Northern Estuaries Performance Measure
Oyster Habitat

Last Date Revised: March 21, 2007

Acceptance Status: Accepted

1.0 Desired Restoration Condition

In the St. Lucie Estuary and Lake Worth Lagoon, the restoration expectation is to promote the expansion of oyster reef communities and add substrate to increase areal extent of oyster reef, where ecologically appropriate. In the Caloosahatchee Estuary, the restoration expectation is to improve the recruitment and survivorship of the Eastern Oyster by restoring oyster beds in suitable habitat, and maintaining habitat function of oyster beds for fish, crabs and birds. In the Loxahatchee Estuary restoration expectations are still being developed.

1.1 Predictive Metric and Target

A variety of ecological and physiological responses of oysters will be used to determine the health of oysters and oyster reefs. These include: density of living oysters, condition index, reproductive activity, larval recruitment, disease prevalence and intensity of *Perkinsus marinus* (and MSX in east coast estuaries). A Habitat Suitability Index (HSI) model currently under optimization will be used to determine exact numbers of live oyster reef acreage increase and suitable locations for reef development (see below). A 5-10 fold increase in live oyster reef coverage is targeted with an overall goal of increasing % oyster reef coverage compared to current conditions. On a longer term (3-5 years), distribution and aerial coverage of oyster reefs will also be considered.

1.2 Assessment Parameter and Target

The Comprehensive Everglades Restoration Plan (CERP) is being implemented as a means of reinitiating, to the greatest degree possible, natural freshwater flow to coastal waters on both coasts of south Florida. The Monitoring and Assessment Plan (MAP) component of CERP is designed to provide a diverse approach to documenting and describing the impacts of changed freshwater flow to the flora and fauna inhabiting inland landscapes and coastal waters. Because of its wide distribution, historical context, and essential habitat value, the Eastern Oyster is included as a target species for monitoring. Changes in oyster distribution, health and abundance will be monitored within several estuarine ecosystems encompassing both the Atlantic and Gulf of Mexico coasts of south Florida. These ecosystems include the St. Lucie Estuary, Loxahatchee River, Lake Worth Lagoon, Biscayne Bay, Ten Thousand Islands area, and Caloosahatchee River. To provide a background for comparison, outlier oyster populations in Tampa Bay, Mosquito Lagoon, and the Sebastian River also will be monitored (Underwood and Chapman, 2003). We anticipate that mapping of oyster reefs to determine actual reef acreage needs to take place every 3-5 years.

The targets for each of the northern estuaries, predicted with the full project implementation, are as follows:

- St Lucie Estuary – to provide approximately 900 acres of suitable oyster habitat.
- Caloosahatchee Estuary – to provide approximately 400 acres of suitable oyster habitat with at least 100 acres of living oyster reefs.
- Loxahatchee River Estuary – The restoration goal for oyster communities in the Northwest Fork of the Loxahatchee estuary is to maintain suitable water quality conditions for all oyster life history stages

near the River Delta while establishing additional oyster communities downstream. Numeric target will be determined once the baseline data collection is completed.

- Lake Worth Lagoon – to provide approximately 185 acres of suitable habitat through the placement of appropriate material on hard bottom currently impacted by muck deposits. In addition, a performance measure for salinity levels has been developed, incorporating seasonality and duration limits, which takes into account the salinity requirements of both larval and adult oysters.

2.0 Justification

In the Caloosahatchee, Loxahatchee, Lake Worth Lagoon and St. Lucie Estuaries, oysters have been identified as a "valued ecosystem component". Oysters are natural components of southern estuaries and were documented to be abundant in these systems. The Eastern Oyster, *Crassostrea virginica*, is the dominant species in these oyster reef communities. Oyster bars provide important habitat and food for numerous estuarine species including gastropod mollusks, polychaete worms, decapod crustaceans, various boring sponges, fish and birds. Over 300 macrofauna species can live in or associated with oyster beds and over 40 species may live in a single oyster bed (Wells 1961). Oysters are also an important commercial and recreational resource. Adult oysters normally occur at salinities between 10 and 30 parts per thousand (ppt) but they tolerate a salinity range of 2 to 40 ppt (Gunter and Geyer 1955). Short pulses of freshwater inflow can greatly benefit oyster populations by killing predators, such as the southern oyster drill and the whelk, that cannot tolerate low salinity water (Owen 1953), while excessive freshwater inflows may kill entire populations of oysters (Gunter 1953, Schlesselman 1955, MacKenzie 1977).

