3.4 SOUTHERN COASTAL SYSTEMS MODULE

3.4.1 Overview of the Southern Coastal Systems Module

Only a few parts of the southern coastal ecosystems that fall under the purview of the Southern Coastal Systems Module can be accurately classified as estuarine, historically or otherwise. Instead, the module encompasses a heterogeneous set of inter-connected aquatic and upland habitats (***Figure 3-33***); an expanded focus that necessitated a name change of the module from the former title of Southern Estuaries (SE) Module to the Southern Coastal Systems (SCS) Module. This module includes Biscayne Bay, Florida Bay the northern Florida Keys, Whitewater Bay, and the Ten Thousand Islands area (including Picayune Strand). These systems are geomorphologically and ecologically very complex. For example, Florida Bay can be divided into over 20 separate sub-basins that are all tidally connected. As such the systems are evaluated and assessed by RECOVER in geographic sub-units based on physical and ecologic characteristics (refer to performance measure descriptions in www.evergladesplan.org).

Historically, natural freshwater flow regimes maintained a continuum of extensive and healthy freshwater, brackish, and marine habitats that supported a wide diversity of plant and animal communities. The quantity and timing of historical freshwater flows supported intermediate salinity conditions (*i.e.,* 5-20 ppt) year round along the mainland and within most adjacent embayments. Over the last century, the urban, suburban, and agricultural development of South Florida's watershed, as well as the replacement of mangrove fringe with seawall, have eliminated or degraded natural systems.

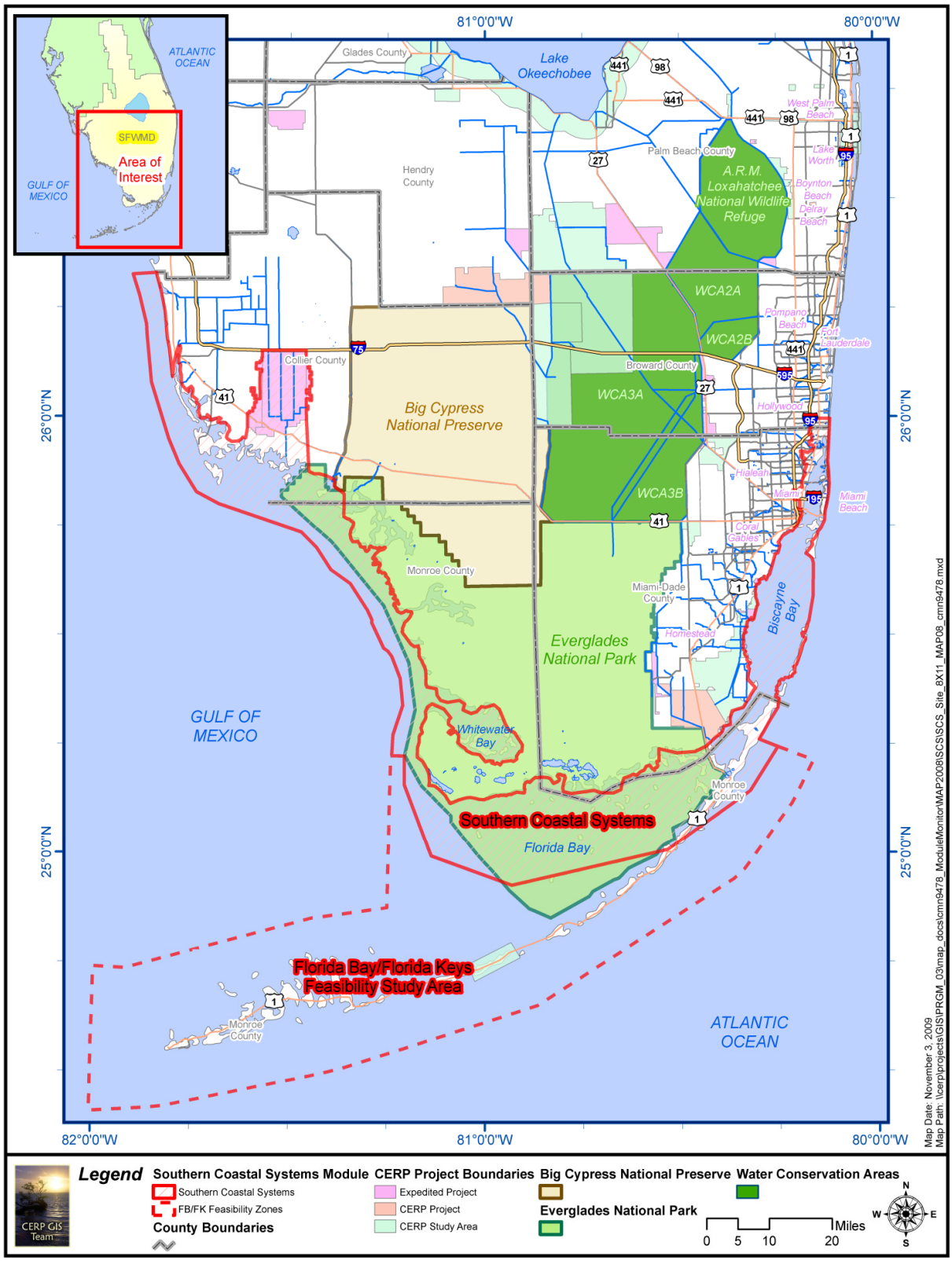

FIGURE 3-33: BOUNDARIES OF THE SOUTHERN COASTAL SYSTEMS MODULE

3.4.1.1 Monitoring Changes Made Between 2004 and 2008

The scope of this module differs from that laid out in MAP 2004, principally through the inclusion of the areas expected to be affected by the Picayune Strand Restoration Project. This required incorporating monitoring associated with activities to improve freshwater wetlands and down-gradient estuarine resources. The Southern Coastal Systems Module in MAP 2009 has attempted to identify a broader scope of monitoring activities in keeping with the intention of MAP 2004 to utilize and complement monitoring activities supported by external (*i.e.,* non-MAP funded) efforts. Changes between MAP 2004 and MAP 2009 are described in ***Table 3-5***.

3.4.2 Restoration Goals

Alterations in the timing, duration, quantity, and quality of freshwater flow have adversely affected the hydrologic regime, estuarine circulation and salinity patterns, and water quality of the Southern Coastal Systems. This in turn has altered the structure and function of the ecosystems. Restoration goals are to reestablish conditions conducive to the development and maintenance of a more natural, extensive, balanced, and desirable floral and faunal mosaic. Restoration of hydrologic conditions in coastal and near-coast wetland habitats will reestablish aquatic prey densities and concentrations across the landscape at sufficient magnitude to improve wading bird foraging success. Changes in shoreline, nearshore, and SAV distribution, abundance, and structure are a particular concern because of their critical roles as nursery and feeding habitats for fishes, invertebrates, reptiles, and birds of economic, ecological, and cultural importance.

Restoration targets envision a more diverse seagrass community with greater spatial coverage of seagrass beds containing mixed species, such as turtle grass (*Thalassia testudinum*) and shoal grass (*Halodule wrightii*). In Florida Bay, turtle grass should have lower density and biomass than during the period prior to the die-off when turtle grass beds had extremely high blade density. A diversity of seagrass habitat is expected to be beneficial to many upper trophic level species (Thayer et al. 1999). Restoration should affect SAV in the north shore mangrove zone lakes and coastal embayments, which are closer to a freshwater source than offshore areas in the Florida Bay ecosystem; however, central Florida Bay should be a primary focus area for assessment. Spatially explicit SAV restoration targets for the Florida Bay ecosystem are discussed in detail in the Florida Bay and Florida Keys Feasibility Study Draft Performance Measures (USACE and SFWMD 2004) and to a lesser extent in the Florida Bay and Everglades Mangrove Estuaries Conceptual Ecological Models (Rudnick et al. 2005, Davis et al. 2005a).

The current salinity regime in the Southern Coastal Systems creates significant stress on its inhabitants via hypersalinity events in areas with no direct freshwater discharge and rapid salinity fluctuations near canals (most notably in southern Biscayne Bay and central Florida Bay). As a consequence, the current nearshore biotic communities differ from historical nearshore communities. For example, along mangrove-lined shorelines in western Biscayne Bay, restoration is expected to decrease the relative presence of sergeant majors (*Abudefduf saxatilis*) and increase that of snook (*Centropomus undecimalis*). Another consequence of the current condition is the reduction in the distribution of eastern oysters (*Crassostrea*

virginica), which require a relatively consistent estuarine salinity condition. Reestablishing a more diffuse runoff pattern that results in a more natural estuarine salinity gradient from nearshore to offshore is expected to allow recolonization. Moreover, decreasing the intensity, duration, frequency, and spatial extent of high salinity events should allow a more productive biotic community at upper trophic levels. Juvenile spotted seatrout (*Cynoscion nebulosus*), a fisheries indicator species, has significantly lower abundance during high salinity events in north-central Florida Bay.

The biotic productivity of estuaries is primarily responsible for their ecologic and economic value. Nutrients, efficient nutrient recycling, and the resultant dynamic community of primary producers (*e.g.,* phytoplankton and benthic macrophytes) constitute the foundation of the trophic web that makes high estuarine productivity possible. It will be an important component of restoration monitoring efforts to track, interpret, and forecast the implications of potentially changing nutrient regimes. Deliveries of flow and the nutrient load associated with that flow will need to be carefully monitored in order to understand localized system response, and to adaptively manage water deliveries to maximize ecological benefit.

