9.3.3 Water Quality Conceptual Ecological Model

Water quality in South Florida estuaries is dependent upon the volume, distribution, and quality of freshwater flowing to the system. The biotic components (e.g., phytoplankton, benthic habitats) of estuaries are sensitive to nutrient loading which may be modified by CERP. Complex interactive mechanisms between water quality and hydrologic drivers as well as internal nutrient cycling will influence CERP effects.

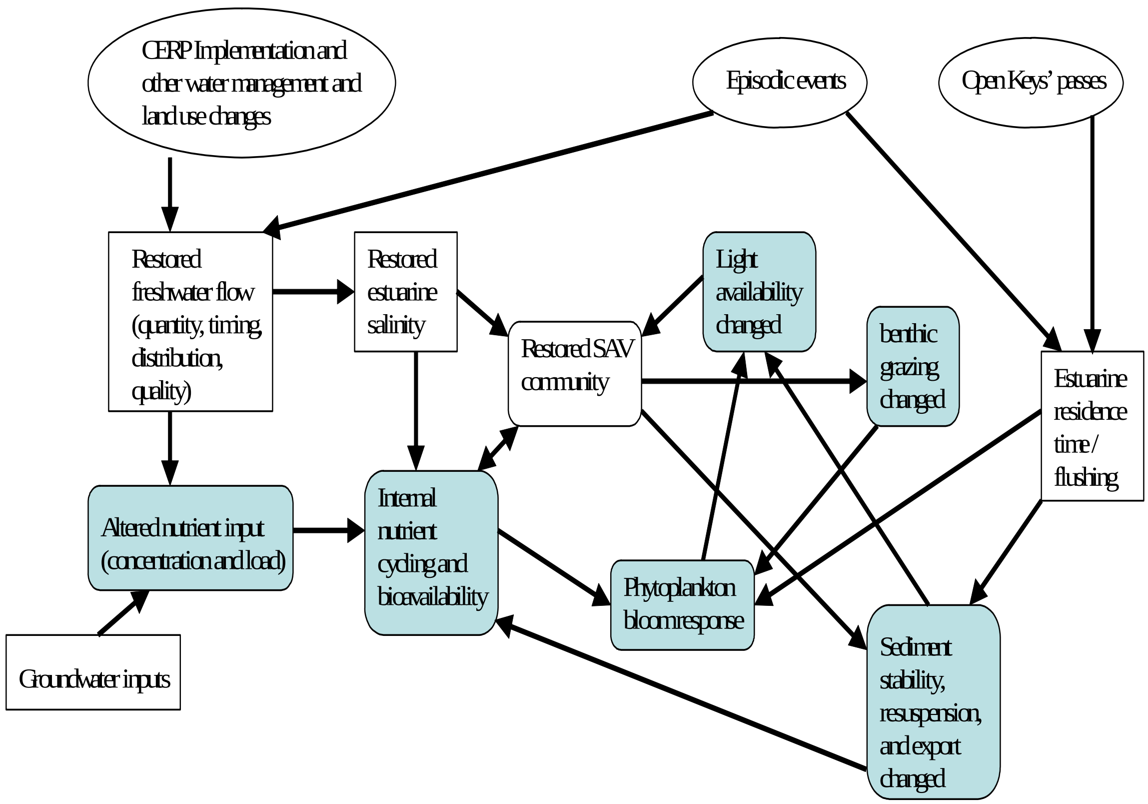

Figure 9-3-1: Water Quality Conceptual Ecological Model

9.3.4 Water Quality Hypotheses

- Through modifications of quantity, quality, timing and distribution of freshwater, CERP implementation will affect dissolved and particulate nutrients delivered to the estuaries and alter estuarine water quality. These modifications will affect primary production and food webs in estuaries. These modifications include:

  1) *changes in the distribution and timing* of nutrient inputs through increased flow via Shark River Slough and diversion of canal flows from 'point source' to more 'diffuse' delivery through coastal wetlands and creeks;

2) *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;

3) *changes in the* bioavailability of nutrients which depend on both the *quality* of nutrients (e.g., inorganic nutrients and DOM) from the watershed and internal estuary mechanisms (e.g., P limitation of DOM decomposition);

- Internal nutrient cycling rates (e.g., nitrogen fixation and denitrification) and biogeochemical processes, such as phosphate sorption, will change with CERP implementation because of salinity and benthic habitat changes.

