REPORT

of the Independent Panel Concerning

PRIORITIZING SCIENCE GAPS IN THE
South Florida Ecosystem Restoration Task Force
Plan for Coordinating Science

Review Panel:
Jeffrey L. Jordan, Chair, University of Georgia
Joanna Burger, Rutgers University
JoAnn Burkholder, North Carolina State University
Robert Ward, Colorado State University
Donald Kent, Environmental Consultant

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EXECUTIVE SUMMARY
Of the Independent Panel Concerning
Prioritizing Gaps and Actions
Plan for Coordinating Science
Submitted January, 2008

The responsibility of the independent panel was to read and review the *Plan for Coordinating Science (PCS,* final draft October 30, 2006) and to develop a method to review the gaps in the *PCS* in order to establish a more refined understanding of the prioritization of these science gaps. The panel was then asked to use the proposed method and prioritize the gaps as established in the *PCS* and present these recommendations to the Task Force.

We began using the overall goals as stated in the Task Force report. These three goals of restoration of the South Florida ecosystem include:

Goal 1: Get the Water Right: both hydrology and water quality.
Goal 2: Restore, Preserve, and Protect natural habitats and species.
Goal 3: Foster Compatibility of the built and natural systems: Land management, flood protection, sufficient water.

The panel sought to find measures that can be used as targets to determine progress to meet these three goals of overall restoration. The panel agreed to identify science gaps based on theTask Force system-wide indicators.

- see *Indicators for Restoration: South Florida Ecosystem Restoration*: http://www.sfrestore.org/scg/documents/index.html

The indicators selected were based on a need to inform policy makers and the public about the status of restoration progress/success within the South Florida ecosystem.

The panel's first step was to select which task force system-wide indicators to use in prioritizing science gaps for the four regional modules as well as the overall system. In doing so, we considered the sequential nature involved in the gaps (what sub-region needs work first? what do we need to know first to get at something else?).

For each water system, our report lists and defines the task force system-wide indicators used to prioritize each gap. Also included is a rationale as to why the task force system-wide indicator would be useful in prioritizing gaps, along with performance measures and information needs. The bulk of this report represents the consensus prioritization of science gaps for each system.

INTRODUCTION

In May 2007, members of the South Florida Ecosystem Restoration Task Force approved a three-step approach for completing the draft *Plan for Coordinating Science.*

The first step involved requesting a panel of independent experts to ascertain a method of further prioritizing science gaps in the current draft plan and then for the panel to use that method to prioritize the gaps for the Task Force.

The responsibility of the independent panel was to read and review the *Plan for Coordinating Science (PCS,* final draft October 30, 2006) and to develop a method to review the gaps in the *PCS* in order to establish a more refined understanding of the prioritization of these science gaps. The panel was then asked to use this proposed method and prioritize the gaps as established in the *PCS* and present these recommendations to the Task Force.

After reviewing the *PCS*, the panel noted that it is difficult to prioritize science gaps without clearly stating the goals or targets of the restoration process. While goals are implicit in the needs, gaps, and tasks that have been identified by previous expert panels, explicit goals would enhance the confidence in the outcome of our process. The report itself notes this "lack of clear, updated characterizations or definitions of restoration success, which is required for establishing effective and attainable restoration goals and prioritizing restoration activities." Thus the panel thinks that clear definitions or targets for restorations success need to be developed first.

Prioritization Method

Given the above, the panel considered methods that could be used to prioritize the science gaps facing the Task Force. We began using the overall goals as stated in the Task Force report for restoration of the South Florida ecosystem:

Goal 1: Get the Water Right: both hydrology and water quality.
Goal 2: Restore, Preserve, and Protect natural habitats and species.
Goal 3: Foster Compatibility of the built and natural systems: Land management, flood protection, sufficient water.

The panel sought to find measures that can be used as targets to measure progress to meet these three goals of overall restoration. The panel agreed to prioritize science gaps based on the task force system-wide indicators as developed using the Conceptual Ecological Models as one of the selection guides (see Wetlands special issue 2004, and as detailed in the *Science Plan* and related documents). The indicators selected were based on a need to inform policy makers and the public about the status of restoration progress/success within the South Florida ecosystem.

The panel's first step was to select which task force system-wide indicators to use in prioritizing science gaps for the four regional modules as well as the overall system. In doing so, we considered the sequential nature involved in the gaps (what sub-region needs work first? what do we need to know first to get at something else?). The indicator assignment below is based on the September 5, 2006 draft report entitled: *Indicators for Restoration: South Florida Ecosystem*

Restoration, authored by the Science Coordination Group of the South Florida Ecosystem Restoration Task Force. This report provides consistency of information about the indicators across all of South Florida that permits comparable assignment.

Table 5 in that report lists 13 "system-wide" indicators for 2006. The descriptions of each indicator explain that some indicators are more relevant to particular modules (physiographic regions across South Florida) than others. The science gaps listed in the report appear to be based on sound thinking in the regional context, likewise for the "total system".

