochemical monitoring of groundwater test wells are needed to determine whether or not the contribution of subsurface seepage plays a major role in the overall composition of Florida Bay waters.

- The PMC should support a group of investigators to resolve key questions in the "River of Sand" such as conductance, residence time, nutrient concentrations, recharge areas and surface effluent zones.

- Atmospheric deposition of nutrients to the Bay remains unquantified and should be addressed.

- The lability of organic matter needs to be calibrated in order to assess the effects of defoliation and death of mangroves from Hurricane Andrew and the contribution of increased seagrass detritus to initiating plankton blooms.

- Attention should be focused on empirical measurements of diagenetic rates to determine the role of the sediments in nutrient cycles in the Bay.

- It is necessary to determine the rate of *Labyrinthula* transmission in the field.

- It is critical to determine whether the pathogen can initiate a seagrass die-off without concomitant physiological stress.

- Identification of other seagrass pathogens should be pursued.

- A GIS map depicting algal blooms, sediment plume distribution, light transmittance, temperature, salinity, and seagrass distribution should be produced.

- Data collection and research on potential grazers of epiphytes, such as mesoherbivores, scarids, and other macroherbivores, should be pursued.

- Seagrass transplantation into unvegetated, declining, and other areas would serve as a valuable research tool as well as act as a living indicator of water quality and sediment stabilization.

- Experiments addressing the interaction of light, salinity, and temperature on seagrass restoration should be undertaken.

- Mesocosm experiments, combined with field manipulations and transplantation, will become critical in evaluating seagrass physiology. Site visits to mesocosm facilities by scientists familiar with mesocosm problems and seagrasses should occur.

- Information on higher trophic level distribution and production needs to be scaled to the whole system not described site by site.

- Links to circulation, water quality, and seagrass models to predict areas of high and low fish and shell-fish production based on physiological and habitat requirements of individual species should be undertaken. The predictions from the models could be tested against actual measurements of growth or production.

- More work needs to be done on the processes of growth, recruitment, and mortality; and less on standing stock.

Develop (and apply) models to predict and evaluate the effects of human activities

- NOAA's Princeton Ocean Model is critical to providing oceanographic and boundary conditions and forcing to the Bay circulation model and must include measures of uncertainty for water levels, velocities, and fluxes.

- Shinn (USGS) should perform a simple Darcy's Law calculation of the potential flux and these water-flux calculations can be contrasted with inlet-flux measurements by the COE and others.

- It is essential that a conceptual model of higher trophic levels in Florida Bay be developed.

Document 6: CESI 2000. Priorities for coastal and estuary science in Critical Ecosystem Studies Initiative

Synopsis

Everglades National Park administers the Critical Ecosystem Studies Initiative for the Department of the Interior. A number of sub-programs comprise this initiative, one of which is the CESI Coastal and Estuary Program. During spring of 2000, managers defined priority needs within each of the sub-programs. These are the priority needs defined for the CESI Coastal and Estuary Program.

Reconstruct historical conditions

- Biscayne Bay: Define pre-drainage conditions for central and southern Biscayne Bay, to the extent possible, salinity regimes in the bay, coastal morphology, surface and groundwater hydrology, and biota that characterized the bay before the C&SF Project.

Develop (and apply) models to predict and evaluate the effects of human activities

- Florida Bay: Develop a practical model of effects of freshwater inflows on salinity patterns in the bay to permit evaluation of the ecological effects of changes in South Florida water management.

- Florida Bay: Develop a model of water circulation in the bay that will permit evaluation of the ecological effects of changes in South Florida water management.

Document 7: VanLent et al. 1999. An examination of the Modified Water Deliveries Project, the C111 Project, and the Experimental Water Deliveries Project: Hydrologic analyses and effects on endangered species.

Synopsis

This document assesses the effects of recent and proposed changes to delivery of water to Everglades National Park. Emphasis is on a comparative analysis based on existing hydrologic and ecological performance measures. Science needs are not discussed.

Document 8: Schmidt et al. 1999. Site Characterization for the Dry Tortugas Region: Fisheries and Essential Habitat.