- Nutrient accumulation and retention in estuaries is affected by episodic storm events, which can export nutrient rich sediments. CERP implementation will modify benthic habitats and nutrient loading which will affect this export.

- The spatial extent, duration, density, and composition of phytoplankton blooms are controlled by several factors that will be influenced by CERP. These include:

    1) external nutrient loading;
    2) internal nutrient cycling (seagrass productivity/die-off, sediment resuspension);
    3) light availability (e.g., modified by sediment resuspension and CDOM);
    4) water residence time; and
    5) biomass of grazers (e.g., zooplankton, benthic filter-feeders).

- Nutrients inputs from groundwater discharges may affect water quality in coastal wetlands and estuaries. CERP implementation will modify these discharges in the coastal zone which will alter nutrient loads to the estuaries.

9.3.5 Benthic Submerged Aquatic Vegetation Conceptual Ecological Model

Seagrasses, along with attached and drifting macro algae and *Chara* (in the coastal lakes inland from Florida Bay), comprise most of the benthic submerged aquatic vegetation (SAV) within the Southern Estuaries region. Seagrasses are the dominant biological community in South Florida coastal waters (Fourqurean *et al.* 2002), including Florida Bay (Zieman *et al.* 1989, Fourqurean and Robblee 1999, Durako *et al.* 2002) and Biscayne Bay. Seagrasses form a highly productive ecosystem that is the basis of the food web and provides habitat for most recreationally- and commercially-important fisheries species in the SEM region (Zieman 1982, Thayer *et al.* 1999). Seagrasses also have a major effect on water quality and clarity through nutrient uptake and storage and by increasing sedimentation and sediment stabilization via their physical structure (Prager and Halley 1999).

The catastrophic die-off of seagrasses, primarily *Thalassia testudinum*, in the late 1980's was accompanied by a cascade of ecological changes, including widspread and persistent phytoplankton blooms, increased turbidity, and dramatic faunal changes (Butler et al. 1995, Philips and Badylak 1996, Matheson et al. 1999, Prager and Halley 1999). The cause of the widespread die-off is not known, but is thought to have been related to changes in salinity, nutrient availability, sulfide toxicity, and disease (Robblee et al 1991, Carlson et al 1994, Durako and Kuss 1994, Rudnick et al 1999). Recent evidence suggests that one mechanism of *Thalassia* short-shoot mortality is the result of internal oxygen stress and sulfide toxicity (Borum et al. 2004), but how these are related to growth conditions or if this is the proximal cause of the initial die-off are still unknown.

Because of their benthic habit and persistence, seagrasses and macro-algae integrate and respond to changes in water quality. Thus, benthic SAV distribution and abundance are valuable ecological indicators of the "health" of the SEM region. In Florida Bay, the state of the seagrass communities is being used as a success criterion for CERP implementation. By altering the volume, timing, and spatial distribution of freshwater inflow, one goal of CERP is to restore and maintain the estuarine character of Florida Bay and in turn to produce a more diverse and sustainable seagrass community.