Indicators Approach by System

For each of the regions, as well as the total system, the panel used the following task force system-wide indicators to prioritize science gaps:

Total System

Water volume
Wading birds (white ibis, wood stork)
Invasive exotic plants
Fish and crustacean macroinvertebrates
Periphyton

Lake Okeechobee

Water volume
Lake Okeechobee littoral zone
Wading birds (white ibis, wood stork)
Invasive exotic plants
Crocodilians
Periphyton

Northern Estuaries

Water volume
Wading birds (white ibis, wood stork)
Fish and crustacean macroinvertebrates
Invasive exotic plants
Eastern oyster (sometimes called American oyster)
Crocodilians (especially Loxahatchee)
Periphyton

Greater Everglades Wetlands

Water volume
Wading birds (white ibis, wood stork)
Invasive exotic plants

Fish and crustacean macroinvertebrates
Crocodilians
Periphyton

Southern Estuaries

Water volume
Biscayne Aquifer saltwater intrusion (SE parts of Dade and eastern Broward Counties)
Wading birds (white ibis, wood stork)
Fish and crustacean macroinvertebrates
Pink shrimp
Wading birds (roseate spoonbill)
Florida Bay SAV
Florida Bay algal blooms
Periphyton
Crocodilians

For each of the indicators above, the following is the rationale for their use in the prioritization process. When an indicator does not apply to a module it may be for several reasons (e.g. there is no monitoring program for the indicator for a particular region or module, or the indicator does not naturally occur in the module)

Water Volume

Definition – Water volume is the quantity of water in three-dimensional space that is contained within, delivered to, or removed from (via export, pumping, evapotranspiration, seepage and other processes) a given ecosystem.

Useful as targets in prioritizing gaps because management of water supplies is central to the Comprehensive Everglades Restoration Plan (CERP) and water volume is an essential integrative indicator. The water volume indicator can be effectively communicated to the general citizenry using a line chart of total water volume over time with a goal volume overlay. This line chart could also incorporate acceptable timing of water volume delivery and export.

Performance measures

- Achievement of desired volumes, flows, depths and timing expressed as percent shortfall per month of the wet and dry seasons. This indicator measures what is referred to in CERP as "new water" defined as being additional water made available through implementation of CERP projects that is greater than the water that was available in the 1995 base year level.
- Salinity.

Information needs–

- Continue model refinement to improve prediction of water volume/timing and flood control.

- Assess present and potential impacts from the sea level rise and severe events (major storms, droughts) related to global warming.
- Develop water quality-related PMs for water volume in addition to salinity.
- For coastal ecosystems, the Kissimmee Chain of Lakes (KCOL), and Lake Okeechobee, assess water volume-controlled N and P loading, and the importance of the timing of delivery of these pollutants.

Wading Birds

Definition - Wading birds are ideal indicators because they integrate over time and space, and are top predators in the system. Wading birds can be defined two ways, both as a group of species (overall wading bird health), and as individual target species (white ibis *Eudocimus albus* L. and wood stork, *Mycteria americana* L). The latter is the most useful for annual work because it limits the species examined, and includes the federally endangered wood stork. They belong in each module because they occur throughout the region, and because they can move between the systems, both within and among years, providing a trend for the health of each system as well as the whole system.

Useful as targets in prioritizing gaps because they are the top-level avian predators within the system, integrate over time and space, and affect the food chain at many different levels. Wading birds are ideal indicators because they integrate over time and space, and are top predators in the system. They are diurnal, conspicuous, and breed in colonies making it possible to track their numbers, especially during the breeding season, and their white plumage makes them obvious from the ground or air while foraging as well. Further, their use can be integrated with mercury as a bioindicator because there are different life stages, which provide different kinds of information. Levels in adults represent exposure over a longer temporal and spatial extent, while levels in young represent very local exposure since the young receive all their food from their parents who gather it relatively close to the nesting colony. They are easy to use by relatively untrained personnel. They are of interest to the public, and there is a long-term data set on their use (allowing for an understanding of changes of the health of the system).

Performance measures - Abundance and distribution of both individual species and as a group (herons, egrets and spoonbill as well as wood stork and white ibis). The level of effort should be similar among modules because part of their strength is in their use as a cross-system indicator of the overall health of the South Florida ecosystem.

Information needs –

- Determine the factors that affect reproductive success and population dynamics of wading birds, as well as the relationship between water levels, food, and wading birds (this will contribute to our overall understanding of ecosystem processes that are generalizable across the system).
- Assess population size and reproductive success of the other species of egrets and herons.

Invasive Plants

Definition – Invasive exotic plants are those species that are not native to the south Florida system, establish and spread in natural areas replacing or harming either the structure or function of natural areas in the Everglades.

Useful as targets in prioritizing gaps because invasive plants are a serious threat to all South Florida ecosystems, and are causing significant ecological harm to natural ecosystems. They are considered as drivers (stressors) in the RECOVER conceptual ecological models. Trends in the spread and density of invasive plants are important to assessment of restoration success.

Performance measures – Presence-absence of selected key species. The ideal specific goal for invasive exotic plants should be zero; the pragmatic goal should be quantified and explained. There is scientific consensus that restoration success must not include replacement of Everglades flora by invasive plants; without control and management of invasive species, restoration efforts may well fail, since these species can cause great damage to natural environments.

*Information need*s–

- Develop improved, standardized techniques for detection and assessment of invasive plant species.
- Conduct research about their basic biology to strengthen control strategies, and (for newly discovered invasive species) to assess the risk for invasive potential.

Fish and Crustacean Macroinvertebrates

Definition–Fish are defined as native fishes such as eastern mosquitofish, bluefin killifish, sheepshead minnows, and sailfin molly. Crustaceans include slough and Everglades crayfish and riverine grass shrimp.