Synopsis

This document reviews and synthesizes literature and data relevant to the extent and current status of natural resources in the Dry Tortugas region. The objective is to provide answers to questions anticipated in the design of a marine "no take" reserve. Long-term science needs are not addressed directly in this document.

Document 9: NOAA 1998. South Florida Ecosystem Monitoring Integration Project Implementation Plan

Synopsis

This document summarizes monitoring strategies under a scaled set of funding scenarios. The strategies were designed "to address monitoring needs defined by managers and scientists" at a series of workshops and focus groups and are categorized as physical, chemical, biological or relating to human activities, i.e. socioeconomic indicators. Monitoring strategies are defined to deal with the following regional issues 1) coral reef health, 2) water quality, 3) contaminated sediments, 4) nutrients, 5) mass plant mortalities, 6) changes in animal populations, and 7) habitat loss.

For the most part, the physical and chemical strategies are congruent with those previously outlined in the Florida Bay science plan, including emphasis on circulation/hydrography, salinity, turbidity, nutrient dynamics, and other contaminants. The biological strategies similarly emphasize issues of algal blooms and seagrass die-off. However, broader biological strategies (coral reef change, diseases of marine organisms, exotic plant pests in coastal uplands, and a specific focus on developing rapid assessment capability for acute events) are also included in this plan. Lastly, specific monitoring strategies are outlined to assess human activities in the coastal system including development/infrastructure effects, habitat/land use changes, and fishery harvests.

Implement monitoring programs to measure ecosystem attributes

Biological Strategy

- B.1 – Standardize bloom-monitoring methods, establish a core monitoring group, and integrate remote sensing.
- B.2 – (none)
- B.3 – Coordinate and supplement current seagrass monitoring programs.
- B.4 – Establish a strategy for rapid assessment of the effects of natural and anthropogenic events.
- B.5 – Assess nutrient enrichment/limitation on primary productivity.
- B.6 – Coordinate monitoring and assessment of coral reef change.
- B.7 – Monitor habitat changes due to invasion of exotic plants.
- B.8 – Establish monitoring of animal and plant diseases.

Chemical Strategy

- C.1 – Establish comprehensive monitoring of nutrient sources, sinks and transformation in the water column and sediments.
- C.2. – Establish comprehensive monitoring of contaminant sources, sinks and transformation in the water column, sediments and food chain.

Human Activities Strategy

- H.1 – Measure population growth and its impact on the environment.
- H.2 – (none)
- H.3 – (none)
- H.4 – Determine extent of wetland, mangrove and forest losses.
- H.5 – Monitor harvest of fish, shellfish in recreational and commercial fisheries.

Physical Strategy

- P.1 – Monitor changes in light attenuation in the water column.
- P.2 – Monitor circulation and exchange between coastal water bodies.
- P.3 – Monitor changes in salinity and related hydrologic fluxes of rainfall and evaporation.

Document 10: The Nature Conservancy Florida and Caribbean Marine Conservation Science Center 1996. Site Characterization for the Florida Keys National Marine Sanctuary and Environs. report prepared under contract to NOAA.

Synopsis

This 10 volume document is primarily a summary of a vast array of information and literature regarding the Florida Keys coastal, marine, and estuarine systems. The individual volumes address 1) Geology and Paleontology of the Florida Keys (FK) and Florida Bay (FB), 2) Oceanography and shallow water processes of FK and FB, 3) Historical overview of development and natural history of FK, 4) Marine benthic communities of FK, 5) Invertebrate infauna and epifauna, 6) Fishes and fisheries, 7) Necton, plankton, and oceanic influences, 8) Functional Ecology and Ecosystem Trophodynamics, 9) Controversies and conservation issues, and 10) Bibliography of the FK and environs. Most volumes contain a “Gaps in Knowledge” section with major foci on A) establishing cause/effect linkage of human activities with manifest ecosystem changes in the FK and environs, B) distinguishing the relative contribution to ecosystem degradation of direct human activities (harvesting, recreational use, boating impacts, etc.) versus indirect (largely water quality) impacts, and C) partitioning water quality impacts between Keys-based sources versus upstream (Everglades/ South Florida water management) influences.