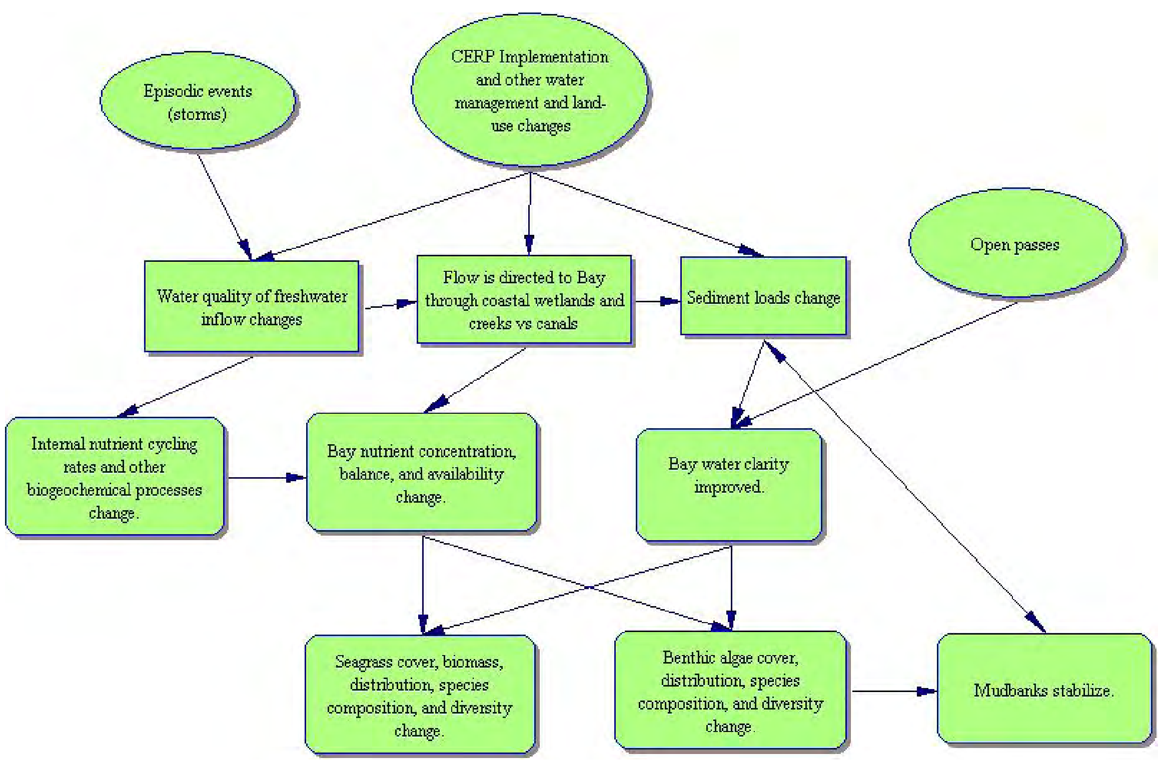

Figure 9-3-2: SAV Conceptual Ecological Model

9.3.6 Benthic Submerged Aquatic Vegetation Hypotheses

- Changes in both salinity and water quality resulting from CERP implementation are expected to result in changes in seagrass cover, biomass, distribution, species composition and diversity though the combined and interrelated effects of light penetration, epiphyte load, nutrient availability, salinity, hypoxia/anoxia, sulfide toxicity, and disease.

- Changes related to CERP implementation will include an expansion of areas with *Halodule* and *Ruppia* cover and a reduction in areas of *Thalassia* monoculture along the northern third of Florida Bay. Based on forecasted changes in hydrology, seagrass density and species composition in the southern two thirds of Florida Bay are not expected to change.

- Changes in both salinity and water quality resulting from CERP implementation are expected to change benthic algae 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 .

- Significant changes in benthic algae and seagrass distribution and density can affect susceptibility to sediment resuspension and the stability of mudbanks as well as nutrient availability to other primary producers.

9.3.7 Nearshore Nursery Function Conceptual Ecological Model

Estuaries provide critical nursery habitat for many species of fish and macroinvertebrates, many of which are spawned offshore. Some, such as pink shrimp, are harvested primarily in offshore fisheries, although inshore live bait fisheries target juveniles in Biscayne Bay. Shoreline and bottom configuration, vegetation, and salinity patterns are characteristics that define nursery habitat and determine their productive capacity, thereby the abundance of favored species. The fundamental assumption of CERP is that the alteration of volume, timing, and spatial distribution of freshwater inflow that occurred with past water management practices has decreased the productive capacity of estuarine nursery grounds by altering both bottom and shoreline vegetation and salinity patterns and the area over which favorable zones of bottom vegetation and salinity overlap. One purpose of CERP is to expand, in both space and time, favorable conditions for the estuarine species that were historically characteristic of the coastal wetland and nearshore zone. This includes oysters, red drum, pink shrimp, spotted seatrout, and species of snappers and grunts that use this habitat at various life stages. Increased availability of complex mangrove-shoreline and seagrass habitat (including a wider representation of seagrass species, e.g., *Ruppia* and *Halodule*, as well as *Thalassia*) and a broadened salinity gradient will increase the diversity of fish and macroinvertebrates that will be accommodated. Complex habitats increase productive capacity by reducing predation, providing a wider variety and abundance of food organisms, reducing physical disturbance, and providing substrates for attachment. The formulation and monitoring of performance measures that adequately reflect nursery function are essential elements of the CERP monitoring program.

