Indicator 4.2 - Submerged Aquatic Vegetation in Southern Estuaries

What is the desired restoration condition?

The desired restoration condition for submerged aquatic vegetation in the Southern Estuaries is to establish and sustain diverse Florida Bay seagrass communities with moderate plant densities and more natural seasonality covering 65-70 percent of suitable bay habitat.

Why is this indicator important and why is this a good indicator of CERP restoration?

Seagrass beds are a key component of South Florida estuarine ecosystems, providing critical food and habitat for shrimp, fish, and other organisms. Seagrass beds also stabilize sediments, thus promoting clear water and helping to minimize algal blooms. Seagrass species composition, abundance, and spatial distribution are affected by spatial and temporal salinity patterns and nutrient and light levels. Freshwater inflow patterns (quantity, timing, and spatial distribution) affect salinity, nutrients, and light.

Restoring more natural freshwater inflow patterns and water quality improvements, as proposed in the Comprehensive Everglades Restoration Plan (CERP), are expected to result in more diverse estuarine seagrass communities, with moderate plant densities and more natural seasonality, and increased spatial coverage of suitable habitat. The spatial distribution and extent (coverage) of seagrass community types represents an effective indicator of estuarine submerged aquatic vegetation response to proposed CERP projects. This indicator is also used in other estuarine ecosystem management programs (e.g., Chesapeake Bay, Indian River Lagoon, Charlotte Harbor, and Tampa Bay National Estuary Programs) to assess submerged aquatic vegetation response to salinity, other water quality parameters, and ecosystem restoration activities.

Seagrass is an important ecological attribute, and a focus of CERP actions in most South Florida estuaries. However, based on the indicator selection criteria of predictability, including adequate existing data and monitoring; ecosystem restoration effect (and thus importance); ease of recognition and understanding by the intended audience; and manageable total number of indicators, the proposed submerged aquatic vegetation indicator for the southern estuaries region will focus only on Florida Bay. The best developed seagrass models for predicting this indicator are for Florida Bay. Coastal hydrologic/hydrodynamic models to predict salinity patterns, on which the seagrass models depend, are better developed for Florida Bay than other estuaries. Florida Bay also has more extensive existing data and monitoring programs for the proposed indicator. CERP actions will likely affect a larger spatial extent of seagrass coverage and biomass in Florida Bay than in other South Florida estuaries.

Water management has altered the natural freshwater flow patterns (quantity, timing, and distribution) to Florida Bay. These changes, including reduced volume of freshwater inflow, are thought to have affected submerged aquatic vegetation in the Florida Bay ecosystem (McIvor et al. 1994, Durako et al. 2003, Rudnick 2004). Reduced freshwater inflow due to water management has been implicated in the widespread mass mortality of the dominant seagrass species, *Thalassia testudinum,* that occurred in central and western Florida Bay from 1987 to 1991. This (later termed) primary mass mortality phase happened only in dense *Thalassia* beds. By 1990, 10,000 acres of seagrass were completely lost and 60,000 acres were affected by the primary die-off (Robblee et al. 1991). Several years later a secondary mass mortality event occurred, mainly due to reduced water clarity from algal blooms and resuspended sediments associated with the primary die-off. Consult Durako et al. (2003) for more details on these die-off events and their causes.

Reduced freshwater inflow has likely affected submerged aquatic vegetation in coastal embayments and mangrove zone lakes along the northern shore of Florida Bay. The more saline conditions in coastal embayments have probably resulted in shifts in submerged aquatic vegetation community types. Localized mass mortality of submerged aquatic vegetation has occurred at the end of the dry season in some years, correlated with relatively high salinities.

For CERP Interim Goals, Florida Bay seagrass patterns can best be described by seagrass community types. Florida Bay has multiple seagrass community types that vary spatial, and, in some locations, seasonally. Florida Bay seagrass community types, as defined in Fourqurean et al. (2003), are 1) sparse *Thalassia* bed, 2) dense *Thalassia* bed, 3) *Halodule* bed, 4) mixed species bed, 5) *Halodule-Ruppia* community, and 6) no seagrass. These are the same community types used in the seagrass model recommended for predicting this indicator. The current state is defined as the period 1996-2000 for which sufficient information is available to describe the state of Florida Bay submerged aquatic vegetation over a broad spatial scale, and to account for short-term interannual variability (Morrison and Bean 1997, Montague et al. 1998, Richards and Fourqurean 2000, Fourqurean et al. 2002, Durako et al. 2003, Fourqurean et al. 2003).