Useful as targets in prioritizing gaps because fish and crustacean macroinvertebrates are critical in the food web as primary and secondary consumers, and as prey for focal Everglades predators such as wading birds.

Performance measures-Density and community composition of a suite of native fishes and crustaceans to describe trends in populations related to hydrology. Fish and crustacean density and community composition are correlated with hydrological conditions (e.g., depth, duration, timing, and spatial extent), water quality, and salinity (Northern and Southern Estuaries).

Information needs–

- Determine how Lake Okeechobee water management activities and lake stages are linked to the quality and abundance of fish foraging and spawning habitat.
- To understand and characterize the current and historical spatial distribution, condition, and ecological relationships of Northern Estuaries fish.
- To understand how changes in water quality and salinity associated with restoration activities and natural events affect Northern Estuaries fish.
- To understand how restoration activities that influence the transport, biogeochemical cycling, and fate of contaminants affect Northern Estuaries fish.

- To understand how changes in hydropatterns and associated stressors relate to Northern Estuaries fish abnormalities.
- To understand and determine how fish and crustaceans of the Greater Everglades are affected by and interact with biogeochemical cycles.
- To understand and determine how the hydrology and primary production in the Greater Everglades ecosystem affect fish and crustaceans.
- To understand and predict the relationship between salinity and the distribution and productivity of pink shrimp and key fishes in the Southern Estuaries.
- To develop baseline biological information on crustaceans and fishes along the Southwest Florida coast and inside Whitewater Bay.
- To understand and predict the effects of water management and restoration activities on fish and crustaceans throughout the Total System.
- Long-term comprehensive monitoring is needed to assess status and trends, and support adaptive management, of fish and crustaceans throughout the Total System.
- To understand how habitat fragmentation and loss of spatial extent affect fish and crustaceans throughout the Total System.

Periphyton

Definition-Periphyton assemblages are benthic microalgal/bacterial biofilms.

Useful as targets in prioritizing gaps because periphyton assemblage are ubiquitous throughout the Everglades wetlands, streams, rivers, lakes and estuaries, and they respond to changes in hydrologic conditions and water quality. Periphyton are important as a food source and a refuge for aquatic invertebrates, which in turn are consumed by small fish, crayfish, and grass shrimp. Periphyton can also influence soil quality, secondary production, nutrient concentration, and dissolved gasses.

Performance measures–Restoration success will be evaluated by comparing recent and future trends and status of the periphyton communities (biomass, species composition) with historical paleoecological data and model predictions.

Information needs–

- To understand and determine how periphyton of the Greater Everglades are affected by and interact with biogeochemical cycles.
- To understand and predict the effects of water management and restoration activities on periphyton throughout the Total System.
- Long-term comprehensive monitoring is needed to assess status and trends, and support adaptive management, of periphyton throughout the Total System.
- To understand how habitat fragmentation and loss of spatial extent affect periphyton throughout the Total System.

The Littoral Zone

Definition – The littoral zone is the area of an aquatic ecosystem with sufficient light to support the growth of rooted aquatic angiosperms.

Useful as targets in prioritizing gaps because the littoral zone is an important component of Lake Okeechobee and the Kissimmee Chain of Lakes (KCOL), and an easily understandable indicator of lake condition that integrates hydrology, water quality, and exotic species. The littoral zone area provides critical nesting habitat and food resources for economically important fauna, and strongly influences lake water quality. The aquatic vegetation is, in turn, influenced by hydroperiods, nutrients, and water clarity. This indicator is integrative across trophic levels, and responds to changing environmental conditions at a scale that makes it applicable to large portions of the lake ecosystems.

Performance measures – Species-specific plant cover of emergent and submersed aquatic rooted plants. CERP Monitoring and Assessment Program (MAP) performance measures thus far include Lake Okeechobee native vegetation mosaic as littoral plant communities and bulrush, and submersed aquatic vegetation.

Information needs –

- Track species-specific plant cover in the KCOL as well as Lake Okeechobee.
- Develop food web models for the major rooted plant communities in Lake Okeechobee. Examine whether hydroperiods influences water lily expansion.
- Identify the yearly range of water levels ("lake stage window") needed to support healthy bulrush populations and SAV in Lake Okeechobee, and healthy littoral zone plant populations in the KCOL.
- Modify the existing model of Lake Okeechobee for fine-spatial-scale prediction of SAV cover under different lake stage management strategies.

Crocodilians

Definition –Crocodilians include American alligators (*Alligator mississippiensis* Daudin) and American crocodiles (*Crocodylus acutus* Cuvier).

Useful as targets in prioritizing gaps because crocodilians are top predators, thus critical in the food web. The American alligator is a keystone species that occurs in Lake Okeechobee, the Northern Estuaries, and the Greater Everglades Wetlands. The American crocodile is an endangered species that occurs in the Southern Estuaries. Crocodilians integrate biological impacts of hydrological operations both directly and indirectly through prey availability, nesting, trails, holes, and in estuaries, the timing, amount, and location of freshwater flow. Alligator and crocodile parameters correlate with hydrologic conditions (e.g., depth, duration, timing, and spatial extent), water quality, and salinity.