Science needs are not addressed directly in this document.

Document 11: NOAA 1996. Florida Keys National Marine Sanctuary Final Management Plan/Environmental Impact Statement

Synopsis
The Management Plan for the Florida Keys National Marine Sanctuary is organized around a socioeconomic analysis for selection of the preferred management and 10 action plans composed of management strategies for various components of the sanctuary operation. Of these 10 action plans, two contain information on scientific information needed for management. These are 6) Research and Monitoring plan and 9) Water Quality plan. Science needs identified below are taken from these two sections of the management plan.

Reconstruct historical conditions

- Strategy Z.2, Z.3, Z.5 – Conduct baseline surveys in the designated ecological reserves, sanctuary preservation areas, and special use areas.

- W.24 – Conduct an historical assessment of Everglades/Florida Bay/Florida Keys hydrology as it has affected water quality and biological communities in the Sanctuary.

Identify key species, habitat indicators and drivers of the ecosystem

- Strategy F.3 – Assess existing research on the impacts of stocking on the genetic integrity of native stocks. Conduct research on natural stock recovery and its role in maintaining genetic integrity.

- Strategy F.7 – Conduct research on the impacts of artificial reefs on fish and invertebrate populations for long-term management.

- Strategy F.10, F.11, F.14, F.15 – Conduct research on fishery harvesting methods to provide information for programs to evaluate, reduce or eliminate adverse impacts.

- Strategy B.2 – Conduct research to develop information needed to plan, direct and monitor habitat restoration efforts.

- Strategy R.5 – Conduct a program to study and implement carrying-capacity limits for recreational activities.

- Strategy W.24 – Conduct studies of the circulation (present-day, long-term net transport and episodic transport) from Florida Bay to the Sanctuary and studies to document the ecological impacts, if any, of Florida Bay waters on Sanctuary communities.

- Strategy W.22 – Conduct special studies to 1) establish pollutant loading thresholds, 2) detect the presence of waste-water pollutants and determine relative contribution from various sources, 3) document transport and severity and extent of ecological impacts.

- Strategy W.23 – Conduct special studies to document the fate and impacts of non-wastewater pollutants, develop innovative monitoring tools, and examine the effects of global climate change on organisms and ecosystems of the Keys.

Develop (and apply) models to predict and evaluate the effects of human activities

- Strategy W.21 – Develop phased hydrodynamic/water quality models and coupled, landscape-level ecological models to predict and evaluate the outcome of in-place and proposed water quality management strategies.

Implement monitoring programs to measure ecosystem attributes

- Strategy F.6 – Evaluate and enhance existing fisheries sampling programs. Initiate a fishery pre-recruitment monitoring effort.

- Strategy W.33 – Develop and implement a Sanctuary-wide program to monitor the status of various biological and ecological indicators to discern the effects of human and natural disturbances and assess the overall health of the Sanctuary.

- Strategy W.5 – Develop and evaluate biochemical and ecological measures to provide early warning of widespread ecological problems. Develop water quality standards appropriate to coral and seagrasses.

- Strategy W.20 – Provide long-term, comprehensive information about the status and trends of water quality parameters and biological resources in the Sanctuary; and evaluate the effectiveness of remedial actions taken to reduce water pollution.

Other research

- Strategy W.1, W.2 - Evaluate innovative, alternative, nutrient-removing on-site (waste) disposal and advanced wastewater treatment systems.

- Strategy W.18 – Develop and implement an independent research program to assess and investigate the impacts of and alternatives to current pesticide practices.

Document 12: Kruczynski 1999. Water Quality Concerns in the Florida Keys: Sources, Effects, and Solutions

Synopsis

This document reviews information related to the nature and extent of water quality problems in the Florida Keys with an emphasis on near shore waters. It also describes how the strategies in the Water Quality Protection Program (a component of NOAA 1996, above) will correct recognized problems. New scientific information is summarized, but the document does not define new science information needs beyond those identified in NOAA (1996).

Document 13: FWS 1999. South Florida Multi-species Recovery Plan

Synopsis

This recovery plan is one of the first specifically designed to recover multiple species through the restoration of ecological communities over a large geographic area. Requirements for recovery are developed at both the species level and at the level of preserving the maintaining the habitat on which these species depend.