Submerged aquatic vegetation composition varies among the embayments along the north shore of Florida Bay. Long Sound has mixed species community type co-dominated by *Thalassia* and *Halodule* (equal abundance) and very low relative abundance of *Ruppia*. *Halodule* abundance has increased in recent years in Long Sound. Most of Joe Bay has *Halodule-Ruppia* community type, with *Halodule* being more abundant. Some parts of Joe Bay have *Halodule* bed community type. Much of Little Madeira Bay has mixed species type of *Thalassia* and *Halodule*, with *Thalassia* usually more abundant. *Halodule* and *Halodule-Ruppia* (near Taylor River mouth) community types are also in northern Little Madeira. In recent years, *Thalassia* abundance has decreased and *Halodule* and *Ruppia* increased in northern Little Madeira Bay. Most of inner Terrapin Bay has *Halodule* bed community type. A small *Ruppia-Halodule* bed is near McCormick Creek, with *Ruppia* dominant much of the year. In some years, at the end of the dry season, *Halodule* will die off in parts of Terrapin Bay and in Garfield Bight. This is correlated with below average dry season rainfall, high salinity (greater than 35 parts per thousand), and low water clarity (low light penetration). Outer Terrapin Bay is mostly moderate density *Thalassia* with some *Halodule*. Most of northern Garfield Bight, especially near Alligator Creek, has *Halodule-Ruppia* community type, with *Halodule* usually more abundant. Most of southern Garfield Bight has *Halodule* bed community type. Submerged aquatic vegetation declined substantially in Garfield Bight from 1996-1999.

Northeastern Florida Bay is mostly sparse *Thalassia* beds. Central and western Florida Bay experienced extensive seagrass mass mortality from 1987 to 1997. Since 1998, *Thalassia* and *Halodule* abundance has increased in areas with seagrass die-off. Currently, sparse *Thalassia*, dense *Thalassia*, and *Halodule* beds are the most common community types across central and western Florida Bay. The occurrence and relative abundance of these community types vary by basin. In Whipray Basin (central bay), which experienced primary mass mortality in dense *Thalassia* beds, sparse *Thalassia* beds are more common than dense *Thalassia* or *Halodule* community types.

CERP implementation should affect submerged aquatic vegetation in the north shore mangrove zone lakes and coastal embayments (closer to freshwater source) more than offshore areas in the Florida Bay ecosystem. However, central Florida Bay should also be a primary focus area. The key restoration objective here is reducing hypersalinity events, and thus reducing the probability of seagrass mass mortality. Spatially explicit submerged aquatic vegetation restoration targets for the Florida Bay ecosystem, including in the north shore mangrove zone, 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 2004, Davis 2004). These targets are summarized here for only the locations for which Interim Goal predictions are made. The Southern Estuaries section of the main body of this document contains a map of these locations. The following baseline conditions refer to those established by the Florida Bay and Florida Keys Feasibility Study:

- **Long Sound -** *Halodule-Ruppia* community with *Ruppia* dominant. Increased *Ruppia* and *Halodule* abundance, decreased *Thalassia* abundance, and decreased seasonal variability compared to baseline conditions.

- **Joe Bay -** *Ruppia* community with some *Chara* in the wet season and early dry season. Increased *Ruppia* abundance and persistence and decreased seasonal variability compared to baseline conditions.

- **Little Madeira Bay -** *Halodule-Ruppia* community with *Ruppia* dominant most of the year. Increased *Ruppia* and *Halodule* abundance, decreased *Thalassia* abundance, and decreased seasonal variability compared to baseline conditions.