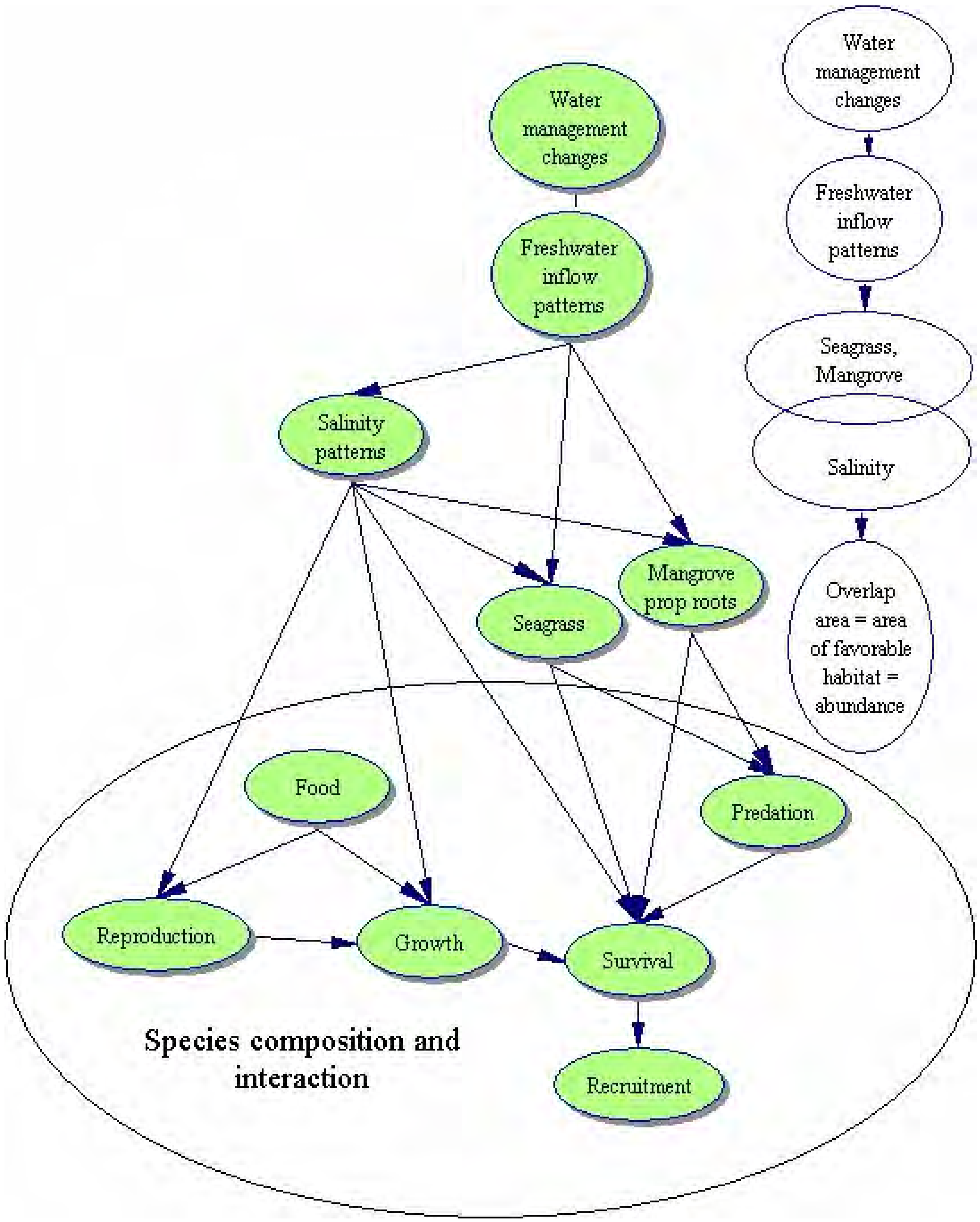

Figure 9-3-3: Nearshore Nursery Function Conceptual Ecological Model

9.3.8 Nearshore Nursery Function Hypotheses

Hypothesis 1
The implementation of CERP will affect the life cycle and abundance of fishery species not only through habitat dependencies (e.g., regarding food availability and shelter) but also through the direct physiological effects of salinity upon growth and survival.