Performance measures–

- American alligator:
    - Relative density (encounter rate)
    - Body condition
    - Nesting effort and success
    - Occupancy rates of alligator holes to describe population trends relative to hydrology.
- Crocodile indicator
    - Relative density
    - Growth
    - Survival to describe population trends relative to hydrology.

Information needs–

- To understand and predict the effects of water management and restoration activities on crocodilians throughout the Total System.
- Long-term comprehensive monitoring is needed to assess status and trends, and support adaptive management, of crocodilians throughout the Total System.
- To understand how habitat fragmentation and loss of spatial extent affect crocodilians throughout the Total System.

Eastern Oysters

Definition – The eastern oyster (*Crassostrea virginica* Gmelin) is a bivalve mollusc macroinvertebrate found in brackish and marine waters.

Useful as targets in prioritizing gaps because abundant eastern oysters in the northern and southern estuaries are an economically important fishery, and provide valuable habitat for various other desirable fauna. Through their filtering activity, they can reduce algal blooms and improve water clarity. In addition, since salinity is a major factor controlling their distribution and abundance, eastern oysters are a reasonable scientific indicator of CERP efforts to restore hydrology and water quality. Eastern oysters are also sensitive to excess suspended solids, pesticides and other toxic substances. The response of eastern oysters to changing environmental conditions make them relevant to all of the estuarine areas affected by the Everglades Ecosystem. Oysters are linked to water volume, water quality, phytoplankton production, and sedimentation, and also influence the success of fish and bird populations.

Performance measures – Oyster survival, distribution, and abundance as reflected by reef cover and the number of live oysters per unit area. Performance measures should also include assessment of oyster disease, and measurement of suspended sediment concentrations and bottom-water dissolved oxygen concentrations near oyster reefs. In the Caloosahatchee, Loxahatchee, and St. Lucie Estuaries eastern oysters have been identified as a valued ecosystem component. They should be similarly identified in the other coastal estuaries and Florida Bay, and specific goals should be defined for each ecosystem.

Information needs–

- Develop antibody-based techniques to aid in assessment of reproductive stage/potential, and maps of oyster occurrence, density, and health.
- Using a consistent approach, obtain time series data on oyster performance measures in all of the southern estuaries.
- Complete the development of a habitat suitability index model in the Caloosahatchee Estuary
- Extend this model, and this indicator, for use in the other Coastal Ecosystems.

Biscayne Aquifer Saltwater Intrusion

Definition–The Biscayne Aquifer is a prolific, sole-source aquifer in southeastern Florida. It is the most transmissive of three separate aquifers that comprise the surficial aquifer system.

Useful as a target in prioritizing gaps because the Biscayne Aquifer is the primary water supply for the Lower East Coast Service Area, and provides base flow to the Southern Estuaries during low rainfall years. Adequate water supplies for current and future users require protecting the primary water supply source. Saltwater intrusion poses a continuing threat to the aquifer. A sufficient freshwater head must be consistently maintained, which is aided by coastal water control structures. This indicator is useful in the southeastern parts of Dade County and eastern Broward County.

Performance measures - Two metrics are used to measure the likelihood of saltwater intrusion.

- Two feet of head is sufficient to protect the 80- foot thick Biscayne Aquifer.
    - The stage where the frequency of exceedences is 90% is used since it reflects lower stage of the dry season when the risk of saltwater intrusion is increased.
    - Stage when the frequency is exceeded 50 % of time, since it represents approximately the midpoint between the wet and dry seasons (i.e., average conditions for the 2000 base condition).

Information needs–

- To understand and predict the effects of water management and restoration activities on salinity and volume of the Biscayne Aquifer.
- Long-term comprehensive monitoring is needed to assess salinity and volume status and trends, and support adaptive management, of the Biscayne Aquifer.
- To understand and predict the effects that modification in land use management and development affect salinity and volume of the Biscayne Aquifer.
- To understand how habitat fragmentation and loss of spatial extent affect salinity and volume of the Biscayne Aquifer.

Pink Shrimp

Definition – Pink shrimp (*Farfantepenaeus duorarum* Burkenroad) is a crustacean macroinvertebrate in the family Pinaeidae. It is especially abundant in broad continental shelf areas, and in shallow bays and estuaries. Pink shrimp spawn on the southwest Florida shelf, migrate shoreward as larvae/post-larvae, and spend their juvenile stage in the Northern and

Southern Estuaries. Juvenile pink shrimp in Florida ecosystems range from 10 to 130 mm in total length.

Useful as targets in prioritizing gaps because pink shrimp are an economically important fishery, and are also important as a food source for fish and wading birds. They are a valuable indicator of hydrology and water quality (salinity) since pink shrimp productivity increases with increasing freshwater flow from the Everglades. They are also an indicator of Florida Bay productivity because the Bay and adjacent coastal areas are primary shrimp nursery grounds. The density of juvenile pink shrimp is related to salinity and temperature, and also influenced by seagrass habitat. Estuarine pink shrimp populations are strongly affected by water management practices, agricultural and urban development, and sea level rise. This indicator is relevant to the estuarine components of the Everglades Ecosystem; it responds to changing environmental conditions at a scale that makes it applicable to large portions of the ecosystem. Pink shrimp are an important food web link between benthic detritus and microalgae, and higher trophic levels such as fish and wading birds.

Performance measure – Shrimp density (April – October). Pink shrimp are included in the Southern Estuaries component of CERP MAP.