- **Terrapin Bay -** *Halodule* community throughout much of inner Terrapin Bay that persists all year; no end of dry season die-off (i.e., decreased seasonal variability relative to baseline conditions). Increased *Ruppia* abundance and expansion of *Ruppia* community near McCormick Creek compared to baseline conditions. In outer Terrapin Bay, increased *Halodule* abundance and decreased *Thalassia* abundance relative to baseline conditions.

- **Garfield Bight -** *Halodule* community, perhaps with some *Ruppia* in wet season, throughout much of Garfield Bight that persists year-round; no end of dry season die-off (i.e., decreased seasonal variability compared to baseline conditions). *Halodule-Ruppia* community around Alligator Creek and north shore, with *Ruppia* dominant in wet season and *Halodule* dominant in dry season. This community type would also persist all year. Increased spatial extent of *Halodule-Ruppia* community relative to baseline conditions.

- **Whipray Basin -** Moderate density *Thalassia* and *Thalassia-Halodule* community types. Increased spatial extent of these communities compared to baseline conditions. Decreased hypersalinity events and thus decreased probability of seagrass die-off relative to the period 1965-1995.

How is the interim goal for this indicator predicted?

The recommended method for predicting Florida Bay submerged aquatic vegetation uses statistical (Fourqurean et al. 2003) and mechanistic (Madden et al. 2003) seagrass models. Modeling parameters for predicting this indicator include the following:

- Percent cover and relative abundance of seagrass (*Thalassia, Halodule*, and *Ruppia*) and macro algal species
- Biomass and relative abundance of *Thalassia*, *Halodule,* and *Ruppia*
- Spatial distribution and extent (coverage) of seagrass community types (based on percent cover and biomass data)
- Seasonal variation (end of dry and wet seasons) in these measures

Predictions using these models will be presented in the form of maps, graphs, and tables with supporting text. Figure 4.2.1 provides an example presentation of the Fourqurean et al. (2003) statistical submerged aquatic vegetation model predictions.

Currently, the Madden et al. (2003) mechanistic seagrass model is not fully functional, and hence can not be used for this series of predictions. The Fourqurean et al. (2003) statistical seagrass model could not be run in the timeframe allotted for producing this series of predictions. Therefore, the submerged aquatic vegetation predictions below are based on the “best professional judgment” of several marine ecologists with expertise and experience in Florida Bay submerged aquatic vegetation.