3.4.3 Overview of Hypothesis Clusters

The development and refinement of hypotheses clusters is an ongoing and inclusive process. Southern Coastal Systems hypotheses relate to how water management-induced changes to quantity, timing, distribution and water quality of freshwater inflow have affected:

- water quality
- phytoplankton
- salinity
- SAV
- nursery habitat
- oysters
- predator-prey interactions of wading birds and aquatic fauna forage base
- native vegetation mosaic

3.4.4 Water Quality and Phytoplankton Hypothesis Cluster

3.4.4.1 Working Hypotheses

The areas included in this hypothesis cluster are Florida and Biscayne Bays, the Ten Thousand Islands area, and the southwest coast from Whitewater Bay to Lostmans River including Shark River. Through modifications of quantity, quality, timing, and distribution of freshwater, restoration would affect dissolved and particulate nutrients delivered to the estuaries and alter estuarine water quality (***Figure 3-34***). These modifications would affect primary production and food webs in estuaries including the following:

- Changes in the distribution and timing of nutrient inputs through increased flow via Shark River Slough and diversion of canal flows from point source discharges to more natural, dispersed delivery through coastal wetlands and creeks.

- Changes in the quantity of nutrient inputs to the estuaries through alteration of the mobilization and release of nutrients from developed and agricultural areas, through nutrient uptake in treatment areas, and through changes in nutrient processing and retention in the Everglades.
- Changes in the bioavailability of nutrients depend on the type, concentration, and load of nutrients entering the system from the watershed as well as internal estuarine mechanisms (*e.g.,* phosphorus limitation of dissolved organic matter decomposition).
- Changes in salinity and benthic habitat as a result of restoration will affect internal nutrient cycling rates (*e.g.,* nitrogen fixation and denitrification) and biogeochemical processes (*e.g.,* phosphate sorption).

The role of nutrient inputs from the Everglades (***Figure 3-34***) as drivers of increased primary and secondary productivity, as well as their potential to initiate undesirable algal blooms (as characterized in the 2007 SSR), in the southern coastal systems is unclear and likely varies throughout the region. Several studies have raised concerns that increased freshwater flow resulting from restoration may intensify algal blooms (CROGEE 2002, Brand 2002, Jurado et al. 2007). To appropriately guide restoration efforts and to guard against unexpected or undesirable consequences, it is necessary to quantify and understand the pre-CERP reference conditions and be capable of identifying deviations that may occur from these conditions. The behavior of water quality variables, particularly salinity and chlorophyll *a*, is distinct throughout individual sub-regions of the southern coastal systems due to differences in freshwater runoff patterns (Kelble et al. 2007, Nuttle et al. 2000), circulation (Lee et al. 2006), sediment biogeochemistry (Zhang et al. 2004), nutrient inputs (Rudnick et al. 1999), grazer biomass (Peterson et al. 2006), and phytoplankton species composition (Phlips and Badylak 1996).

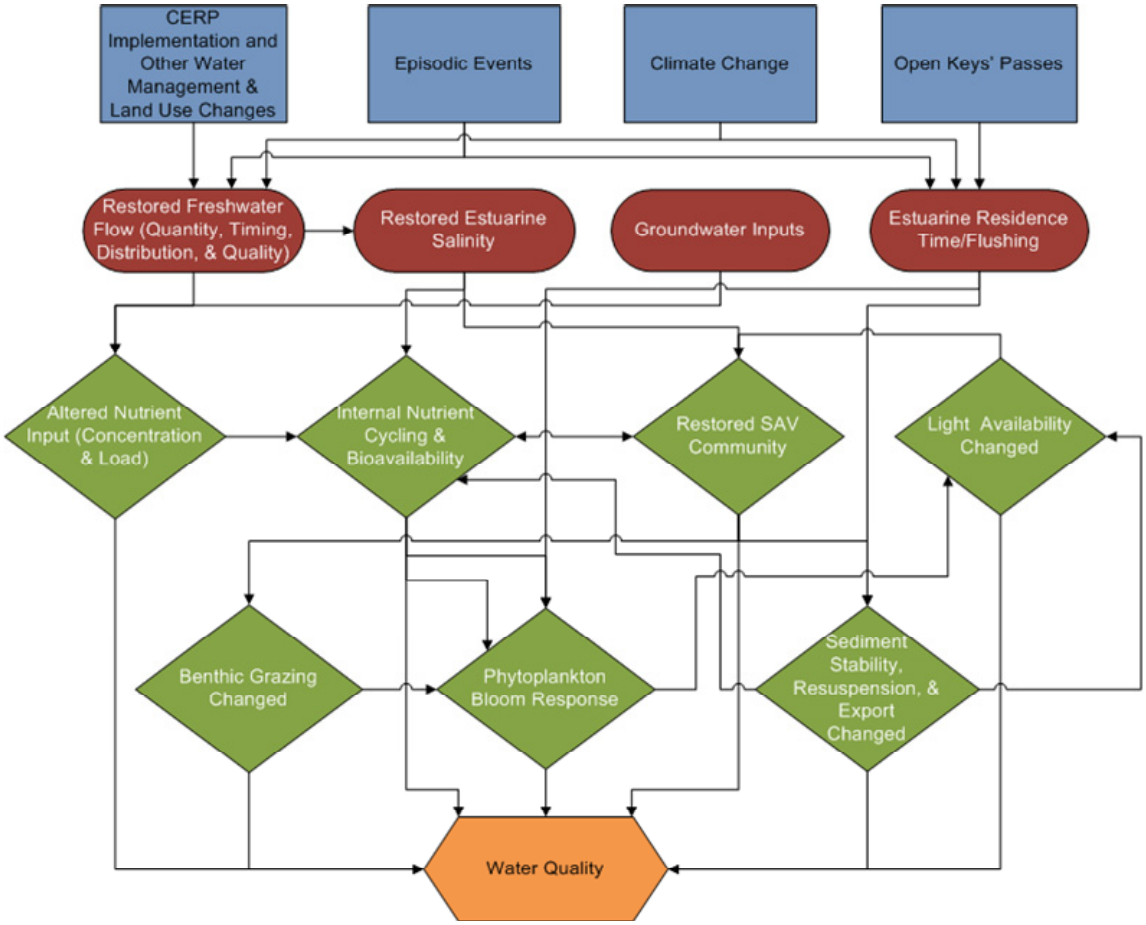

FIGURE 3-34: SOUTHERN COASTAL SYSTEMS WATER QUALITY AND PHYTOPLANKTON HYPOTHESIS CLUSTER DIAGRAM

Key: blue squares=drivers, red ovals=stressors, green diamonds=ecological effects, orange hexagons=attributes

3.4.4.2 Monitoring Components and Sampling Design

In 1979 the Miami-Dade Department of Environmental Resource Management (DERM) began a systematic water quality monitoring program in Biscayne Bay. Since 1988, under an ongoing cooperative agreement between SFWMD and DERM, water quality samples have been collected monthly and currently include 104 stations located in canals, bays, and adjacent waters.

The South Florida Coastal Water Quality Monitoring Network of 111 stations was established in 1989. It extends from northern Biscayne Bay southward before wrapping around the Florida peninsula through Florida Bay and extending up the west coast to Charlotte Harbor. Four regional areas are being sampled: Biscayne Bay, Florida Bay (including White Water Bay and Lostman's River), the Ten Thousand Island region, Rookery Bay (including Estero and San Carlos Bays), and Pine Island Sound in Charlotte Harbor.

The southwest Florida Shelf was include in the original network but was discontinued in 2002.

Beginning in the mid-1990s, NOAA Atlantic Oceanic and Meteorological Lab began monitoring water quality and circulation throughout the southern coastal systems via fixed station sampling and continuous synoptic sampling. Fixed stations, except those located on the southwest Florida shelf, were sampled monthly by both programs until funding shortfalls reduced sampling frequency to six times per year in Florida and Biscayne Bays and to four times per year on the southwest Florida shelf. In addition, Collier County monitors water quality at nine sites on a monthly basis in the vicinity of the Picayune Strand Restoration Project (PSRP).

Ongoing restoration projects (*i.e.,* C-111 Spreader Canal, Biscayne Bay Coastal Wetlands Phase I, and PSRP) have the potential of affecting the region by providing more natural freshwater flows to the nearshore waters, thereby improving salinity regimes for estuarine flora and fauna. Currently, the monitoring network is undergoing a reengineering effort with consideration given to the project-level monitoring plans that have been developed. The new design will be described in future SSRs.

3.4.4.3 Predictive and Assessment Tools

Numerous statistical tools to interpret and understand water quality data are well established (*i.e.,* Spearman rank correlation, seasonal Kendall tau, principal component analysis). Predictive tools for evaluating restoration alternatives (*i.e.,* water quality models) are being developed for Florida and Biscayne Bays; however, they have not been adequately calibrated and validated for use at this time.

3.4.4.4 Key Uncertainties

The key uncertainties associated with water quality and phytoplankton are as follows:

- Data gaps in the monitoring can confound interpretation, which may undercut the ability to correctly adaptively manage and maximize benefits in the future.
- Climate change, sea level rise, episodic events (*e.g.,* tropical storms, droughts), and anthropogenic activities also confound data interpretation.
- The lack of an accurate water quality model for the region limits predictive ability.
- Understanding the cause of algal bloom events remains a challenge.