***Rationale*:** Species abundance and recruitment to adult populations is a function of the area of overlap of favorable habitat and favorable salinities for each species. Maintaining a discernable spatial salinity gradient with persistent salinities in the lower range will result in an expansion of the area of optimal nursery habitat for estuarine dependent species and this, in turn, will increase the overall abundance (density x area) of invertebrate and vertebrate species, including pink shrimp, pinfish, rainwater killifish, mojarras, gray snapper, and spotted seatrout.

Hypothesis 2
Responses to change in both biotic (vegetation structure and cover) and abiotic (salinity pattern) aspects of habitat may vary.

***Rationale*:** Responses may vary by life stage because habitat use and salinity requirements often differ depending on life stage. Responses vary by species both because of different salinity tolerances and because of life-history differences that affect requirements and when required conditions are needed. Responses may be stepwise for some species/stages versus continuous for others because of physiological or behavioral influences.

Hypothesis 3
There is a direct quantitative relationship between the abundance of small juvenile pink shrimp in Biscayne Bay and Florida Bay and catch per unit effort of larger juveniles and adult pink shrimp in fisheries.

***Rationale*:** Small juvenile pink shrimp become recruits to the fisheries.

Hypothesis 4
The annual production of small prey fish in nearshore shallow water habitat, as determined by salinity patterns and other factors affected by freshwater inflow, will be reflected in annual production rates of their consumers in the mangrove prop-root habitat of coastal creeks and shorelines (e.g., gray snapper and other species).

Rationale: The fish that shelter in mangrove prop-root habitat of coastal creeks and shorelines are thought to forage in grassbeds; therefore the abundance of small prey species in nearshore flats may be reflected in the growth rates of the consumers.

Hypothesis 5
Redistribution of flow from canals to coastal creeks and a reliable supply of fresh water to the creeks during the dry season will increase the epifaunal abundance and substrate coverage (percent available). Species composition will include oysters and their associates.

***Rationale*:** A change in the spatial and temporal distribution of freshwater inflow will result in changes in the abundance, substrate coverage, and species composition of epifauna on mangrove prop-roots.

9.3.9 Nearshore Community Structure Conceptual Ecological Model

Many of South Florida's estuarine habitats have been diminished or eliminated by past and current water management practices. Waters that are consistently of intermediate salinity (e.g., 5-20 psu) tend to support highly productive, but relatively low diversity, plant and animal communities. In many nearshore areas of Biscayne and Florida Bays, freshwater flow is so variable that downstream salinity regimes are suboptimal for freshwater, brackish and marine organisms alike. Among the objectives of the CERP is to restore the function of the coastal creeks that once supplied diffuse, but consistent, freshwater flow to southern Biscayne Bay. The restoration of a more natural freshwater delivery regime and associated salinity patterns would be accomplished by diverting a portion of the surface flow carried to the bay area by canals. An understanding the interaction of salinity pattern and habitat with the species composition, diversity and abundance of the nearshore fish, invertebrate and seagrasss communities is critically needed to develop appropriate performance measures.