Eastern oysters are highly valued as food, but their ecological significance remains under-appreciated and under-studied (Coen et al. 1999a). Individual oysters filter 4-34 liters of water per hour, removing phytoplankton, particulate organic carbon, sediments, pollutants, and microorganisms from the water column. This process results in greater light penetration immediately downstream, thus promoting the growth of submerged aquatic vegetation. Although oysters assimilate the bulk of the organic matter that they filter, the remainder is deposited on the bottom where it provides food for benthic organisms. Furthermore, the oyster's ability to form large biogenic reefs (Coen et al. 1999b) qualifies it as a keystone species. Oysters and the complex, three-dimensional, reef structure they form, attract numerous species of invertebrates and fishes. These "ecosystem engineers" (Coen et al. 1999b) attract predators such as mud crab (*Panopeus herbstii*) (Meyer 1994), black drum (*Pogonias cromis*) (Ingle & Smith 1956), and crown conch (*Melongena corona*) (Woodburn 1965) which feed on the living oysters themselves. Oyster shells serve as sites for egg laying or nesting in the crown conch (*M. corona*) (personal observation) and Florida blenny (*Chasmodes saburrae*) (Peters 1981), respectively. Oyster reef structure provides a refuge from predation for such species as the mud crabs *Eurypanopeus depressus* and *P. herbstii* (McDonald 1982). To date, over 300 species have been identified as depending, either directly or indirectly, on oyster reefs (e.g., Wells 1961, Crabtree & Dean 1982, Abbe & Breitburg 1992, Wenner et al. 1996, Coen et al. 1999a). Based on the relative degree of dependence, oyster-reef fauna can be classified as reef residents, facultative residents, and transients (Coen et al. 1999a). Many of these organisms in turn serve as forage for important fisheries species (e.g., spotted seatrout, *Cynoscion nebulosus* [Tabb & Manning 1961, McMichael & Peters 1989]; red drum, *Sciaenops ocellatus* [Peters & McMichael 1987]; common snook, *Centropomus undecimalis* [Marshall 1958, Fore & Schmidt 1973, Gilmore et al. 1983]) and birds (e.g., yellow-crowned night-heron, *Nycticorax violaceus* [Watts 1988]).

For the St. Lucie Estuary, an historic acreage estimate of approximately 1,400 acres was calculated from a 1940- 1960 oyster GIS coverage developed by Woodward-Clyde Inc. (1998a). This historic coverage represents an interpretation of anecdotal information and general oyster location accounts found through a literature review (Woodward-Clyde Inc. 1998b). This coverage was not intended for estimating acreage, but it is the only known source of information for approximating acreage. In 1997, 207 acres of oyster habitat (15% of historic) were identified in the St. Lucie Estuary (Woodward-Clyde 1998a). Shell mining, altered freshwater inflow, and changes in hydrodynamics are largely responsible for this reduction. For example, large freshwater discharges from Lake Okeechobee and the St. Lucie Estuary watershed occurred in the Spring 1998 and Summer 1999, killing more than 90% of the remaining oysters. Some recruitment has been observed since then and a comprehensive study under the RECOVER Monitoring and Assessment Plan began in January 2005. This baseline monitoring study will provide information on the abundance, recruitment, and health of living oyster reefs in the St. Lucie, Loxahatchee, Lake Worth estuaries and Biscayne Bay. Current estimate (2003-2004) for the Caloosahatchee River is 18.4 acres of oyster reefs. Caloosahatchee River and Estuary (including San Carlos Bay that forms the estuary portion of the Caloosahatchee River) has an accommodation space of 62,644,983 m2 (6264 Ha or 15,479.36 acres) with oyster reefs comprising of 74,336 m2 (7.43 Ha or **18.37 acres**). This translates to 0.12% coverage of total surface area available in the estuarine portion (Volety et al., unpublished results). Percent coverage of oyster reefs along various Gulf of Mexico estuaries (Texas, Coastal Louisiana, Mississippi, Alabama and Florida) ranges between 0 – 5.78%, with areas of intermediate salinities accounting for higher values (Data compiled by the US EPA). The lower percent coverage of oyster reefs in the Caloosahatchee River is a combination of freshwater inflows into the estuary from Lake Okeechobee and lack of suitable substrate. Most of the benthic habitat in the river is comprised of silty muds, sand, clay and shell. Similar estimates of present acreage and potential accommodation space for east coast estuaries is needed.

Previous studies by URS Greiner Woodward (1999) for the St. Lucie Estuary and by the Loxahatchee River District (2003) for the Loxahatchee Estuary, plus a U.S. Fish and Wildlife Service funded study being conducted by the Florida Fish and Wildlife Conservation commission, Fish and Wildlife Research Institute in Lake Worth Lagoon and Biscayne Bay will provide estimates of living oyster reef acreage in each of those systems.