3.4.5 Salinity Hypothesis Cluster

3.4.5.1 Working Hypotheses

This hypothesis cluster encompasses Biscayne and Florida Bays, the lower southwest mangrove coast, and the Ten Thousand Islands region. Salinity patterns in the coastal wetlands and estuaries will change in response to changes in the quantity, timing, and distribution of freshwater inflow. Sub-hypotheses derived from the CEM (***Figure 3-35***) are as follows:

- CERP implementation would affect freshwater delivery patterns and the resultant coastal wetland and estuarine salinity in many areas of the SCS. CERP would increase flows to some areas and decrease flows to other areas (*e.g.,* central and south Biscayne Bay).
- Restoration of the distribution of freshwater flows to coastal wetlands would result in spatially and temporally diffuse surface and groundwater flow into the estuaries. This would produce a gradient of increasing salinity from interior wetlands into the nearshore zone with a greater spatial extent of estuarine salinity zones and more gradual seasonal changes in salinity patterns.
- Groundwater discharges presently affect salinity in coastal wetlands and estuaries, particularly along the western shore of central and south Biscayne Bay. CERP implementation would modify groundwater stages and resulting discharges in the coastal zone, which would alter estuarine salinity patterns. Specifically, maintaining a higher groundwater table in southeastern Miami-Dade County would provide groundwater flow into south Biscayne Bay, even during the dry season, allowing for estuarine salinity conditions to persist longer into the dry season.
- Diverting freshwater from northeast Florida Bay into north-central Florida Bay and maintaining a higher water table in the southern Everglades would decrease the magnitude, duration, and spatial extent of hypersalinity in north-central Florida Bay.

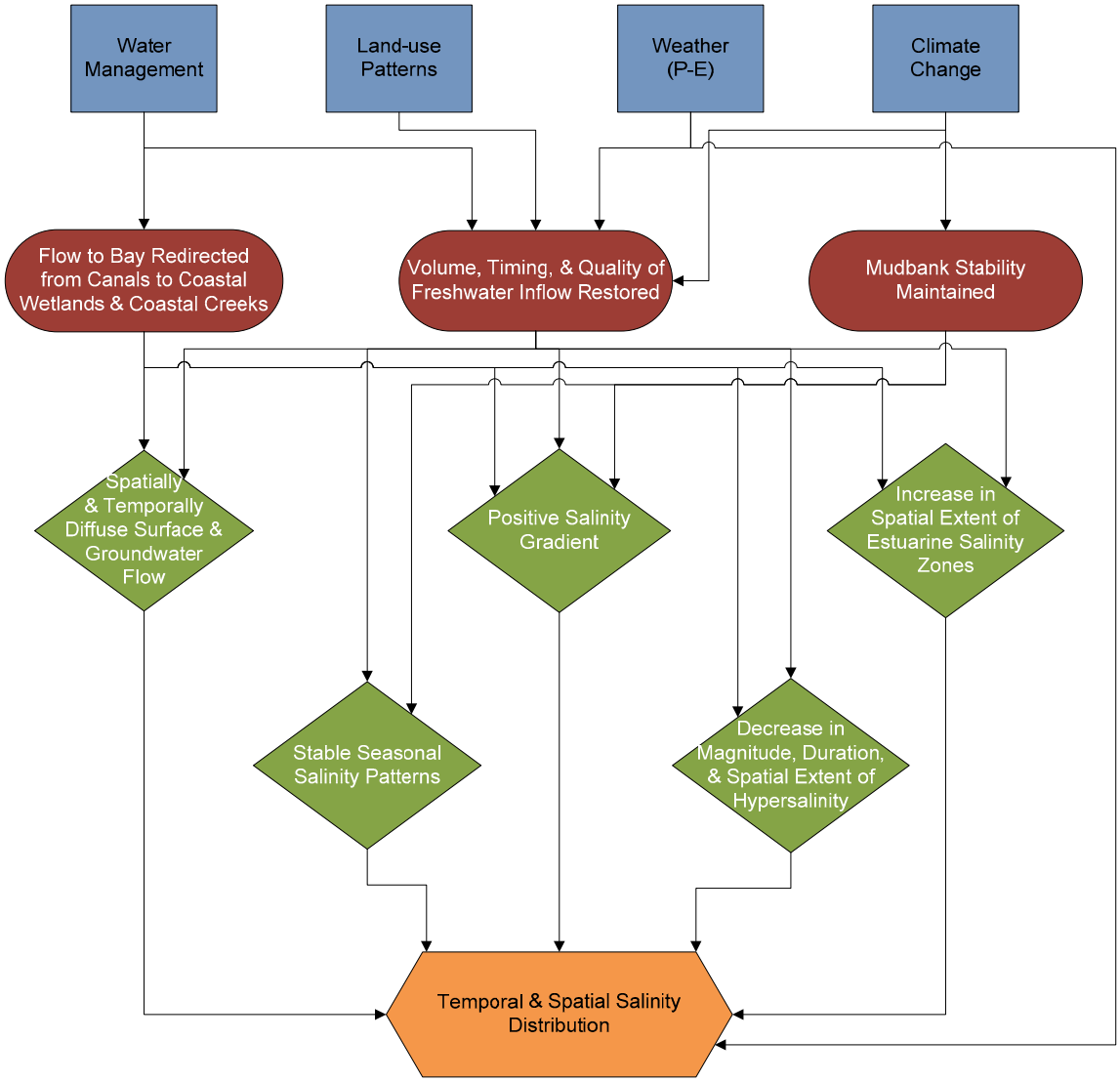

FIGURE 3-35. SOUTHERN COASTAL SYSTEMS SALINITY DISTRIBUTIONS HYPOTHESIS CLUSTER DIAGRAM

Key: blue squares=drivers, red ovals=stressors, green diamonds=ecological effects, orange hexagons=attributes

3.4.5.2 Monitoring Components and Sampling Design

Currently, five MAP projects are related to salinity monitoring in the SCS Module: (1) NOAA/USACE Salinity and Circulation Monitoring in the CERP/Southern Coastal Systems Module Domain; (2) Biscayne National Park (BNP)/USACE Nearshore Benthic Salinity Monitoring; (3) Everglades National Park's Salinity Monitoring Network; (4)

Rookery Bay National Estuarine Research Reserve's Salinity Monitoring Effort, and (5) USGS Coastal Gradients Project. These projects are complementary in their spatial and temporal coverage. For example, the NOAA/USACE project is spatially extensive, whereas the BNP/USACE project in Biscayne Bay and the ENP monitoring project in Florida Bay are temporally intensive.

In the Ten Thousand Islands area, which may be affected by the Picayune Strand Restoration Project, a cooperative effort amongst USGS/USACE/SFWMD (pers. comm. Eduardo Patino, USGS), measures flow and salinity at seven bridges along the Tamiami Trail. An additional five flow and salinity monitoring stations are located at strategic points in riverine downstream areas. In addition, on a quarterly basis, synoptic surface salinity maps are generated four times per year. Complementing this effort are three continuous salinity and flow monitoring stations managed by SFWMD.

The Biscayne and Everglades National Parks projects both use continuous recording instruments at fixed locations to monitor salinity. This gives good temporal resolution at the fixed locations, but spatial resolution is relatively weak. Spatial resolution is increased in the nearshore area of southern Biscayne Bay where changes are most likely to be detected from CERP projects. The NOAA/USACE salinity and circulation monitoring measures salinity utilizing a flow-through system to obtain high spatial resolution observations of salinity. Rookery Bay National Estuarine Reserve Research maintains continuously recording sondes in Fakahatchee, Faka Union, and Pumpkin Bays, and in Blackwater River.

3.4.5.3 Predictive and Assessment Tools

Currently, the South Florida HYCOM, the CAFE3D Numerical Hydrodynamic and Mass Transport Model of Biscayne Bay (Wang et al. 2003), the FVCOM, the EFDC, the TIME, and the TABS-MDS models provide salinity predictions for the SCS module. The HYCOM model is focused on the surrounding oceanic waters and is capable of interfacing with and providing boundary conditions for the more finely resolved estuarine models. The CAFE3D and TABS-MDS models are focused on Biscayne Bay, and the EFDC is focused on Florida Bay and the lower southwest coastal shelf. These models generally provide reliable results although there is some concern about the EFDC's capability of predicting the intensity and spatial extent of extreme hypersalinity events in north-central Florida Bay. In addition, accurately incorporating groundwater's role in the nearshore Biscayne Bay salinity regime, which the Biscayne Bay continuous salinity monitoring network suggests is significant, has proven difficult. The TIME model domain overlaps the Taylor Slough and Shark River Slough areas but currently ends shy of the Ten Thousand Islands region. The TIME model provides a mechanism for translating outflows from coarse scale upland water management models into the estuarine models with the proper distribution and timing. The finite volume FVCOM model focuses on the Rookery and Naples Bays estuary complex.

3.4.5.4 Key Uncertainties

The key uncertainties associated with salinity in the SCS are as follows:

- Many of the programs from which salinity data are drawn for CERP support are not funded by the MAP, including the NOAA/USACE project, ENP continuous salinity monitoring, the South Florida Coastal Water Quality Monitoring Network, and some of the Ten Thousand Islands monitoring (including Rookery Bay). If these projects were to cease, a significant lack of spatial salinity data would result, making assessments difficult and their accuracy questionable.
- Predicting accurate pre-drainage and restoration scenarios remains a key uncertainty because it relies on coupled models (NSM and Marshall's MLR equations) along with the inaccuracies inherent in both.