Information needs –

- Further quantify the relationship between salinity and spatial/temporal patterns of juvenile pink shrimp densities.
- Assess seasonal and inter-annual variability of pink shrimp in all of the coastal estuaries.
- Determine the influence of transport processes on pink shrimp recruitment.
- Extend this indicator to other Coastal Ecosystems.

Submersed Aquatic Vegetation

Definition – Submersed aquatic vegetation (SAV) in Florida Bay consists of seagrasses, which are aquatic flowering plants that grow in marine and (less so) brackish environments. Seagrass species are classified within a limited number of plant families, all within the super order Alismatiflorae.

Useful as targets in prioritizing gaps because the seagrass community is the structural and functional foundation of the Florida Bay ecosystem, and an excellent “end-of-the-pipe” indicator of efforts to restore Everglades hydrology. A conceptual ecological model of Florida Bay developed for RECOVER identifies the SAV community (structure and dynamics) as central to the health of the entire Florida Bay ecosystem. Seagrasses are highly productive, provide critical nursery and other habitat for higher trophic levels, strongly influence the physical and chemical dynamics of Florida Bay, strongly influence water quality via sediment stabilization and nutrient retention, and provide integrative information about changing water quality conditions.

Performance measures – Effective performance measures are species-specific cover and density. SAV metrics are important performance measures within RECOVER, the Florida Bay and

Florida Keys Feasibility Study, and most other environmental management projects and programs in the Florida Bay region.

Information needs–

- Evaluate whether aerial photography to assess SAV cover distribution can accurately detect mixed beds.
- Assess macroalgal cover and biomass, and track dominant species of epiphytes and macroalgae to provide important information about the role of salinity versus other water quality conditions in controlling Florida Bay SAV.
- Experimentally examine and quantify the importance of nutrient-salinity interactions in controlling SAV in Florida Bay to strengthen the reliability of modeled predictions about SAV dynamics.

Algal Blooms

Definition – Algal blooms are proliferations or overgrowths of algae that can be noxious or toxic.

Useful as targets in prioritizing gaps because algal blooms are an excellent integrator of bay water quality, and provide valuable information about bay health. Algal blooms are stimulated by nutrient (nitrogen, phosphorus) over-enrichment by external and internal sources. They can adversely affect beneficial seagrass meadows by reducing water clarity, and can contribute to hypoxia and other habitat degradation that is detrimental to desirable fauna such as fish and shrimp. Algal blooms have been a major feature of the Florida Bay ecosystem since the early 1990s, indicating a shift to a system where seagrass production is less dominant and less stable. They now cover large areas of the central and western bay for extended periods each year. The incidence and magnitude of algal blooms are sensitive to related to restoration and other human activities.

Performance measures –

- Chlorophyll *a* concentrations (acceptable threshold values have been established RECOVER and the Florida Bay and Florida Keys Feasibility Study).
- Bloom magnitude, frequency, and spatial extent.
- Performance measures should also consider the abundance of dominant phytoplankton species, and the abundance of potentially harmful species of macroalgae as well as phytoplankton, based on weekly to biweekly sampling during bloom events.

Information needs–

- Assess the forms, fates and effects of dissolved organic N and P inputs (as well as inorganic N and P) on phytoplankton abundance and species dominance, including external and internal nutrient inputs.
- Quantitatively evaluate the species-specific response of algal blooms to changing hydrology, water residence time, salinity, nutrient inputs, seagrass community cover and productivity, sediment stability, and grazer abundance.
- Extend this indicator to the other Coastal Ecosystems.

Prioritization of Science Gaps

For each of the regional systems, as well as the total system, the numbering is the panel's consensus on priority.

TOTAL SYSTEM GAPS

1. There is no planned effort to evaluate and update the current characterization or definition of restoration success, or to define restoration goals at the Total System scale to support the prioritization of restoration activities.

   This is a necessary precursor to the effective prioritization of all gaps for all modules as well as the total system.

2. Only four modules have had CEMs (and their sub-models) developed; all other eco-regions of the South Florida Ecosystem need CEMs.

   This is a necessary precursor to effective use of indicators for all of the modules that do not yet have CEMs.

3. The Natural System Model (NSM) does not simulate pre-drainage hydrology well in many locations and cannot be used at all in some locations; some NSM predictions are considered unrealistic based on other scientific expectations and evidence. The NSM does not adequately address the transition from wetlands to coastal areas, and requires better elevation data to create a more accurate representation of the natural system baseline.

   This is related to water volume. If the NSM is to be the basis for decisions, the model needs to be expanded, updated, and verified/validated.

4. Restoration planning and modeling do not account for anticipated changes in sea-level rise, rainfall, and tropical storm frequency and intensity for the coming decades.

   The completed NSM gap number 3, coupled with climate models, can be used to help address this gap.

5. There is a lack of biological risk assessment tools, including unified system-wide monitoring, biological control programs, and indicators, to predict species invasiveness and evaluate and prioritize management actions to support a comprehensive and unified management approach for invasive species.

   This is directly related to the invasive exotic plants indicator. These tools should include unified system-wide monitoring, biological control programs and indicators to enable a unified management approach for invasive species. This well also be used to address gap number 7.

6. The Comprehensive Integrated Water Quality Feasibility Study has not been completed (for both contaminants and nutrients) in the South Florida Ecosystem.