3.0 Scientific Basis

3.1 Relationship to Conceptual Ecological Models

The indicator for this performance measure is an ecological attribute (Oyster Habitat) in the following conceptual ecological models:

Regional Models (RECOVER 2004a)

St. Lucie Estuary and Indian River Lagoon
Loxahatchee
Lake Worth Lagoon
Caloosahatchee Estuary

Ecological Model for Hypothesis Clusters (RECOVER 2005)

Oyster Abundance and Health Conceptual Ecological Model (see Figure 1 below)

3.2 Relationship to Adaptive Assessment Hypothesis Clusters

Ecological Premise: Prior to upstream water management (and post-inlet construction), the Northern Estuaries exhibited an ecologically appropriate range of salinity conditions, with fewer salinity extreme events, and supported healthy oyster communities

Northern Estuary Oyster Hypotheses:

Hypothesis 1 - Undesirable shifts in the estuarine salinity envelope result in decreased survival, reproduction, spat recruitment, growth and increased susceptibility to diseases by *Perkinsus marinus* and MSX (in the southeast estuaries oysters).

Rationale. Large rainfall events and subsequent watershed run-off, or large volume releases from Lake Okeechobee cause large volumes of freshwater over a short period of time to enter the estuary causing a sudden drop in salinity. This sudden drop can lead to significant mortality in the oyster population, and decreased growth, reproduction, and spat recruitment. Extreme droughts can also negatively impact oysters by making them prone to disease and predation.

Hypothesis 2 - Accumulation of muck (high organic content depositional matter) on available substrate or nearby areas will make substrate unsuitable for oyster larval settlement and thus recruitment and growth of larval oysters. In addition, accumulation of muck may also impact the dissolved oxygen content making the area / substrate unsuitable for larval settlement and growth.

Rationale. Oyster recruitment is negatively effected by the accumulation of mucky sediments in the estuary. Muck is unsuitable substrate for spat settlement. Areas that once contained sand and/or shell have been covered by these very soft, unconsolidated sediments. Freshwater inflow carries sediments with silt, clay and high organic content. Freshwater inflow from canals can also result in an increase in the transport of floating aquatics, which then degrade and contribute to the rate of muck accumulation.

Hypothesis 3 - Increased sediment loads in the water column impair respiration and feeding of oysters resulting in decreased growth and condition index of oysters. In addition, sediment accumulation on oyster shell negatively affects spat recruitment.

Rationale. Oyster populations are affected by increased sediment loads resulting from alterations to the natural hydrology. Adult oysters have effective morphological adaptations for feeding in much higher levels of suspended solids than are usually encountered under normal conditions. Oysters from relatively turbid estuaries appear to be capable of feeding at total suspended solid concentrations as high as 0.4 g/l but significantly reduce their pumping rates at as low as 0.1 g/l. Suspended solids may clog gills and interfere with filtering and respiration of oysters. Deposition of sediment on oyster shells also makes them unsuitable for spat settlement.

Hypothesis 4 - Increase in oyster reef coverage will enhance secondary habitat for other estuarine species resulting in increased diversity and abundance.

Rationale. Oysters are natural components of south Florida estuaries and were documented to be abundant in the system. Although currently less abundant, they continue to be important. Reduction in oyster coverage was largely due to altered freshwater inflow, shell mining, and changes in hydrodynamics. This decrease has resulted in a loss of oyster reef community and the estuarine species that use this habitat.