3.4.6 Submerged Aquatic Vegetation Hypothesis Cluster

3.4.6.1 Working Hypotheses

This hypotheses cluster applies to Florida and Biscayne Bays, and the Ten Thousand Islands region. CERP would alter the volume, timing, and spatial distribution of freshwater inflow into the SCS. SAV community structure is affected by water management, land use, and episodic events, which affect the quantity, quality, and timing of freshwater flows (***Figure 3-36***). SAV serves as habitat for numerous estuarine organisms. The hypotheses for SAV are as follows:

- Changes in both salinity and water quality resulting from restoration are expected to cause changes in seagrass cover, biomass, distribution, species composition and diversity through the combined and interrelated effects of light penetration, epiphyte load, nutrient availability, sediment depth, salinity, temperature, hypoxia/anoxia, sulfide toxicity, and disease.
- Changes related to restoration would include an expansion of areas with *Halodule wrightii* and *Ruppia maritima* cover and a reduction in areas of *Thalassia testudinum* monoculture along the northern third of Florida Bay. Based on forecasted changes in hydrology, seagrass density, and species composition are not expected to change in the southern two-thirds of Florida Bay and the eastern half of Biscayne Bay.
- Changes in both salinity and water quality resulting from restoration are expected to change benthic algal cover, biomass, distribution, species composition, and diversity though the combined and interrelated effects of light penetration, nutrient availability, salinity, temperature and changes in seagrass density and species composition. For example, *Chara* species are anticipated to expand in northern Florida Bay and along nearshore areas of southwestern Biscayne Bay.
- Significant changes in benthic algae and seagrass distribution can affect susceptibility of sediments to resuspension, the stability of mud banks, and nutrient availability to other primary producers.

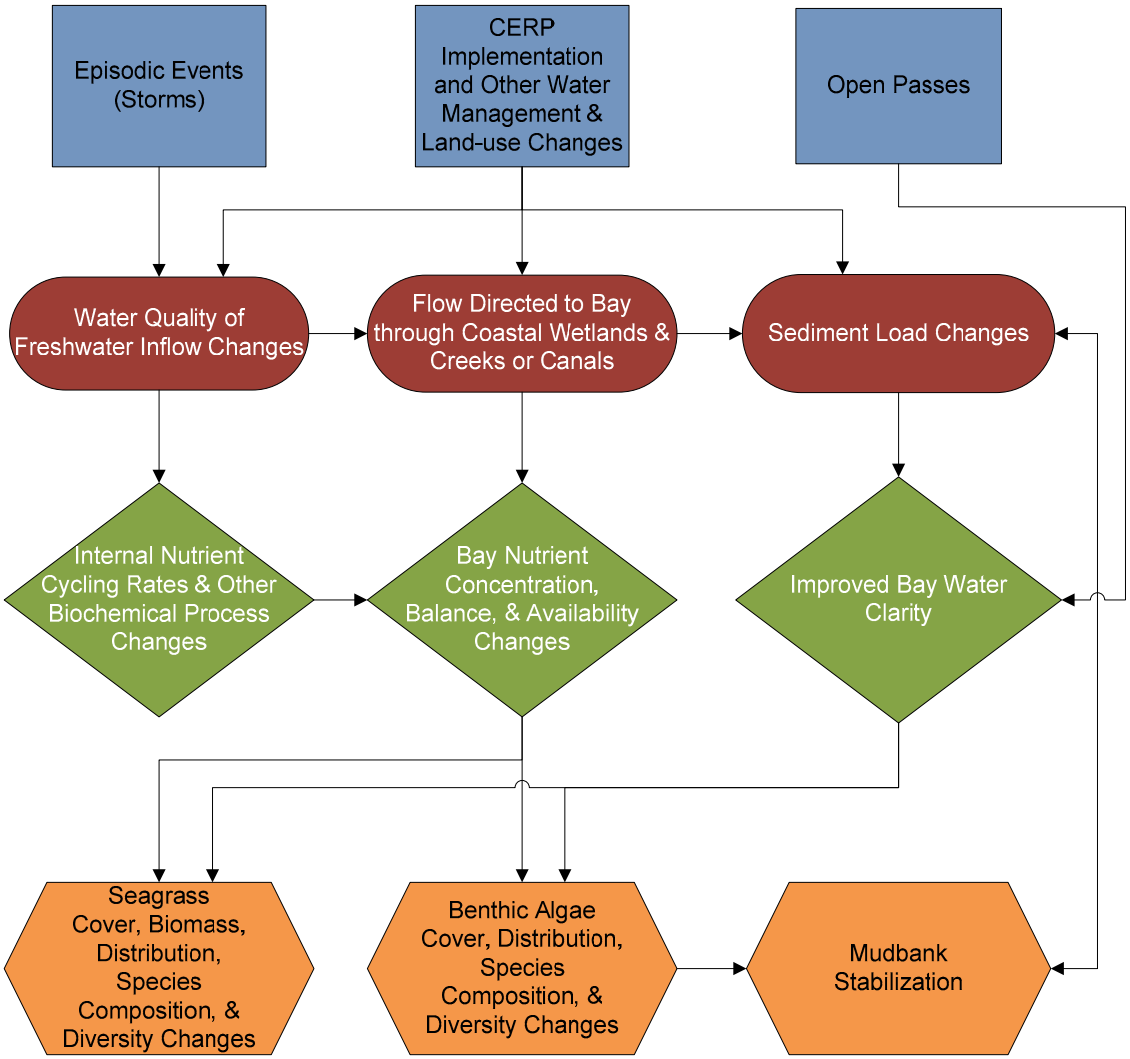

FIGURE 3-36. SOUTHERN COASTAL SYSTEMS SUBMERGED AQUATIC VEGETATION HYPOTHESIS CLUSTER DIAGRAM

Key: blue squares=drivers, red ovals=stressors, green diamonds=ecological effects, orange hexagons=attributes

3.4.6.2 Monitoring Components and Sampling Design

The SAV field data and concomitant water quality information are being collected to establish pre-CERP reference conditions against which the extent of system change will be measured as restoration is implemented. Analysis of these pre-restoration data is needed to determine the extent of system change that would be detectible and how long that might take once CERP implementation advances. It should also reveal at an early stage systematic

problems in the monitoring or analysis, and highlight areas where significant improvements can be made.

The distribution, diversity, abundance, diversity, and physiological condition of the main components of the SAV community in Florida and Biscayne Bays are presently evaluated by two complementary programs, the Fisheries Habitat Assessment Program (FHAP) and the Nearshore Benthic Assessment Program.

As part of FHAP, ten sites were sampled in Florida Bay from 1995 to 2004. The number of sites was expanded in 2005 to a total of 22 locations extending from Lostman's River to Biscayne Bay. This program documents the status and trends of seagrass distribution, abundance, and reproduction, as well as providing process-oriented data such as photosynthetic quantum yields and epiphyte loads. Specific objectives of FHAP are to develop a basic understanding of the relationships among salinity, water quality, and seagrass species distribution and abundance in South Florida, to provide data to separate anthropogenically-induced changes from natural ecosystem variation, and to verify model predictions on species- and ecosystem-level responses to perturbations. Sampling is conducted once per year at the end of the dry season (May-June) when salinity stress is generally highest.

The Nearshore Benthic Assessment Program focuses on nearshore benthic habitats (less than 500 meters from shore) of southern Biscayne Bay, from Matheson Hammock to Manatee Bay, which have been largely understudied due to the difficulties associated with access to extreme shallow zones (less than one meter in depth), but where significant changes are most likely to occur as a result of restoration. This program was designed specifically to evaluate spatial and temporal patterns of abundance, diversity, and distribution of SAV in relation to distance from shore and freshwater discharge from water management canals. Sampling locations are selected based on a stratified random sampling design. High-resolution digital images of the bottom are obtained from a shallow-draft skiff, and locations are documented using an innovative survey methodology called the Shallow Water Positioning System. Digital images are imprinted with depth and GPS location providing a permanent geo-referenced visual record of the benthic community.

Since 1993, Miami-Dade DERM in cooperation with SFWMD has monitored SAV in 12 basins that may be affected by upstream water management practices. These are Manatee Bay, Barnes Sound, Highway Creek, Long Sound, Little Blackwater Sound, northwest Blackwater Sound, Joe Bay, Alligator Bay, Davis Cove, Trout Cove, Little Madeira Bay, and an area south of Little Madeira Bay. In addition, Miami-Dade DERM measures light penetration at 64 sites monthly, which should assist in deciphering seagrass dynamics.

A one-time benthic habitat coverage survey was performed in 2004-2005 in Fakahatchee, Faka Union, and Pumpkin Bays, part of the Ten Thousand Islands region. The Faka Union and Pumpkin Bays are expected to benefit from the Picayune Strand Restoration Project. Fakahatchee Bay is relatively pristine and is used as a reference site. The study used side-scan sonar and acoustic mapping techniques, combined with bottom sampling for ground truthing the acoustic imagery interpretations, and for mapping sedimentological

characteristics. The study documented oyster and SAV distributions. Results will be used to establish a pre-CERP reference condition for SAV in the TTI region.