In the Southern Coastal Areas, seven higher-trophic level species are listed as endangered. The Recovery Plan defines as a region the "Florida Keys, including Biscayne Bay, Card Sound, and the Lower Southwest Estuaries." This subregion is geographically within Monroe County and a portion of Miami-Dade County. It covers the estuarine waters contiguous with Florida Bay and the Florida Keys. Endangered animals in this region are:

- American crocodile - *Crocodylus acutus*
- West Indian manatee - *Trichechus manatus*
- Green sea turtle - *Chelonia mydas* (incl. *agassizi*)
- Hawksbill sea turtle - *Eretmochelys imbricata*
- Kemp's (=Atlantic) ridley sea turtle - *Lepidochelys kempii*
- Leatherback sea turtle - *Dermochelys coriacea*
- Loggerhead sea turtle - *Caretta caretta*

The "Ecological Communities" section of the Recovery Plan consists of individual community accounts, similar in format to the species accounts, that discuss the biological composition, status, trends, management and restoration needs of 23 major ecological communities within South Florida. The accounts include recommendations on how to manage, reconstruct, or restore habitats in the South Florida Ecosystem in ways that will optimize benefits to the greatest number of listed species. Protection of coral reef habitat in the Florida Keys Marine Sanctuary is not covered in this report. Three of the major ecological communities occur within the Southern Coastal Areas.

- Mangrove
- Saltmarsh
- Seagrass
- Nearshore and Midshelf Reefs

Below, the science needs defined in the Recovery Plan are summarized separately for species and ecological communities.

Information from species recovery plans:
Identify key species, habitat indicators and drivers of the ecosystem

- Support research on the physiology, life history, and ecology of the manatee. Studies of physiology, life history, and ecology are needed for understanding population status and trends, and to help assess what habitats are most important to manatees and why. Collect additional biological information on number of individuals, age-class structure, habitat use, reproductive viability, food use and availability, and threats.

- Conduct research on the biology and life history of crocodiles. Although basic information on the biology of the American crocodile has been collected, more detailed information is needed to determine the status of the crocodile population in South Florida.

- Conduct research on the habitat relationships of the American crocodile. Much of the habitat-based research needed for the recovery of the American crocodile is currently addressed in one or more research projects dealing with the maintenance and recovery of the Florida Bay ecosystem. However, specific research information on the relationship of American crocodiles to salinity regimes, exotic species, and adjacent land uses will be critical to the design of future management actions for the American crocodile.

- Continue to gather information on green turtle, hawksbill sea turtle, Leatherback sea turtle, and Loggerhead sea turtle species and population biology.

- Conduct research to evaluate the relationship of sand characteristics (including aragonite) and green turtle, hawksbill sea turtle, Leatherback sea turtle, and Loggerhead sea turtle nesting behavior, nesting success, hatching success, hatchling emerging success, hatchling fitness, and sex ratios.

Implement monitoring programs to measure ecosystem attributes

- Support the investigation of the distribution and status of the manatee and its habitat in South Florida by continuing flying synoptic statewide aerial surveys. Aerial survey sighting data have provided and continue to provide useful data on manatee distribution and, in some situations, relative abundance. When combined with telemetry data, certain types of aerial sightings provide a sound basis for determining habitat use patterns. Aerial sightings also provide useful information on the proportion of calves. Because of uncertainty in the number of animals not seen in turbid water, uncertainty as to the proportion of the population within a survey area, and other problems, however, aerial sighting data generally do not permit scientists to estimate or detect trends in population size.

- Support the monitoring of manatee populations in South Florida. The success of efforts to develop and implement measures to minimize manatee injury and mortality and to protect manatee habitat will depend on the accuracy and completeness of data on manatee life history and ecology, population status, and habitat condition.

- Develop and implement a manatee habitat-monitoring program. In addition to efforts to monitor the status of manatee populations, work should be undertaken to monitor the condition and status of manatee habitat. Information from such a program could provide an early warning of future threats to manatee populations and help explain observed manatee population trends. Presently, there is no systematic approach to monitoring the condition of key manatee habitats.