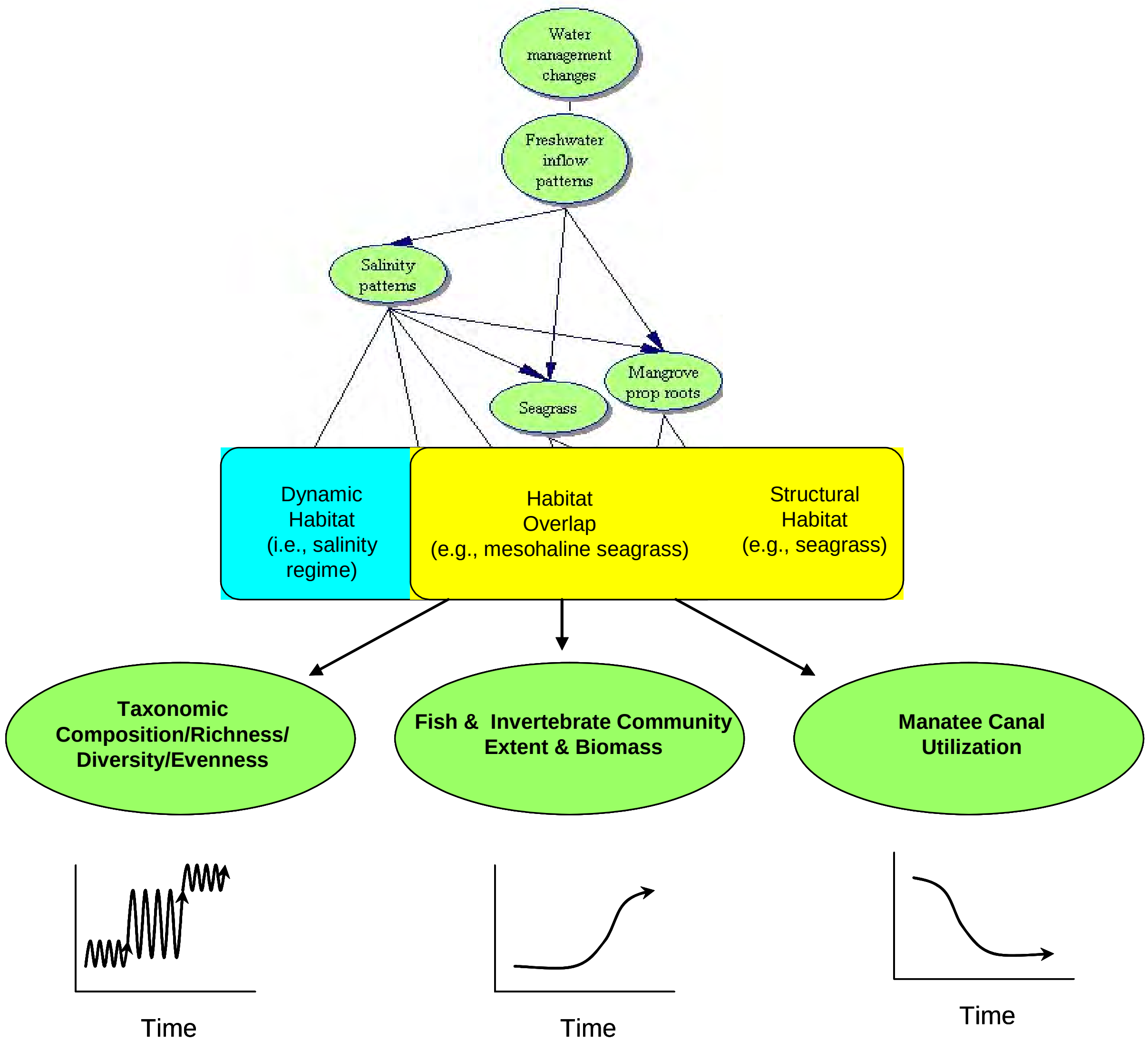

Figure 9-3-4: Nearshore Community Structure Conceptual Ecological Model

9.3.10 Nearshore Community Structure Hypotheses

Hypothesis 1

Shoreline and nearshore benthic communities are directly impacted by (and to some degree reflect) the volume, timing and variation in freshwater inflow, salinity patterns, and the range and rapidity of salinity fluctuation.

Rationale: Even estuarine species are more abundant somewhere within the full salinity range found in south Florida estuaries (i.e., 0-70 psu), rather than across the entire range. Few estuarine species can tolerate rapid high amplitude fluctuations in salinity.

Hypothesis 2
Reestablishing a persistent nearshore positive salinity gradient will increase the optimal habitat and abundance of estuarine fishes, oysters and other species.

Rationale**:** Estuarine species presently are limited by the lack of a persistent positive salinity gradient in both Biscayne Bay and Florida Bay.