3.4.6.3 Predictive and Assessment Tools

Relationships between salinity and SAV speciation are being developed and validated (*e.g.,* Lirman et al. 2008).

3.4.6.4 Key Uncertainties

SAV community health is dependent upon multiple factors including salinity, water quality, water clarity, and sediment type. Restoration will likely have uneven effects within the SCS. A few key uncertainties in achieving the optimum balance include:

- Sporadic or missing salinity and water quality data, or problems with sampling design and data analyses.
- In areas where seagrasses have been lost and sediments are more easily resuspended, the concomitant decrease in light penetration may slow recolonization by SAV.
- Sample design versus patchiness of SAV and whether the results can be used statistically to detect significant changes.
- Sediment depth, grazing, and epiphyte cover may confound interpretation of CERP affects.

3.4.7 Estuarine Nursery Habitat Hypothesis Cluster

3.4.7.1 Working Hypotheses

Estuarine nursery habitats are being studied in Biscayne and Florida Bays, in the lower southwest mangrove estuaries, and the Ten Thousand Island region. Implementation of CERP projects is expected to improved salinity patterns in space and time, creating a salinity regime that is more characteristic of estuaries (***Figure 3-37***). Faunal densities and species diversity within these areas are expected to increase. The hypotheses for estuarine nursery habitat are as follows:

- Restoration would increase the length of shoreline receiving freshwater, expand the spatial extent of desirable salinities, and reduce salinity fluctuation to a range and frequency characteristic of natural estuarine conditions, thereby increasing the area of optimum habitat for many species. As a result, these changes will expand local distribution, increase abundance, and allow a richer species assemblage of estuarine species.
- Restoration would reduce the intensity, duration, and spatial extent of hypersaline conditions, thereby increasing the area of optimum habitat for nearshore fish and invertebrates.
- Anticipated changes in fish community structure in response to increasing the area of optimum habitat include an increase in the utilization of mangrove shorelines by euryhaline species such as gray snapper (*Lutjanus griseus*) and snook (*Centropomis unidecimalis*), while the use by stenohaline marine species (*e.g.,* damselfishes) should decrease. There should be occasional observations of

species associated with both fresh and brackish conditions (*e.g.,* a suite of killifishes).

- Restoration would increase the area covered by patchy or heterogeneous seagrass habitat, thereby increasing the area of optimum habitat for seagrass-associated fish and invertebrate species.
- Restoration would re-establish sheet flow to the coast that would rehydrate coastal marshes and re-create habitat for freshwater fish and other prey for utilization by wading birds and other high trophic level species.

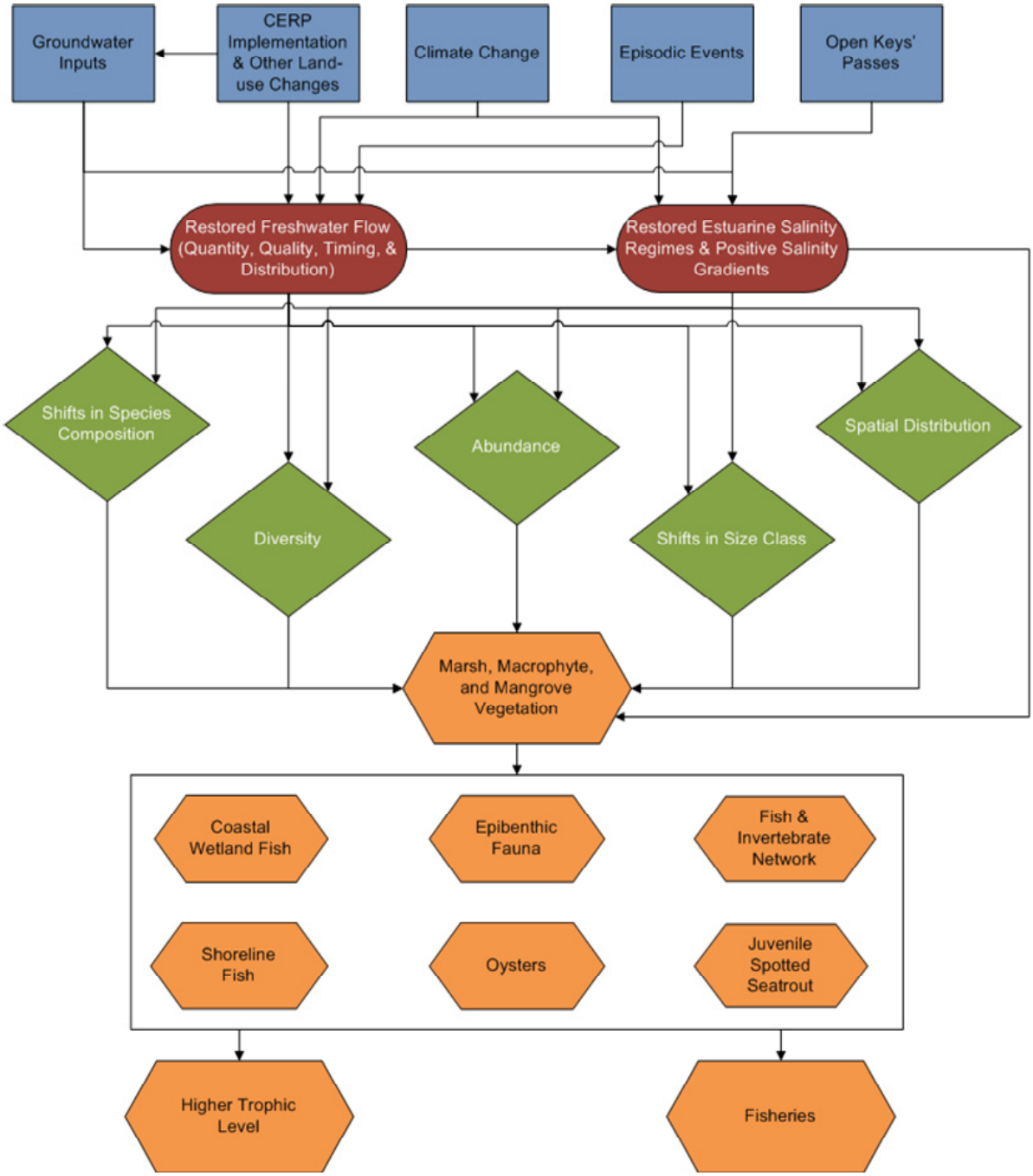

FIGURE 3-37. SOUTHERN COASTAL SYSTEMS ESTUARINE NURSERY HABITAT HYPOTHESIS CLUSTER DIAGRAM

Key: blue squares=drivers, red ovals=stressors, green diamonds=ecological effects, orange hexagons=attributes

3.4.7.2 Monitoring Components and Sampling Design

Seagrass Fish and Invertebrate Assessment Network. (FIAN) – Comprehensive synoptic sampling with throw-trap gear in southern estuaries from Biscayne Bay to Lostman's River to assess the status of pink shrimp (*Farfantepenaeus duorarum*) and other faunal associates of seagrass and benthic algal communities (sampling design coordinated with FHAP). Consists of 30 samples in a randomly sited tessellated grid at 19 locations per collection, with a dry season and wet season collection each year.

Epifauna monitoring along south Biscayne Bay shoreline. This effort employs throw traps to evaluate community compositional structure of small fishes and invertebrates, including killifish, gobies, shrimp, and crabs, in relation to salinity patterns, benthic habitat, and shoreline fishes. Three samples are taken at 72 locations along the shoreline between Shoal Point and Manatee Bay, with locations corresponding to that of shoreline fishes transects.

Visual shoreline fish monitoring in mangroves. Visual monitoring of shoreline fishes along the western, mangrove-lined margins of southern Biscayne Bay, and Card and Barnes Sounds is conducted using a stratified random sampling design. Sampling currently entails approximately 120 visual belt transect fish surveys during the wet and dry seasons. Serafy et al. (2003, 2007) and Faunce and Serafy (2007, 2008a, 2008b) have published data from these studies in addition to providing summaries in the system status reports.

Juvenile Seatrout. Trawl sampling for juvenile spotted seatrout is conducted in northwestern Florida Bay, Rankin Lake, Whipray Basin, and Crocodile Dragover. Sampling follows a stratified random approach using otter trawls and is conducted monthly from June through November, corresponding to the season when juvenile spotted seatrout are found in greatest number.

Rookery Bay National Estuarine Research Reserve fish and invertebrate monitoring. Biological monitoring of fish and invertebrates occurs via four monthly collections at randomly selected sites using otter trawls in Fakahatchee, Faka Union, Pumpkin, and Rookery Bays. The collections document the relative abundance of a variety of fish species and commercially important invertebrates within these bays, including stone crabs (*Menippe mercenaria*), blue crabs (*Callinectes sapidus*), and pink shrimp. Of the above, only this component is not funded by the MAP.

3.4.7.3 Predictive and Assessment Tools

Faunal abundance metrics are being evaluated as a function of observed salinity toward developing statistically rigorous regression relationships that can then be incorporated into habitat suitability models for SCS fauna (Serafy and Johnson 2008). This work uses the delta approach to generate HSI models for 12 fish species and pink shrimp. These habitat suitability relationships will be refined via an extrapolation tool that will permit estimation of time series salinity at both sampled and un-sampled locations. Efforts have begun to validate these relationships via laboratory-based, salinity preference trials**.** Field testing the animal-salinity relationships is a logical next step, as well as integrating salinity output from

hydrodynamic models against which fluctuations in animal abundance and diversity may be examined.