- Conduct surveys to determine the current distribution and abundance of American crocodiles. Survey all remaining suitable habitats in South Florida for American crocodiles. Most knowledge about the current distribution of crocodiles comes from surveys conducted within Everglades NP, the upper Florida Keys, and areas surrounding Turkey Point in Miami-Dade County. These areas correspond to locations with the highest known crocodile densities, but do not represent the entire range of the American crocodile. Surveys for crocodiles have not been conducted in large portions of South Florida; for example, American crocodiles have been observed in increasing numbers on the southwest coast of Florida, north to the J.N. Ding Darling NWR. These areas should be surveyed in order to determine the size and distribution of the American crocodile population and should include occurrence of individuals and nesting effort.

- Monitor the South Florida crocodile population. Long-term monitoring is essential to the assessment of the status of the crocodile population.

- Continue to monitor crocodile habitat.

- Continue standardized surveys of nesting beaches to determine if Kemp's ridley sea turtles nest in South Florida.

- Continue standardized surveys of green turtle, hawksbill sea turtle, Leatherback sea turtle, and Loggerhead sea turtle nesting beaches. Nesting surveys are undertaken on the majority of nesting beaches. In the past, beach coverage varied from year to year, as did the frequency of surveys, experience and training of surveyors, and data reporting. Consequently, no determination of nesting population trends had been possible with any degree of certainty. However, in 1989, to better assess trends in nesting, DEP, in cooperation with FWS, initiated an Index Nesting Beach Survey (INBS) program to collect nesting data that can be used to statistically and scientifically analyze population trends. The INBS program should continue to gather a long-term database on nesting activities in Florida that can be used as an index of nesting population trends.

- Monitor trends in green turtle, hawksbill sea turtle, Leatherback sea turtle, and Loggerhead sea turtle nesting activity. DEP and FWS should continue to refine standardized nest survey criteria, identify additional index survey beaches to be monitored, and continue to conduct training workshops for surveyors. Consequently, DEP and FWS should ensure that routine monitoring of nesting beaches is done on at least a weekly basis during the time that green turtles, hawksbill sea turtle are nesting, including the timeframes of any nesting that occurs outside of the regular survey period.

Information from ecological community recovery plans:
Reconstruct historical conditions

- Identify historical and geological trends in mangrove distribution relative to hydrology and sea-level in the mangrove communities of South Florida.

Identify key species, habitat indicators and drivers of the ecosystem

- Identify the extent of mangrove habitat. Although the existing GIS information, aerial photography, and ground-truthed land cover information are available for this community throughout South Florida, a comprehensive regional analysis has not been conducted.

- Continue and update studies on the utilization of mangrove communities by endemic and wide-ranging species, including the development of landscape-scale management recommendations for the recovery of these species in South Florida.

- Perform a hydrologic study of the flood attenuation and storm buffering potential of mangrove habitat under natural sheetflow conditions.

- Examine the population dynamics by invasive exotics in the understory of mangrove habitat.

- Examine the habitat value of buttonwood forests in South Florida.

- Identify and characterize the extent of remaining salt marsh habitat. Salt marshes are found throughout most of South Florida, but specific information on community types and extent is not known.

- Conduct research on salt marshes in South Florida by examining their structure, composition, and ecological processes. Very little is known about the ecological processes of South Florida salt marshes. Additional information is needed to help restore and preserve these habitats.

- Characterize the importance of salt marshes to other flora and fauna, especially less-known taxa like insects and marine invertebrates.

- Investigate the effects of hydrologic alterations on salt marsh processes.

- Investigate salt marsh nursery grounds.

- Continue to conduct genetic research of salt marsh vegetation.

- Investigate the effects of non-native species on salt marshes.

- Compare the ecology of marshes in different regions of South Florida, especially to the Keys.

- Compare restored marshes to natural marshes.

- Compare and evaluate salt marsh restoration techniques to determine the ability of different techniques to replace the structure, composition, and ecological processes of natural marshes.