Hypothesis 3
CERP implementation will lead to an expanded community of estuarine species and new estuarine habitat will be created (e.g., oyster beds).

Rationale**:** Plant and animal diversity will increase as more natural freshwater flows, and salinity regimes, are restored.

Hypothesis 4
Oyster populations will increase when fresh water destined for estuaries is routed through new/restored coastal marshes, which will reduce sediment loads and areas with soft, unconsolidated substrate.

Rationale**:** High sediment loads and benthic "muck" accumulation can deleteriously affect oyster recruitment, growth and survival. Reducing the loads will improve oyster spat recruitment and oyster growth.

Hypothesis 5
Changes in timing, location and volume of freshwater inflow will affect manatee distribution and manatee use of canal habitat, which will in turn affect their susceptibility to mortality from motorboats and water control gates.

Rationale**:** Manatees are attracted to freshwater sources. Presently the sources are the canals. When freshwater creeks provide a more continuous source of fresh water, the manatees will orient toward the creek mouths and away from the canals.

9.3.11 Toxins and Contaminants

Because contaminants are conveyed to the estuaries through surface and ground-water flux, changes in distribution or sources of freshwater or ground-water stages may affect the fate, amount, and pattern of toxicants and other contaminants introduced to bay waters sediments and biological resources which will in turn affect estuarine organisms, populations, and communities as follows: Accumulated toxicants and other contaminants will eventually cause stress in organisms. Stress would initially be expressed biochemically as changes in osmoregulation, clinical hematology, immunology, and histopathology, etc. Biochemical and physiological changes could lead to adverse effects on survival, growth, development and reproduction. The level of stress created by divalent metals would depend upon their bioavailability, a function of partition coefficients and factors influencing equilibrium (e.g., redox potential); Organismal affects can affect populations and population changes in turn can result in community shifts.

9.3.12 Status of Toxins/Contaminants MAP Monitoring

Revised MAP Monitoring Components:

Monitoring Components	MAP Section	STATUS
Sediment Contaminants		Proposed; no funding source.
Contaminant Loading		Proposed

Existing MAP Key Uncertainties and Supporting Research

Monitoring Components	MAP Section	STATUS
Causal Factors of Fish Abnormalities in Biscayne Bay	3.2.4.8	No funding
Bottlenose Dolphin Health Assessment in Biscayne Bay Mercury Module	3.2.4.9	Funding uncertain and inadequate at present

Revised MAP Key Uncertainties and Supporting Research

Monitoring Components	MAP Section	STATUS
Risk assessment for Biscayne Bay		Proposed