3.4.7.4 Key Uncertainties

Among uncertainties for estuarine nursery habitat is the validity of extending to restored systems inferences based on impacted systems when they may be fundamentally different. Today, for example, salinity mean and salinity variation are strongly and inversely correlated historically this was not the case. Therefore, uncertainty exists when determining if an apparent response to a decrease in mean salinity is in fact a response to an increase in salinity variation. Similarly, sustained low mean salinities are a rarity during the present day dry season, but such conditions did occur historically and may occur when more natural patterns of freshwater inflow are restored. Because present day salinity regimes differ in many ways from both historical and restored salinity and nutrient regimes, fauna-salinity relationships may not transfer into the future. Similarly, it may not be a valid extension to extrapolate wet season results into the dry season because time of the year may influence responses. The expectation that fish habitat suitability will increase in the restored system based on inferred relationships may not be realized, as present observations of abundance may be an artifact of currently unknown or un-sampled factors. Current understanding of habitat suitability may be overly simplified and require substantial revision as learning proceeds. Laboratory experimentation represents one of the few possible approaches for resolving this and other confounding factor issues, although laboratory experiments are not without their own artifacts and complications. Long time series are important in determining faunal relationships with salinity and other major influencing factors.

3.4.8 Oyster Hypothesis Cluster

3.4.8.1 Working Hypotheses

The areas that the oyster hypothesis cluster pertains to are Biscayne Bay, the lower southwest coast mangrove estuaries from Whitewater Bay to Lostman's River and the Ten Thousand Islands region. Restoration of more natural freshwater inflows by retention in reservoirs, wetland rehydration, and changing delivery patterns should provide beneficial salinity and habitat conditions that promote the reestablishment of healthy oyster beds. Undesirable shifts in the estuarine salinity envelope result in decreased survival, reproduction, spat recruitment, and growth, and increased susceptibility to *Perkinsus marinus* infections. Increase in oyster reef coverage would enhance secondary habitat for other estuarine species, resulting in increased diversity and abundance. Oyster populations would increase when fresh water destined for estuaries is routed through new and restored coastal marshes, which would reduce sediment loads and areas with soft, unconsolidated substrate.

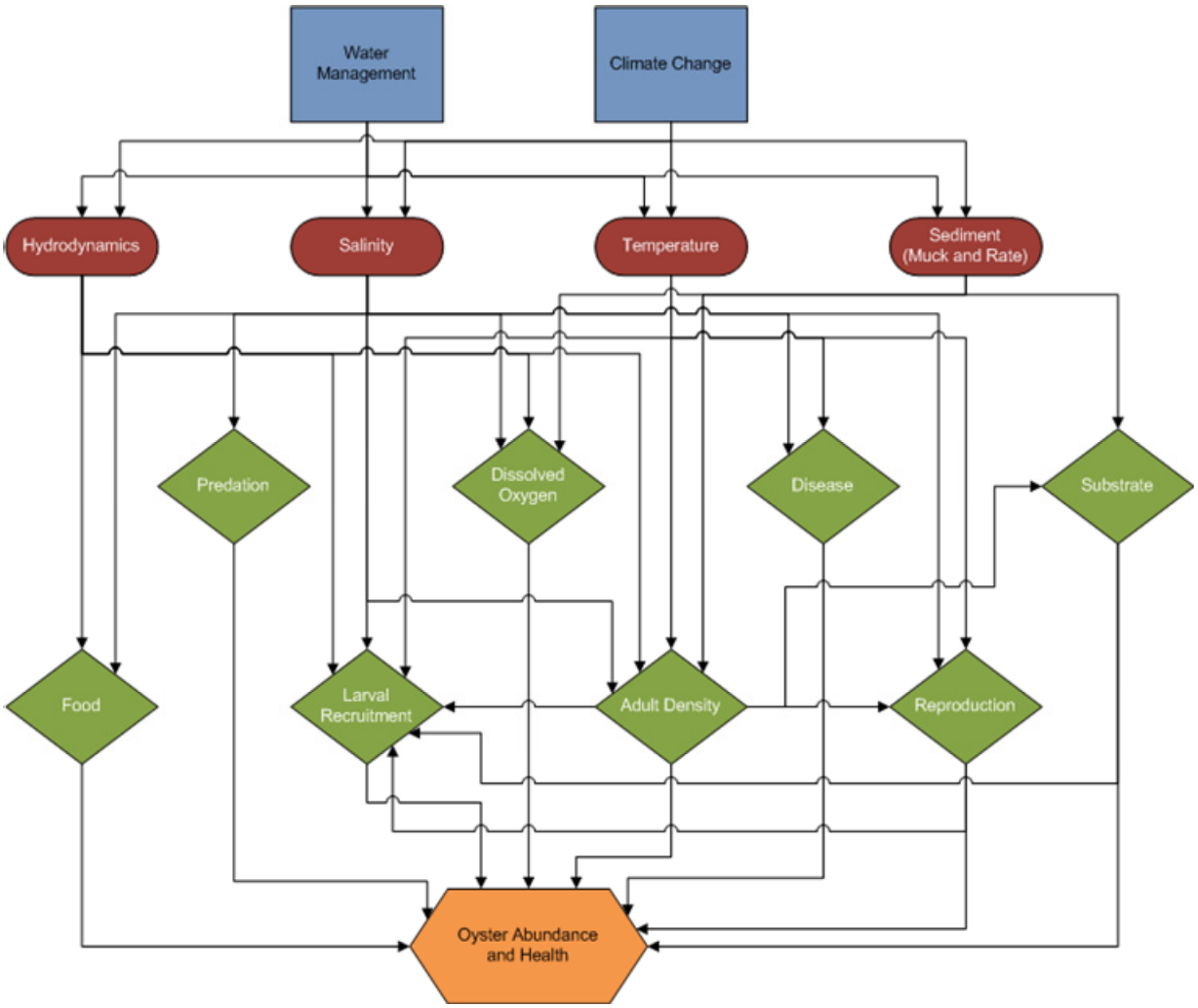

FIGURE 3-38: SOUTHERN COASTAL SYSTEMS OYSTERS HYPOTHESIS CLUSTER DIAGRAM

Key: blue squares=drivers, red ovals=stressors, green diamonds=ecological effects, orange hexagons=attributes

3.4.8.2 Monitoring Components and Sampling Design

The main objective of the oyster monitoring program is to implement sustainable monitoring for the eastern oyster (*Crassostrea virginica*) in South Florida estuaries to track changes as restoration implementation progresses. Six aspects of oyster ecology are being monitored including: (1) spatial and size distribution patterns of adult oysters, (2) reproduction, (3) recruitment, (4) juvenile oyster growth and survival, (5) physiological condition as measured by condition index, and (6) prevalence and intensity of oyster diseases. Biscayne Bay was synoptically sampled for three years (2005-2007) to establish pre-CERP reference

conditions but was halted because of the paucity of oysters present under the current salinity regime. Oyster monitoring in the Shark River Slough area was conducted for one year, but was halted due to restoration implementation uncertainty. Oyster resources within the Ten Thousand Islands region associated with Picayune Strand restoration were sampled for two years to establish pre-CERP reference conditions, but further monitoring is currently on hold until timeline for the restoration plan is finalized.

3.4.8.3 Predictive and Assessment Tools

The Caloosahatchee River Oyster HSI Model (Volety et al. 2005) was the first to be developed for the NE module and is currently being validated. This model is a modification of the original model developed by Cake (1983) and modified by Soniat and Brody (1988) for the Texas estuaries. It is anticipated that the HSI will be adapted for use in the SCS. See the NE module for more details on this HSI.

3.4.8.4 Key Uncertainties

The key uncertainties associated with the eastern oyster are as follows:

- The existing sampling design and frequency can adequately assess the direction and magnitude of change in the indicator, but the sampling design may need to be adjusted to better capture the spatial variation of responses. Seasonal trends may need to be examined before any adjustments are made.
- The affects of contaminants on oysters needs future study.
- The most accurate and cost effective method of mapping oyster beds must be determined. Different techniques may need to be used in the four different estuaries due to their differing water clarity conditions as well as the varying depths of the beds themselves.
- The adequacy of oyster bed mapping spatial resolution should be addressed, as well as need to survey areas included in CERP performance measures that have yet to be mapped (*i.e.,* Snake Creek in Biscayne Bay).
- The ability to adapt the NE oyster HSI to the SCS is a key uncertainty.
- Oyster monitoring in the module is in a state of uncertainty principally due to uncertainty of the timelines for project implementation.

3.4.9 Predator-Prey Interactions of Wading Birds and Aquatic Fauna Forage Base Hypothesis Cluster

3.4.9.1 Working Hypotheses

Within Picayune Strand, the success of wading bird foraging is influenced by wet season population densities and dry season concentrations of marsh fishes, crayfishes, and other aquatic prey organisms. Restoration of the natural water surface coverage and duration would optimize feeding conditions for wading birds in the Picayune Strand vicinity. Improvements in foraging opportunities would contribute to nesting success of colonies in the area. The diagram for predator-prey interactions of wading birds and their aquatic fauna forage base is the same as for the GE module (***Figure 3-39***). Sub-hypotheses include:

Wading bird foraging. Wading bird foraging success would improve as prey biomass increases with the restoration of more extensive wetlands including short hydroperiod wetlands and more natural dry season water table recession rates.