- Determine the relationship between light and water quality to seagrasses. Increases in turbidity and nutrients occur both in short pulses and over long periods of time. In order to determine the effects to South Florida's estuaries from episodic events, measurements (*i.e.* monitoring) of photosynthetically active radiation, water quality, and seagrass cover and abundance need to be taken at the fixed transect sites. Implement site-specific monitoring protocols to identify causes of seagrass decline. Integrating these measurements should identify the effects light and water quality have on seagrasses.

- Because of the problems experienced by Florida Bay, the effect of extensive phytoplankton blooms (*i.e.*, light availability, nutrient regimes) as well as slime mold disease (*i.e.*, *Labyrinthula*) on seagrass communities should continue to be investigated. In addition, the effects of freshwater flows (*i.e.*, quality, quantity, timing, distribution) on seagrasses should be investigated further.

Develop (and apply) models to predict and evaluate the effects of human activities

- Develop predictive models that link light attenuation to water quality and to nutrient loading and epiphyte abundance. The most critical factor affecting seagrass distribution and abundance is light availability, which is a function of water quality. Hence, identifying the water quality constituents regulating light availability in the water column is an initial step. Understanding how nutrients and epiphytes affect light availability is just as crucial. These predictive models will be linked to identify pollutant load reduction goals for specific estuaries or specific segments within estuaries.

Implement monitoring programs to measure ecosystem attributes

- Update the GIS database for mangroves to monitor cumulative impacts. As areas of mangroves are converted to other land uses, changes should be mapped to identify and analyze trends in habitat loss.

- Monitor mangrove communities to evaluate biodiversity. Monitor community- level processes, structure, and composition, including rare and imperiled species. Improve reference information for community composition, biodiversity, and site-to-site variability

- Develop a long-term monitoring plan to evaluate status of salt marshes. Monitor the extent of salt marsh habitat by updating the loss or change of habitat due to residential or commercial construction through GIS databases.

- Identify the extent of seagrass habitat. Using existing GIS databases, satellite/thematic images and aerial photographs (scales =1:12,000; 1:24,000; or 1:48,000) coupled with ground-truthing efforts, produce maps of seagrass distribution and abundance as an initial step in evaluating the extent of seagrasses in South Florida. Many of the region's estuaries have already been mapped or are currently being mapped for seagrasses (*e.g.*, Indian River Lagoon, Biscayne Bay, Florida Bay, and the Florida Keys).

- Assess the status and condition of existing seagrass habitat. Monitoring selected areas within the region will be used to determine if seagrass beds are healthy or stressed and whether conditions are stable, improving, or declining and to what degree.

Document 14: Rudnick, D., C. Madden, and F.Sklar 1999. Sufficiency Review of Information Needed to Establish Minimum Flows and Levels for Florida Bay (draft)

Synopsis

It is the objective of the South Florida Water Management District to establish minimum flows and levels (MFL) for freshwater discharge into Florida Bay by 2005. The Florida Bay MFLs are the minimum inputs of freshwater from the southern Everglades that are required to prevent significant harm to the Bay ecosystem.

This document reviews current knowledge of the role of freshwater runoff into the Bay and identifies six areas where scientific information is needed to support development of the MFL criteria. These are:
1) Review and synthesis of existing strategies and information
2) Ecosystem monitoring
3) Physiological responses to stress
4) Effects on nutrient processing and water quality
5) Models

Identify key species, habitat indicators and drivers of the ecosystem
3a) Primary producers – Measure the primary production of seagrasses, algae, and mangroves during wet and dry seasons using techniques that establish reference conditions. Correlate variance around the reference condition with environmental variables such as water quality and quantity.

3b) Secondary producers - Initiate a program to review and examine the growth requirements [, i.e. environmental conditions] of economically, ecologically and legally important animals.

4) – Investigate nutrient cycles, transport and availability in response to freshwater flows by 1) evaluating sediment accretion and erosion across marsh-mangrove and basin-bank ecotones; 2) measuring water and nutrient fluxes across sediment-water interfaces and mangrove-bay transects and determine the effects of high salinity on nutrient retention by sediments and soils; and 3) conduct wetting/drying studies across marsh-mangrove ecotone.