   This should be completed and linked to indicators. This gap underscores the need for development of toxic contaminant indicators (including performance measures) for each module and the total system.

7. The species-specific ecology, biology, reproduction, and biological impacts of exotic species invading the South Florida Ecosystem are not well understood, preventing effective management and control.

   This is directly related to the invasive exotic plants indicator. Key taxa of plants have been identified for some regional modules, and key taxa of both plants and animals should be developed as indicators of restoration success for the remaining modules as well as for the total ecosystem. The information used to address gap number 5 will be valuable in addressing this gap.

8. The current scope and schedule for the RECOVER MAP, including the monitoring is not funded by CERP but by the other Task Force member organizations, is not assured.

   This is not linked to indicators. This is not a science gap but, rather, a management/infrastructure gap that strongly controls the success or failure of the *Plan for Coordinating Science.*

9. Multiple models developed for particular regions of the South Florida Ecosystem are not coupled across the regions.

   This is not linked to indicators but deserves attention.

10. The Natural System Regional Simulation Model is several years from development and use.

    The link to indicators is not established. The relevance to the restoration schedule is not clear.

LAKE OKEECHOBEE GAPS

1. There is insufficient information regarding how restoration and water management activities particularly those related to extreme lake stages (high/low, duration, frequency and timing), affect the lake's communities, including submerged and emergent aquatic vegetation and associated fauna.

   This is related to all indicators, directly or indirectly. Hydrology is a major driving-force affecting this module and all indicators within it.

2. The resolution and detail of the bathymetric information available for Lake Okeechobee and its littoral zone are insufficient to assess the impacts of lake management and storms.

   This is required to evaluate how restoration and water management activities affect lake communities. It is related directly to water volume, littoral zone indicators and indirectly to wading birds, invasive plants, crocodilians, and periphyton. Resolution of the Lake bathymetry must go hand-in-hand with gap number 1.

3. There is insufficient information to evaluate the effects that lake management activities and storms will have on:

   - Re-suspension and movement of nutrient (and sediments).
   - Nitrogen dynamics under current conditions, and when phosphorus levels reach restoration goals.
   - Changes on the species composition of the submerged and emergent marsh community.

   The third bullet particularly is related to littoral zone and invasive plants indicators. The first two are poorly related to selected indicators and unlikely to be a major factor in the near term. Phosphorous (water and sediment) is unlikely to attain goals until decades in the future.

4. There is insufficient information to understand the linkage between the primary producers and the structure of the upper level trophic constituents, and the effects of water management on that linkage.

   This gap is indirectly related to wading birds and crocodilians.

5. There is insufficient information to understand if exotic species management activities are affecting non-target elements of the lake's ecosystem.

   This is related directly to invasive plants, and indirectly related to littoral zone, wading birds, crocodilians, and periphyton.

NORTHERN ESTUARIES GAPS

1. Mapping and fish monitoring programs that relate fish and other aquatic fauna habitats to high-resolution bathymetry and bottom classification of the Northern Estuaries are not available.

   This fundamental information is needed as a foundation before other gaps can be soundly addressed. High-resolution bathymetry and bottom classification maps are needed to address all of the indicators – the information is directly related to fish, crustaceans, oysters, and indirectly to wading birds.

2. Current monitoring programs are insufficient with respect to appropriate metrics, scale of the present metrics, and effectively assessing the species-specific spatial extent and geo-

referenced locations of SAV in the Northern Estuaries, and the temporal and spatial changes in SAV that occur in relation to:

- Photosynthetically active radiation (PAR) and light fractionation.
- Water quality
- Salinity.
- Suitable substrate.
- Sediment dynamics.

SAV are critically important in the evaluation of restoration efforts for each of the Northern Estuaries. They integrate hydrology, substrata, and water quality dynamics.

3. The effects that multiple chronic stressors have on fish are not understood in the Northern Estuaries; specifically, there is a lack of information on how these stressors relate to abnormalities (e.g., diseases, tumors, lesions, etc.) and to the freshwater discharges.

   This is directly related to fish which is linked in turn to water volume, quality, etc.

4. A comprehensive benthic monitoring program for the Northern Estuaries that includes sampling in seagrass beds, such as the one for St. Lucie, is not available.

   Seagrasses integrate water volume, water quality, and many other stressors. This gap is directly related overall ecosystem function and all other integrators in each of the Northern Estuaries.

5. The current interim goal for oysters in the Northern Estuaries addresses only magnitude of spatial dimension (i.e., acres of oysters) and does not include other relevant ecosystem information that is currently being collected in the Northern Estuaries-wide monitoring program such as:

   - Reproductive success.
   - Abundance and population size classes
   - Health.
   - Predation
   - Population growth/decline rates.

   Oysters are linked to water volume, water quality, phytoplankton production, and sedimentation, and also influence the success of fish and bird populations. Eastern oysters are also important in evaluating restoration efforts. As the *PCS* indicated, the present goal is based only on spatial dimension (acreage covered) and also needs to consider other relevant, available information such as reproductive success, abundance of size classes, health, predation, and population growth/decline rates including influences of exotic species such as green mussels.

6. The existing oyster model does not cover the east coast estuaries. Oyster models are needed for predicting and assessing the effects of water management and restoration activities in all Northern Estuaries.