A complete description of the predator-prey hypothesis cluster is found in the GE module in this report.

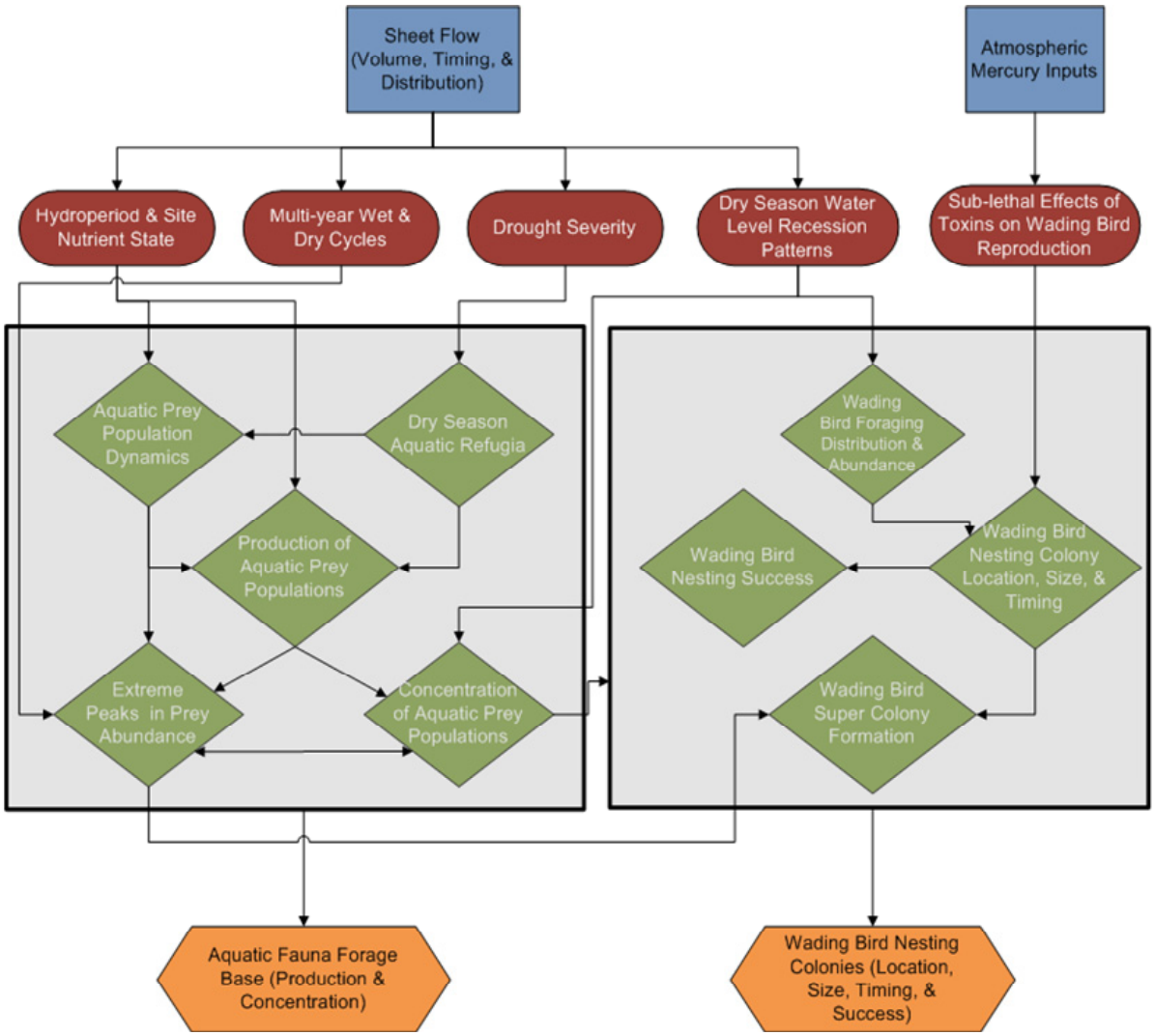

FIGURE 3-39. SOUTHERN COASTAL SYSTEMS PREDATOR-PREY INTERACTION OF WADING BIRDS AND AQUATIC FAUNA BASE HYPOTHESIS CLUSTER DIAGRAM

Key: blue squares=drivers, red ovals=stressors, green diamonds=ecological effects, orange hexagons=attributes

3.4.9.2 Monitoring Components and Sampling Design

The strategy for the assessment of wading bird and aquatic prey interactions is to track the production of aquatic prey populations during the wet season, the concentration of those populations during the subsequent dry season, and the location and size (number) of wading bird feeding opportunities across the landscape. The monitoring components include aerial surveys, faunal sampling, and stage monitoring.

Aerial surveys. Wading bird population, distribution, and occupation surveys are flown using fixed-wing aircraft along 24 transects spaced two kilometers apart and oriented in an east-west direction. Surveys are conducted twice monthly, coinciding with low tide for seasonal comparisons.

Faunal sampling. Sampling for freshwater macroinvertebrates, amphibians, and fish occurs three times each year in July-August, October-November, and January-February to determine species presence/absence, relative abundance, and plant community associations. Samples are collected from major plant communities in the vicinity of each stage monitoring well when water is present.

Stage monitoring. Hydrologic regimes, as a principle driver in the predator-prey dynamics, are documented via 24 groundwater stage monitoring wells installed in 2003. Three additional wells were installed in downstream brackish marshes in 2006. Data from the 24 groundwater stage wells monitored monthly in Fakahatchee Strand since 1987 are available for comparison and to facilitate interpretation.

3.4.9.3 Predictive and Assessment Tools

Non-metric multi-dimensional scaling and other statistical methods are available for use with predator-prey interactions between wading birds and aquatic fauna.

3.4.9.4 Key Uncertainties

Wading bird utilization of an area may be affected by non-monitored factors such as disturbance, the availability of a nearby “preferred” feeding site, or proximity to nesting areas. Bird surveys in wooded wetlands are problematic because birds feeding under the trees, as in cypress domes, cannot be seen from the air. Wading birds move around and may be present in an area during a time when they are not observed. By and large, wading birds that feed in Picayune and Fakahatchee Strands nest in other places, and the presence of wading birds in Picayune Strand may be affected by feeding conditions in other areas around the nesting colony.

3.4.10 Native Vegetation Mosaic Hypothesis Cluster

3.4.10.1 Working Hypotheses

The vegetation of southwest Florida, including Picayune Strand, and coastal Biscayne Bay can be described broadly in terms of visually and ecologically distinct landscape units, or mosaics. These mosaics are made up of a background matrix of marl-forming wet prairie, or short hydroperiod marsh, interspersed with distinct patches of vegetation, varying from swamp hardwood forest, cypress strands, cypress domes, bayheads, and willow ponds to tropical hardwood hammock.

In the Picayune Strand area, the cypress strands and swamp forests are found in elongated depressions and the bay heads and cypress domes are found in circular depressions. Bald cypress and temperate swamp species are associated with the strands and domes. Temperate forest species contribute to the hardwood hammocks in the Picayune Strand area, whereas tropical hardwoods make up the major species components of the remnant hardwood hammocks in the Biscayne Bay coastal wetlands. Today, the marl prairie vegetation is degraded in both areas, and invasive exotic species infiltrate the forests. In Picayune Strand, the shift has been toward cabbage palm (*Sabal palmetto*) forests.

In coastal Biscayne Bay, the marl prairie community has been degraded and reduced in size by invasions of exotic vegetation, encroachment of upland mangroves, and replacement of *Eleocharis* species by sawgrass (Cladium jamaicense) and woody shrubs. An area of low productivity that can be seen on aerial photographs and is referred to as “the white zone” has spread along the coastal wetlands of Card and Barnes Sounds (and also Florida Bay). This inland spread appears to be associated with an inland movement of the influence of salt water into the freshwater marsh. Some have speculated that the inland movement of the white zone might be due to sea level rise (Ross et al. 2002). However, the white zone reaches further inland on the eastern side of Highway US 1 than the western side, clearly indicating that it cannot be due under current conditions to sea level rise alone.

The composition and distribution of plant communities along elevation gradients are determined by hydropatterns (hydroperiod and water depth), nutrient dynamics, and fire patterns and would shift to a more freshwater wetland dominated plant community when more natural hydrologic conditions with longer hydroperiods are restored (***Figure 3-40***). Through modifications of quantity, quality, timing, and distribution of freshwater, exotic and other undesirable species would gradually give way to appropriate native vegetative communities. However, it should be noted that mature stands of exotic vegetation may have to be physically or chemically removed to allow hydrologic modification to effectively promote and maintain native communities. The following hypotheses have been developed to describe the expected effects of a more natural hydrologic regime:

- The component of exotic vegetation in plant communities would decrease in both Picayune Strand and Biscayne Bay wetland areas.
- Grasses and sedges tolerant of wet conditions would become a larger component of the marl prairie vegetation in both Picayune Strand and Biscayne Bay wetland areas.

- Cabbage palm invasion would decrease or be halted, and areas where cabbage palm are removed and/or treated would be restored long-term in Picayune Strand.
- Areas in Picayune Strand presently shifting toward palm forest would gradually experience an increase in cypress seedlings and saplings.
- The boundary of the white zone in Biscayne Bay wetlands would move seaward and the overall white zone area would shrink.