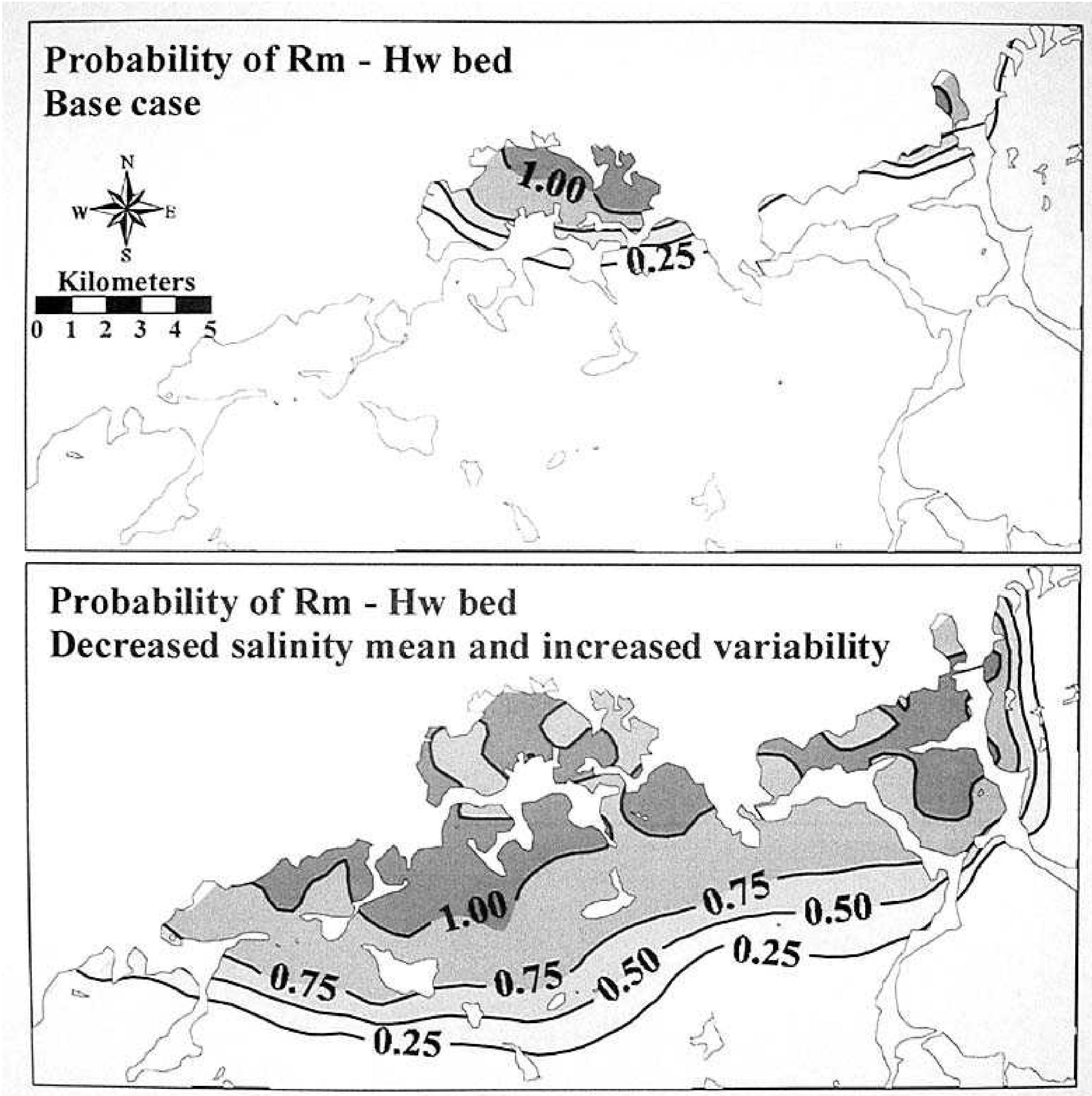

Figure 4.2.1. An example presentation of the Fourqurean et al. (2003) statistical submerged aquatic vegetation model predictions; Rw-Hw represents *Ruppia maritime – Halodule wrightii*.

<u>Uncertainty</u>

The primary information used for predicting submerged aquatic vegetation is predicted salinity values. Nutrients and light, in addition to salinity, affect submerged aquatic vegetation, but simulated nutrient and water clarity data are not available; thus, submerged aquatic vegetation predictions are based only on simulated salinity patterns. Two simulation models are used to produce the predicted salinity values: South Florida Water Management

Model (SFWMM) for predicting freshwater inflow and Marshall et al (2004) salinity simulation models.

The SFWMM is not very effective at predicting freshwater flow into Florida Bay. It hind casts simulated water management conditions over the climatic pattern and conditions from 1965 to 1995. This assumes that future climatic conditions and patterns will be similar to those from 1965-1995, only a 31-year period of record.

The Marshall et al (2004) salinity simulation models use SFWMM output to produce predicted salinity values. Uncertainties and assumptions related to the Marshall models are discussed on the sheet for Indicator 1.4 – Salinity Patterns in Salinity Patterns in Florida and Biscayne Bays. The hydrologic and salinity patterns produced represent the "average" of the 31-year period of record. No statistical measure or estimate of variability was provided for these patterns. Simulated wet and dry year type patterns would provide an estimate of variability around the average, but these could not be produced in time for this publication.

Multi-annual rainfall patterns (e.g., drought), tropical storms, and sea level rise could affect CERP estuarine ecosystem restoration actions and its ability to attain goals and targets, including those for Florida Bay submerged aquatic vegetation. These factors, although external to the CERP and consequently not controllable by the CERP, need to be considered in evaluating CERP's performance.

What are the predictions for five-year increments?