   This is directly related to the oyster indicator.

7. The relationship between red tides, harmful algal blooms, and changes in hydro patterns and nutrient dynamics because of restoration activities is not well understood.

   Although algal blooms are not an indicator for the Northern Estuaries, they are directly related to water volume and indirectly related to other selected indicators.

8. The functionality and dependencies of estuarine faunal associations with SAV communities are not well characterized, including how their relationships with SAV species are affected by the Northern Estuaries water quality and salinity.

   This is directly related to crustaceans, fish and wading birds.

9. Additional species-specific SAV models are needed for predicting and assessing the effects of water management and restoration activities in all Northern Estuaries.

   Although not an indicator this would be useful if others are completed.

10. The contaminants (e.g., pesticides, metals, and EPOCs) of the Northern Estuaries are not well characterized, and their role and effects, particularly as they relate to restoration activities, are not fully understood.

    At low concentrations, toxic contaminants can significantly damage the reproduction, physiology and behavior of species ranging from algae to mammals. They are easily transported by water or sediment particles, and they often act synergistically to promote disease and death. Thus, adequate assessment of major toxic substances is critical to accurate water quality analysis for ecosystem recovery.

11. There is insufficient understanding and prognosis of how estuarine communities, including oyster communities, respond and are affected by the fate, transport, and bioaccumulation of contaminants (e.g., pesticides, metals, and EPOCs), and sediments.

    Toxic substances accumulate in soils and sediments, and many of them also bioaccumulate up the food chain in higher trophic levels such as fish, birds, and mammals. Studies in some Florida estuaries have shown that various toxic substances are accumulating in estuarine sediments and fish tissues, and experimental data point to serious effects of these chemicals on key indicator species.

GREATER EVERGLADES GAPS

1. The current monitoring and research programs are insufficient to characterize and understand the hydrological and water quality relationships throughout the Greater Everglades at a spatial and temporal scale that is relevant to both restoration assessments and biological investigations.

   This is directly related to water volume and indirectly related to all other indicators. The information is fundamentally important to guide all Everglades restoration efforts.

2. There is a lack of understanding of the role of extreme events and sea-level rise, and how they will interact with freshwater flows and water management to control the structure and function of coastal ecosystems.

   The Everglades Mangrove Estuaries, at the final "receiving end" of the watershed, has sustained impacts from the changes in hydrology imposed by management activities. If resource managers can "get the water right" for the Everglades Mangrove Estuaries, they will largely have achieved "getting the water right" for the upstream Greater Everglades watershed as well.

3. There is a lack of understanding of the aquatic fauna forage base in relation to the formation of super colonies of wading birds, particularly how they use crayfish as prey, and the relative role of periphyton and hydrology as limiting factors for the development of prey base. The integrative hydrology, wading bird, fish/microcrustacean, and periphyton indicators are all emphasized in addressing this important gap about food web interactions in the Greater Everglades.

   This is directly related to wading birds, fish/microcrustaceans, and periphyton.

4. There is a lack of understanding of the distribution and impacts of exotic and invasive species.

   This is directly related to invasive exotic plants. Although basic information has been obtained about the physical/chemical conditions of the Greater Everglades and its native vegetation, a major, pressing gap in understanding present-day Greater Everglades dynamics is the impact of exotic and invasive plant and animal species. One invasive native species, cattail, has been a major focus, and a few invasive exotic plants are being tracked, but there remains a critical gap in understanding the distribution, abundance and impacts of many other key invasive/exotic plants. Moreover, indicators for exotic animals are lacking and represent another critical gap in addressing the exotic/invasive species issue.

5. There is a lack of understanding of the pre-drainage landscape processes and characteristics (e.g., soils, vegetation, and hydrology), and trophic interactions.

The relevance to existing management options needs to be described. A strong understanding of pre-drainage conditions in the Greater Everglades can serve as a "road map" to help guide restoration.

6. There is a lack of understanding of the factors controlling the current distribution of native plant and animal species, particularly on tree islands, in short hydroperiod marshes and in the sloughs.

   This is directly related to wading birds, fish and crustaceans, crocodilians, and periphyton.

7. There is a lack of understanding of the physiological requirements and hydrologic tolerances (e.g., resilience to changes in hydroperiod and depth) of the dominant herbaceous and woody species in the Everglades communities.

   This is related to the water volume indicator; moreover, an argument can be made to consider an herbaceous/woody indicator.

8. There is a lack of understanding of the hydrologic connectivity and nutrient exchanges across tree islands and the surrounding marshes as influenced by tree island geomorphology, soil types, marsh characteristics, and vegetation.

   This is directly related to the water volume indicator, and is of critical importance for tree islands.

9. There is a lack of understanding of the role of fire in creating and maintaining landscape patterns and plant communities.

   This is indirectly connected to wading birds, invasive plants, fish/crustacean macroinvertebrates, crocodilians and periphyton. It is an important factor in Everglades ecology and deserves incorporation in the plan.

10. There is a lack of understanding of soil dynamics (e.g., accretion, decomposition, sediment transport) in relation to hydrology and water management, vegetation, and fire in the Greater Everglades.

    This is directly related to invasive plant indicators and indirectly related to wading birds and periphyton. Soil dynamics is unlikely to lend itself to management.

11. There is a lack of understanding of the dynamics of nitrogen cycling in the Greater Everglades and the impacts it may have on Florida Bay through freshwater transport.