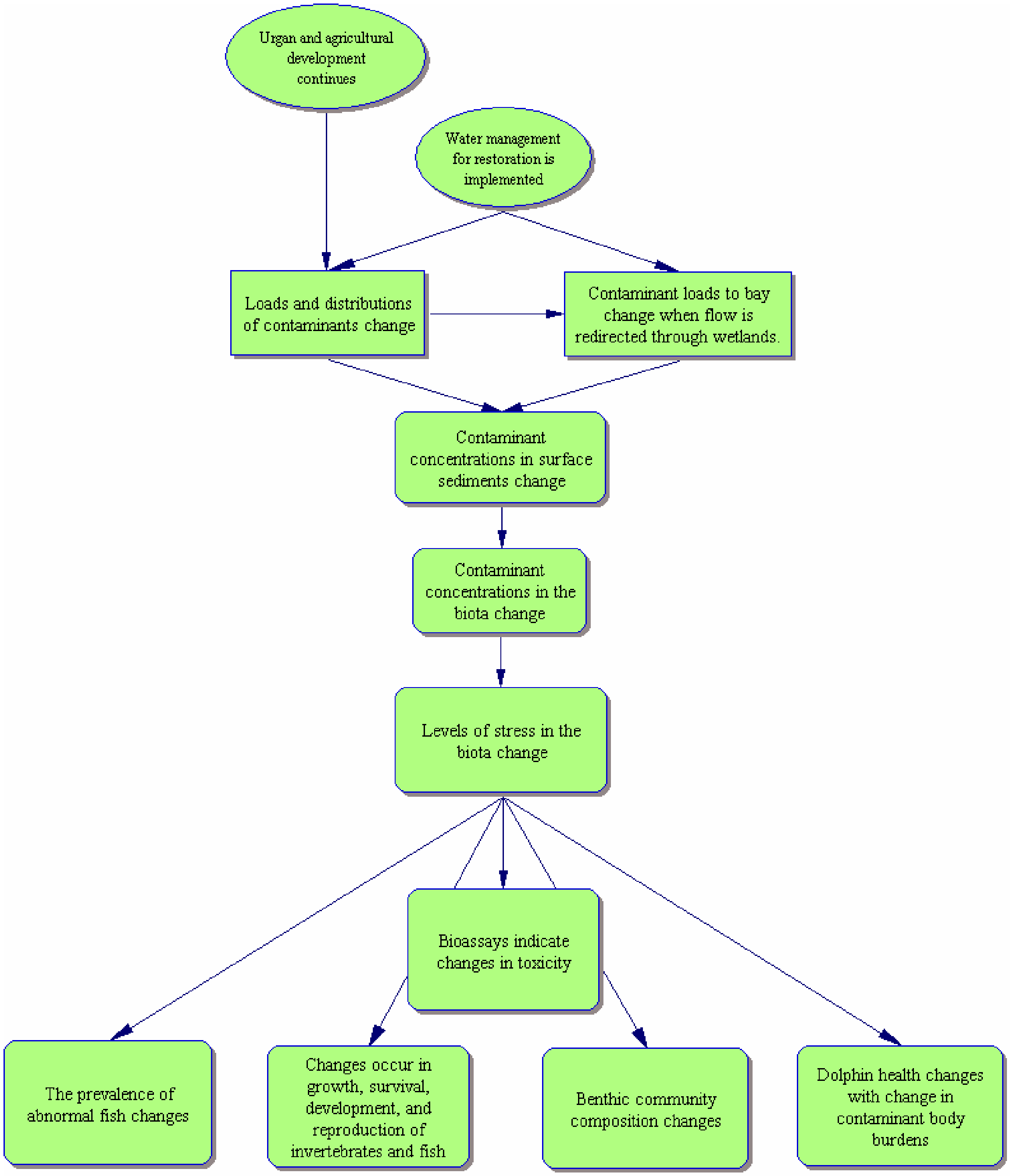

Figure: 9-3-5: Hypothesis Flow Chart for Toxins and Contaminants in the SE

9.3.13 Toxins and Contaminants Hypotheses

- CERP is going to change the quantity, timing and distribution of in flow to the southern estuaries and the source of this freshwater is expected to include waste water reuse and both urban and agriculture runoff, which may increase the contaminant load to the estuaries.
- Water will be routed through areas undergoing rapid urban development and redevelopment which will may also increase contaminant loads
- Contaminant loads to the bays will also be affected by the planned rerouting of water through coastal wetlands. Coastal wetland soils and vegetation may take up and retain organic contaminants and heavy metals, reducing loads to the bays and associated contaminant concentrations in surface sediments.
- With the increased input loading sediment concentrations and associated sediment toxicity, as indicated in bioassays (.e.g., clam bioassays), is expected to change.
- Organic contaminant and heavy metal burdens in the biota will change over time reflecting changes in contaminant loading and concentrations in surface sediments.
    - Body burdens and biochemicals in sentinel organisms with limited mobility (e.g., mollusks) will reflect sediment chemical concentrations, and biological effects, if occurring, will be indicated by biochemical markers.
- Increasing body burdens will eventually result in increased stress upon the organisms
- This stress will be reflected in the following changes in monitored parameters:
    - Benthic community composition (i.e., of burrowing, infaunal, epibenthic species) will change in response to changes in sediment contamination.
    - Filter feeders (e.g., oysters) and organisms in the water column (e.g., zooplankton, fish, shrimp) will be affected (survival, growth, etc.) by resuspension of contaminants from sediment.
    - The prevalence of fish with morphological abnormalities will change in response to changes in sediment toxicants and other contaminants.
    - The health of the resident bottlenose dolphin population will change in response to exposure, as reflected by changes in body burdens, and body burdens will reflect sediment concentrations of heavy metals and organic contaminants.