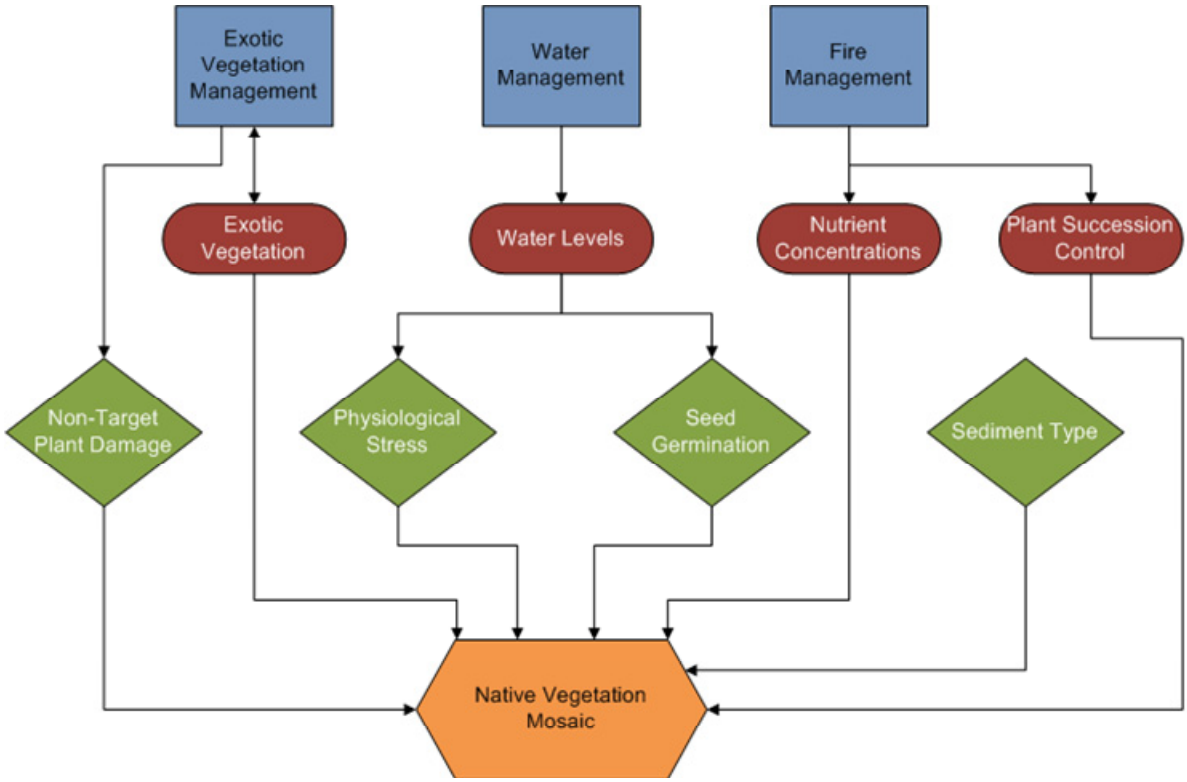

FIGURE 3-40. SOUTHERN COASTAL SYSTEMS NATIVE VEGETATION MOSAIC HYPOTHESIS CLUSTER DIAGRAM

Key: blue squares=drivers, red ovals=stressors, green diamonds=ecological effects, orange hexagons=attributes

3.4.10.2 Monitoring Components and Sampling Design

System-wide aerial photo interpretation is employed to evaluate changes in large-scale patterns of the vegetative mosaic in the SCS on six-year cycles. The Biscayne Bay Coastal Wetlands Project team has proposed augmenting photo interpretation with ten transects, each consisting of about ten permanent plots where speciation would be mapped in detail.

All vegetative strata within examples of the major plant community types would be monitored in and adjacent to the Picayune Strand Restoration Project area to determine changes in species composition and dominance, and to compare them to similar types of relatively undisturbed reference communities in nearby natural areas. Two permanently marked 50-meter vegetation transects have been established at each of the 27 groundwater well sites, and one additional transect has been established at each of nine relatively undisturbed reference sites.

3.4.10.3 Predictive and Assessment Tools

Water table depth data at the 27 wells would be compared to existing topographic surveys at nearby vegetation transects to determine their hydrologic regime. This information would be correlated to measured changes in wetland vegetation along these transects as the latter relates to established restoration goals.

3.4.10.4 Key Uncertainties

Plant communities would develop in accordance with the restored hydrologic pattern, which may not exactly coincide with the pre-drainage pattern. Different species require different hydrologic regimes and most likely would become established wherever the appropriate conditions are maintained. Soils may have changed in some areas to such an extent that the previous vegetation of the area cannot become reestablished. This is most likely to be the case where there has been significant organic soil loss and restored water levels are significantly deeper and hydroperiods longer. Exotic and nuisance vegetation may prove difficult to control or eradicate and may delay reestablishment of a desirable vegetative mosaic. Frequency and intensity of freezes or fires may also affect plant distribution patterns. Mangroves have moved inland and may prove resilient to restored hydrology. Sea level rise may also move inland at a rate sufficient to reduce or counteract attempts to change hydrology.

3.4.11 Evolution of the Southern Coastal Systems Module between MAP 2004 and MAP 2009

TABLE 3-5. SOUTHERN ESTUARIES MAP 2004 VERSUS SOUTHERN COASTAL SYSTEMS MAP 2009 MONITORING COMPONENTS, KEY UNCERTAINTIES, AND SUPPORTING RESEARCH

Monitoring Components MAP 2004	Monitoring Components MAP 2009	Changes Made Comments
Water Quality and Phytoplankton Monitoring Network (3.2.3.1)	Water Quality and Phytoplankton Monitoring Networks	Biscayne Bay monitoring network continues; Florida Bay and southwest coast monitoring modified; monitoring near Picayune Strand incorporated.
Salinity Monitoring Network (3.2.3.2)	Salinity Monitoring Network	BNP network continues; network expanded to incorporate monitoring performed by ENP in Florida Bay,

		FDEP/SFWMD near Picayune Strand, USGS in Coastal Gradients, and NOAA efforts.
South Florida Fish Habitat Assessment Program (3.2.3.3)	South Florida Fish Habitat Assessment Program	Network integrated with non-MAP funded Miami-Dade DERM network.
Large-Scale Remote Sensed SAV Monitoring Program (3.2.3.4)	Remote Sensed SAV Monitoring	Inactive.
Seagrass Fish, Pink Shrimp, and Invertebrate Assessment Network (3.2.3.5)	Fish and Invertebrate Assessment Network	Ongoing as originally designed. Project officially started in July 2004. First sampling was in September-October 2004; however first sampling for time series was April 2005.
Shoreline Fish Community Visual Assessment (3.2.3.6)	Shoreline Fish Community Visual Assessment	Ongoing as originally designed. This project officially started in July 2004, building upon a previous project initiated 1998.
Juvenile Spotted Seatrout Monitoring in Florida Bay (3.2.3.7)	Juvenile Spotted Seatrout Monitoring in Florida Bay	Ongoing as originally designed. This project officially started in July 2004. Sampling started in summer of 2004.
Previous name of Lorenz' bird work in BBCW as shown in MAP04	Current name of this effort	Ongoing as originally designed. The predator-prey hypothesis cluster is located in the GE module section.

Key Uncertainties and Supporting Research MAP 2004	Key Uncertainties and Supporting Research MAP 2009	Changes Made Comments
Florida Bay Sediment Dynamics: Sea Level and CERP Influences (3.2.4.1)		Not implemented by RECOVER.
Measurement of Submarine Ground Water Discharge to Biscayne Bay (3.2.4.2)		Not implemented by RECOVER; may be part of USGS TIME modeling.
Biological Availability of Organic Nitrogen in Florida Bay (3.2.4.3)		Partially completed; reassessing new needs.
Present and Past Distribution of Oysters in South Florida Coastal Complex (3.2.4.4)	Past and Present Distribution of Oysters in the South Florida Coastal Complex	Monitoring in Biscayne Bay on hold until salinity data indicates resumption; preliminary monitoring on southwest coast completed in early 2009; monitoring adjacent to Picayune Strand to be reinitiated in 2010.
Factors Controlling Epibenthic Communities of Near Shore	Documenting Everglades Restoration Impacts on Biscayne Bay's Shallowest	Underwater high-resolution photographic monitoring of nearshore Biscayne Bay, Card Sound and Barnes

Biscayne Bay (3.2.4.5)	Benthic Habitats	Sound.
Salinity Relationships of Epifaunal Species in Near-Shore Biscayne Bay (3.2.4.6)	Epibenthic Monitoring	Epibenthic fauna adjacent to the south Biscayne Bay shoreline is monitored in relation to seagrass, shoreline fishes, and freshwater change in the SCS module.
Empirical Research on Fishery Resources of Biscayne Bay (3.2.4.7)	Laboratory Validation of Field -derived Fauna-Salinity Relationships	Laboratory studies of species-specific salinity preferences to support observed species presence to salinity correlations to be initiated in 2009.
Causal Factors of Fish Abnormalities in Biscayne Bay (3.2.4.8)		Not implemented; addressed by other programs.
Bottlenose Dolphin Health Assessment in Biscayne Bay (3.2.4.9)		Not implemented; addressed by other programs.
Manatee Abundance and Distribution Relative to Freshwater Inputs (3.2.4.10)		Not implemented; addressed by other programs.