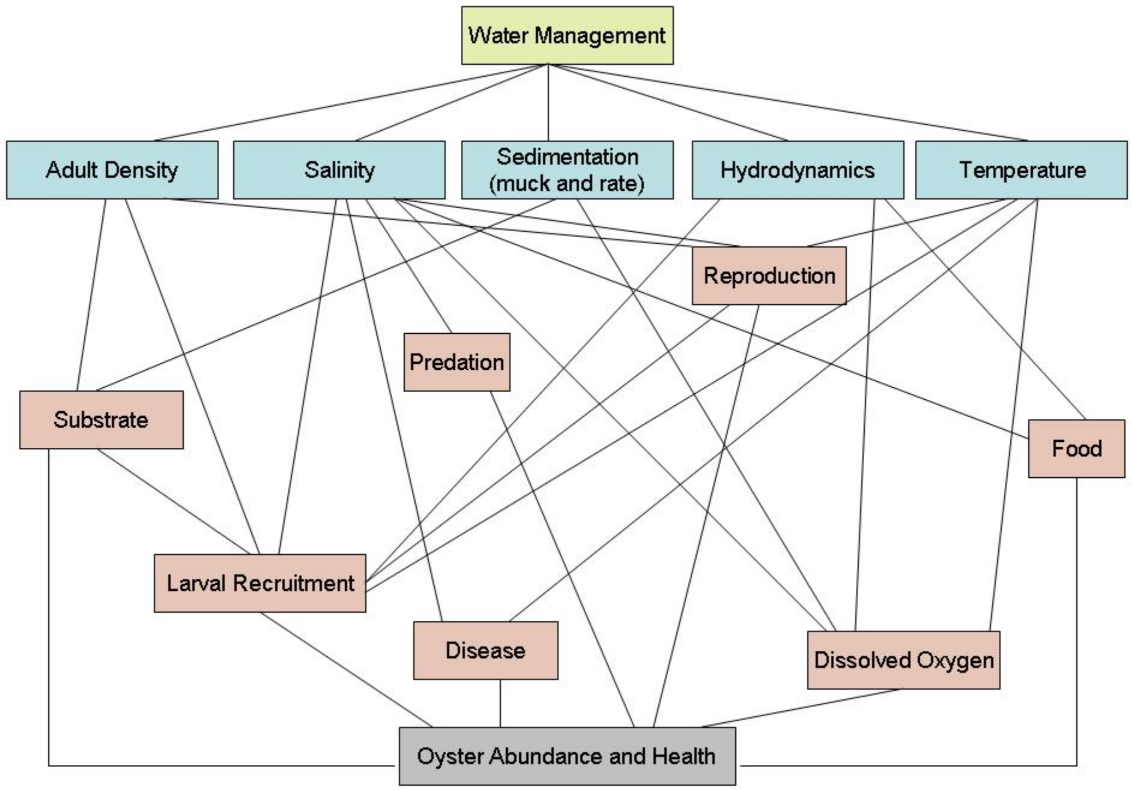

Figure 1 – OYSTER CONCEPTUAL ECOLOGICAL MODEL

4.0 Evaluation Application

4.1 Evaluation Protocol

4.2 Normalized Performance Output

4.3 Model Output

4.4 Uncertainty

5.0 Monitoring and Assessment Approach

5.1 MAP Module and Section

See CERP Monitoring and Assessment Plan: Part 1 Monitoring and Supporting Research - Northern Estuaries Module section 3.3.3.6 (RECOVER 2004a)

See The RECOVER Team's Recommendations for Interim Goals and Interim Targets for the Comprehensive Everglades Restoration Plan – Interim Goal 1.1 American Oysters in Northern Estuaries (RECOVER 2005).

5.2 Assessment Approach

NA

6.0 Future Tool Development Needed to Support Performance Measure

6.1 Evaluation Tools Needed

6.2 Assessment Tools Needed

Oyster Model

The proposed model (Volety et al. 2005; Mazzotti et al. 2005) is a modification of the original model developed by Cake (1983) and modified by Soniat and Brody (1988) for the Texas estuaries. For the HSI model for the Eastern oyster, a larval component index (LCI) and adult component index (ACI) are being examined. Monthly mean salinity, temperature, and inflow of freshwater comprise the LCI. The ACI is comprised of salinity, and temperature. The Habitat Suitability Index of oysters is calculated as:

$$HSI_{\text{May-November}} = \text{MIN (LarvaeComponentIndex, AdultComponentIndex)}$$

$$HSI_{\text{December-April}} = \text{(AdultComponentIndex)}$$

Average HSI for the year are calculated based on the monthly HSI values. The weight can take on different values for different variables; however, the sums of the weights must be equal to one. Refinement of the HSI will help identify exact locations or areas that have the greatest potential to develop as reefs, extent of reef coverage assuming certain growth rates, and above all reasonable predictive capability of oyster reef survival should conditions change in the future, e.g. amount of freshwater etc. Areas that show high HSI from this model are being targeted for restoration and enhancement of oysters in the Caloosahatchee Estuary. When baseline values of ecological responses (condition index, disease intensity of *P. marinus*, spat recruitment, time of reproduction) of oysters become available in the future, these aspects will be incorporated into the model and optimized.

While this model is being developed for the Caloosahatchee Estuary, the model can be exported and used in other estuaries with minor modifications. The model will be strengthened and/or trained to better predict oyster responses with the continuous input of monitoring data. The model was generated based on the flow data from the SFWMD and oyster response data from the Caloosahatchee Estuary collected by Dr. Aswani Volety and his colleagues at Florida Gulf Coast University.

7.0 Notes

This Performance Measure supersedes and addresses NE-12 Northern Estuaries Oyster Habitat (Last Date Revised: Sep 21, 2005).

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