    Nitrogen is of major importance in controlling algal blooms in Florida Bay. Algal overgrowth can reduce the light needed for seagrasses to grow. Thus, nitrogen enrichment can also contribute to the destruction of valuable seagrass habitat and the beneficial animal life that depends on it.

12. The sources, dynamics, and effects of sulfates and sulfides on the biota of the Greater Everglades are independent of the interactions with mercury and not well understood.

    The sulfur cycle strongly influences phosphorus availability to Everglades plants; in addition, high sulfide accumulation can be inhibitory or toxic to plant roots.

    Both priority 11 and 12 are important research areas that are long-term in nature and are being conducted throughout the Everglades. While these projects continue, the other priorities should proceed as noted.

SOUTHERN ESTUARIES GAPS

1. Biscayne Bay lacks coupled hydrodynamic and water quality models, linked with regional hydrological models that can be used to evaluate effects of restoration of the introduction and distribution of nutrients or contaminants, (these have been initiated within the Biscayne Bay Feasibility Study).

   Water volume is an indicator, and all other indicators are indirectly related to hydrodynamics and water quality.

2. Salinity tolerances and optima for key Biscayne Bay fish and invertebrates have not been determined, despite recommendations in the Biscayne Bay Strategic Science Plan and a priority assignment within MAP.

   Fish and crustacean macroinvertebrates and pink shrimp are indicators.

3. Little is known about the specific habitats in Shark River Slough, Whitewater Bay, and adjacent rivers (Robert's to Lostman's) and the nursery functions they serve with respect to red drum, snook, tarpon, and other estuarine-dependent fish species, despite priority assignment in MAP.

   This is related to the fish indicator.

4. Little is known about the historical distribution of oyster reefs in Biscayne Bay, despite recommendations in the Biscayne Bay Strategic Science Plan and priority assignment within MAP.

   This is related to the oyster indicator. A strong understanding of the historic distribution of oysters can serve as a "road map" to help guide restoration.

5. Little is known about the degree to which climate change (e.g., sea-level rise, global warming, and ocean acidification) will affect the Southern Estuaries system and its geomorphology between now and 2050, despite inclusion in the Florida Bay Strategic Science Plan and increasing recognition of the issue during the MAP assessment process.

Although management options for climate change issues are beyond stakeholders' control, this key issue will strongly influence the success or failure of management options. The information will be critical in guiding how management strategies will have to be altered for restoration success.

6. There is a lack of information about mercury speciation and methylation within estuarine systems, despite recommendations in the Florida Bay Strategic Science Plan.

   This is potentially related to the fish/ crustaceans macroinvertebrates indicator as well as pink shrimp, wading birds and crocodilians. High levels of methylmercury in estuarine fish and other organisms should be verified and tracked, and the effects on fish and wading birds determined.

7. There is insufficient baseline information about groundwater quality in the Biscayne Bay watershed, despite recommendations in the Biscayne Bay Strategic Science Plan.

   Groundwater is a potentially major source of nutrient loading to the Southern Estuaries, and should be rigorously assessed to enable sound evaluation of effects of various management activities on water quality in these ecosystems.

8. There is insufficient information about the functional relationships between freshwater inputs and manatee abundance and distribution, despite priority assignment within MAP.

   Although manatee is not an indicator, as a protected species this will deserve some attention.

9. There is insufficient information on the rates of atmospheric nutrient loading into the Southern Estuaries, despite recommendations in the Florida Bay Strategic Science Plan.

   It is not clear that atmospheric nutrient loading is a prime driver of ecological health. This source of nutrient loading is potentially major, however, and should be quantified.

10. There is insufficient information on the flux of nutrients from sediments in the water column in Biscayne and Florida Bays, despite recommendations in both Strategic Science Plans and the FB/FKFS plans.

    Nutrients are a major factor supporting algal blooms in the Southern Estuaries, and the relative importance of external (under some management control) versus internal (already deposited in the estuaries) sources needs to be resolved to assist in developing restoration strategies.

11. There is insufficient information on benthic algal mats in terms of functional importance and as an indicator of eutrophication, despite recommendations in both Strategic Science Plans.

    This is related to the periphyton indicator.

12. There is a lack of fish tissue contaminants information for nearshore environments in the Southern Estuaries (with the exception of mercury in Florida Bay), despite recommendations in the Florida Bay Strategic Science Plan.

    Toxic contaminants in fish tissues can be a health hazard to people who consume the fish as seafood.

13. There is insufficient information on concentration and distribution of EPOCs in the Southern Estuaries and their watersheds and in alternative sources of water, such as reclaimed wastewater, that may be needed to meet natural system and other water supply needs in Biscayne Bay.

    The link to indicators is not established.

14. There is insufficient information on the ecological risk of contaminant (e.g., pesticides and trace metals) exposures that may result from restoration changes in the sources, distribution, and flows of freshwater introduced into the Southern Estuaries despite recommendations in the Biscayne Bay Strategic Science Plan.

    Toxic substances accumulate in soils and sediments, and many of them also bioaccumulate up the food chain in higher trophic levels such as fish, birds, and mammals. Studies in some Florida estuaries have shown that various toxic substances are accumulating in estuarine sediments and fish tissues, and experimental data point to serious effects of these chemicals on key indicator species.