Develop (and apply) models to predict and evaluate the effects of human activities
5a) Statistical models – Use statistical approaches to explore cause and effect relationships and design experiments.

5b) Hydrodynamic models – Use hydrodynamic models to predict exchange rates and residence times for zones and sub-basins within the Bay and to predict the salinity distribution in the Bay for a given rate and distribution of freshwater input.

5c) Water quality models – Use water quality models to evaluate the spatial effects of MFL policy on water quality.

5d) Vegetation models and 5e) Higher trophic level models – Use models to integrate results from growth and scope studies (higher trophic level), mesocosm experiments (on physiological responses), studies of primary productivity, and analysis of biogeochemical processes. This needs to be done in order to understand the long-term responses of a plant community or plant species to freshwater delivery schedules related to setting MFLs.

Implement monitoring programs to measure ecosystem attributes
2a) Hydrologic conditions – Quantify water flow and exchange around the Bay's boundaries, including creeks and marshes draining mangrove wetlands, inlets along the Florida Keys, and

across the wide Gulf of Mexico boundary. As well, quantify precipitation, evaporation, surface water and groundwater flow within the Bay, including flow among its banks, channels and basins.

2b) Water quality – Continue operation of the water quality monitoring network established in 1991. This network tracks salinity, temperature, dissolved oxygen, pH, chlorophyll and nutrients.

2c) Soil and sediments – Monitor sediment and porewater geochemistry in various regions, including [mangroves and] several seagrass communities to document the effects of salinity fluctuations on sediments and ecosystem health.

2d) Flora – Monitor seagrass, its productivity, distribution and health, and algal blooms, their composition, magnitude, and distribution, in the Bay. Also expand existing monitoring of the macrophytes and periphyton in and near the transition zone between the Bay and the freshwater Everglades.

2e) Fauna and 2f) Endangered &threatened species – Quantify health, reproduction, abundance, spatial distribution, and variability of upper trophic resources of the Bay. Resources to be monitored include not only designated endangered and threatened species, important game fish, shrimp, and lobster, but also the basic components of the food web on which they depend.

Other scientific information
1) Perform a review of available information on Florida Bay, and assessment of available tools (such as numerical models) and an evaluation of how MFL criteria have been developed for other estuaries in the U.S. and in other nations.

Document 15: South Florida Water Management District 1999. 2000 Everglades Consolidated Report

Synopsis
This document consolidates annual reporting required of the South Florida Water Management District by the Everglade Forever Act along with other required reporting on natural resource management in the Everglades ecosystem. This document serves as a decision-support document and a permanent record of findings and trends for the Everglades.

Science needs related to Florida Bay are covered in chapter 2 of the report, “Hydrological Needs: The Effects Of Hydrology On The Everglades.” The report summarizes information from Rudnick et al. (1999) on science needs for setting minimum flows and levels in the Everglades for benefit of Florida Bay. See the summary of Rudnick et al. (1999) elsewhere in this document for a description of these science needs.

Document 16: Ogden, J.C. and S.M. Davis 1999. The Use of Conceptual Ecological Landscape Models as Planning Tools for the South Florida Ecosystem Restoration Programs

Synopsis

This document describes conceptual ecological models that have been developed for various subregions within South Florida. Of these, three are of interest with respect to science needs in the Southern Coastal Areas, the mangrove estuary transition, Florida Bay and Biscayne Bay.

Conceptual ecological landscape models are an essential component of the Applied Science Strategy that is evolving to direct the planning and evaluation of the C&SF Restudy Program. The models summarize consensus opinion of the causal assumptions that best explain how ecosystems in South Florida have been altered by human activities. In this way, the conceptual models assist in defining science information needs for restoration management in two ways. First, the models direct attention to information needed to close gaps in the understanding of cause and effect linkages that tie specific human, i.e. management, activities to changes in the ecosystem. Second, the models identify those attributes of the ecosystem that will serve as performance measures, and for which research is needed to construct predictive models and establish restoration targets.

The science needs defined by the conceptual models are subject to change and revision, as knowledge of the ecosystems increases and the models themselves evolve over time. At the current, early stage of development of the conceptual ecological models, the descriptive document does explicitly address science needs.