Florida Bay submerged aquatic vegetation predictions can only be made for 2010, 2015, and full implementation of the CERP (D13R) water management operational and structural conditions, and 2050 without CERP implementation, because predicted salinity data were generated for only these conditions. Florida Bay submerged aquatic vegetation predictions are made for Long Sound, Joe Bay, Little Madeira Bay, Terrapin Bay, and Garfield Bight, all north shore embayments, and Whipray Basin in central Florida Bay. Time and data constraints prevented predictions for other Florida Bay areas. Changes in submerged aquatic vegetation are relative to the current state (described above). The predictions are as follows:

- **2010** - No change in submerged aquatic vegetation is expected in Long Sound, Joe Bay, Terrapin Bay, Garfield Bight, and Whipray Basin. *Thalassia* might continue to decrease slightly and *Halodule* and *Ruppia* may increase in Little Madeira Bay.

- **2015** - No change in submerged aquatic vegetation is expected in Long Sound, Joe Bay, Terrapin Bay, Garfield Bight, and Whipray Basin. *Thalassia* might continue to decrease slightly and *Halodule* and *Ruppia* may increase in Little Madeira Bay.

- **D13R** - In Little Madeira Bay, submerged aquatic vegetation will change substantially relative to the current state. *Ruppia* will increase and *Thalassia* decrease considerably and *Halodule* will increase. *Ruppia-*

Halodule community type, with *Ruppia* dominant most of the year, will occur in most of Little Madeira. The area near Taylor River mouth probably will be *Ruppia* community type. Seasonal variation should be lower. Desired restoration conditions for submerged aquatic vegetation will likely be achieved in Little Madeira. In Whipray Basin, hypersalinity events will likely be less and thus chances of seagrass die-off will lessen relative to the period of record. In Terrapin Bay, the only change might be a lower probability of dry season *Halodule* die-off. No change in submerged aquatic vegetation is expected in Long Sound, Joe Bay, and Garfield Bight.

- **2050 Without CERP Implementation** - No change in submerged aquatic vegetation is expected in Long Sound, Joe Bay, Little Madeira Bay, Terrapin Bay, Garfield Bight, and Whipray Basin.

How will we track whether the interim goals established for this indicator have been achieved?

The modeling parameters stated above, except for seasonality, are parameters in the submerged aquatic vegetation monitoring protocols detailed in the *CERP Monitoring and Assessment Plan: Part 1, Monitoring and Supporting Research* (RECOVER 2004). Only end of dry season sampling is called for in this plan; however, end of wet season sampling should also be conducted. The monitoring methods include aerial photography to evaluate spatial distribution and extent of seagrass community types; however, it is uncertain how effectively this method will differentiate seagrass species and community types. This monitoring will begin in 2005. Also, existing agency programs for monitoring seagrass in Florida Bay will continue (Durako et al 2003). Baseline conditions, which are needed to assess progress toward achieving the desired restoration condition, have not yet been established for Florida Bay seagrass.

What additional work is needed to improve this interim goal?

The interim goal for Florida Bay seagrass is based on an estimate of ecosystem conditions prior to major human interventions. These conditions (i.e., Florida Bay ecosystem history) are determined from paleoecological research and historical accounts (Brewster-Wingaard et al. 2003). Additional ecosystem history research will help refine this interim goal.

Additional work needed to improve predictions for Southern Estuaries submerged aquatic vegetation are as follows:

- The Fourqurean et al. (2003) statistical seagrass model needs additional seagrass and water quality data to expand its coverage in Florida Bay. These data will start being collected in 2005.

- The Madden et al. (2003) mechanistic seagrass model is still being developed. The model currently predicts *Thalassia* biomass, but not biomass for *Halodule* and *Ruppia*. The model should be able to predict biomass for all three species in early 2005. The model should be able to incorporate interspecific competition by mid-2005.

- Both seagrass models incorporate water quality parameters (nutrients, light) in addition to salinity. Therefore, both models will not be fully effective until a proposed Florida Bay water quality model is developed that can provide predicted water quality parameters.

- A Florida Bay landscape seagrass model (Smith et al. 2002) that will help apply the Madden et al. (2003) model predictions on a bay-wide scale needs to be completed.

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