Northern Estuaries Performance Measure
Benthic

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1.0 Desired Restoration Condition

Better managed fresh water inputs and reduced sedimentation rate in the St. Lucie Estuary are expected to reduce the number of anoxic/hypoxic events in estuarine sediments. This will significantly reduce the few r-strategist taxa (i.e. taxa with high reproductive rates and ecological opportunism) that now dominate large areas of the estuary and give way to a healthy and stable macrobenthic community, with high abundance, taxonomic diversity, and a diverse representation of feeding strategies. These communities constitute a major link in the estuarine food web and will benefit higher trophic levels.

1.1 Predictive Metric and Target

A large variety of approaches are available to determine the changes/improvements in the St. Lucie Estuary and the southern part of the Indian River Lagoon. Basic statistical analyses include determination of taxa, abundance, diversity and evenness. Multivariate approaches will primarily be used to elucidate changes/improvements within the benthic communities, and identify the major causes for those observed changes (salinity, oxygen, sediment, nutrients). Information from the literature on separate taxa will also be used to define the quality of changes in community structure as currently extirpated species are permitted to return and re-establish. Overall, a return to a healthy, well-balanced, and appropriately stable estuarine benthic community is targeted.

1.2 Assessment Parameter and Target

The Comprehensive Everglades Restoration Plan (CERP) is being implemented as means of reinitiating, to the greatest degree possible, natural freshwater flow to coastal waters of south Florida. The Monitoring and Assessment Program (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 extreme importance to the entire estuarine ecosystem, the benthic macrofauna is included as a target for this program. As described earlier, changes in the benthic communities will be monitored by using well established approaches, used both nationally and internationally. Separate basic and multivariate analyses of the macrofauna sampled quarterly (3 replicates) from the established 13 sampling sites will be performed. Additionally, in order to better detect trends, sites will be combined for analysis into groups. For a group of sites the mean abundance values, representing all the replicates from a single site, will first be averaged for all sites from each sampling occasion (quarterly) to form a single time series for the group. The mean and standard deviation for all sampling occasions for the time series will be computed, and these values will be used to convert the abundance for each occasion into standard normal deviate values (Sokal and Rohlf 1981). Conversion of all data into standard deviates allows data from sites differing substantially in absolute abundance to be presented on the same abundance axis and allows a more ready visual comparison of trends.

A return to natural freshwater flows should leave the SLE with a diversity of salinity regime “zones” that represent a gradient typical of a natural estuary (e.g. McLusky 1989). A target is also to develop a regional Benthic Index of Biotic Integrity for the SLE-IRL region.

2.0 Justification

The restoration of volume, timing, and spatial distribution of freshwater flows will provide for conditions in the St. Lucie estuarine system that will result in reduced input, transport, resuspension, and accumulation of soft sediments/muck and ooze. These sediments tend to become anoxic/hypoxic and sequester and concentrate available toxicants. A reduction in deposition rate of these sediments would improve water quality and enhance the diversity of estuarine epibenthic and infaunal macroinvertebrate communities. Moreover, restoration of historic fresh water flows would also improve the salinity regime that estuarine communities depend on. In the St. Lucie Estuary (SLE), fluctuations between periods of high and low discharge cause alternating shifts between estuarine and freshwater species, resulting in poor communities of either type. During an experimental freshwater release of 2,500 cfs (ca 70 $m^3 s^{-1}$) for a three-week period, it was found that an overall reduction of 44% of the benthic macroinvertebrates occurred (Haunert and Startzman 1985). The greatest change in benthic species composition occurred in the newly created oligohaline zone (0.5 to 5 ppt). The freshwater midge, *Chironomus crassicaudatus,* increased dramatically. Additionally, six freshwater species were introduced and at least four estuarine species were lost from the oligohaline zone. During periods of low freshwater release, the estuarine macrobenthic communities are usually dominated by a few r-strategic (opportunistic) taxa, and the community is typically not permitted to fully recover to a natural status before the next freshwater release occurs.

The St. Lucie Estuary and the southern Indian River Lagoon (IRL) macrobenthic infauna is a critical component of a healthy functional estuary and, as such, is a necessary component of a successful monitoring program. The Chesapeake Bay Benthic Monitoring Program (2003) found that macrobenthic communities are reliable and sensible indicators of habitat quality in aquatic environments. They respond to multiple types of environmental stress, they reflect environmental conditions that vary over time, and live in bottom sediments where exposure to contaminants and oxygen stress are most pronounced. The fact that they are ubiquitous features of the seabed, they therefore vary predictably in association with the physical habitat and in response to natural and man-made changes (Dauer 1993; Wilson and Jeffrey 1994; Tunberg and Nelson 1998). Thus they are good indicators of locally induced environmental changes (Wass 1967; Gray 1979; Boyd 2002). Benthic infauna are in many ways superior to many other biological groups that could be monitored (e.g. plankton, fishes, marine birds) because they are sedentary and must adapt to environmental stress or perish (Bilyard 1987). Benthic infauna are also effective indicators of impacts at higher levels of biological organization (e.g. community level) because of their importance to overall ecosystem structure and function (Bilyard 1987).

Their responses to sediment contamination facilitate the spatial definition of impacts (Gray 1980; Hartley 1982; Phillips and Segar 1986). Benthic assessments are also used frequently in studies of trends, where the problem of habitat induced variation can be minimized by returning to the same site or area (Weisberg et al. 1997). Tett (2004) also states that the benthic environment and the macrozoobenthos respond to disturbance in well-characterized ways. So far as the consequences of nutrient enrichment are concerned, the main effects are likely to be: changes of benthic community structure resulting from increased food supply, intense local pulse disturbances resulting from sinking red tides, chronic changes in community structure as deep water oxygen content falls and/or the anoxic region of the sediment extends toward the surface, catastrophic widespread destruction of benthos associated with hypoxia and anoxia.

Beyond their importance as indicators of environmental health, the benthos is a crucial component of the SLE and the IRL ecosystems. The link between benthic macrofauna and other estuarine components should be highly valued due to its importance to commercially harvested resources (e.g. fish, crabs, and shrimps). Additionally, benthic infauna play a crucial role in estuarine nutrient cycling and the transfer of energy to other food web components (e.g. Rhoads 1974; Schaffner et al. 1987).

Detailed national and international guidelines and recommendations exist on how to conduct long term macrobenthic monitoring programs, including statistical data treatment (e.g. Holme and McIntyre 1984; Warwick and Clarke 1991; Clarke and Warwick 2001; Boyd 2002; OSPAR 2002; Magni et al. 2005). Procedures set forth by Clarke and Warwick (2001) contain specific guidance for utilizing PRIMER (Plymouth Routines in Multivariate Ecological Research) statistical software which has been custom-tailored for analyses of macrobenthic datasets. This constitutes a significant advantage of macrobenthic monitoring over other approaches, where procedures to interpret monitoring data may not have been as well documented and implemented.

In spite of the fact that the benthic macrofauna provide fundamental data that are relevant to objectives of most marine monitoring programs (Bilyard 1987), it has from a few sources earlier been stated that this is a labor intensive approach and therefore expensive to perform. This is, however, far from the truth. When following the guidelines for this monitoring approach and having the taxonomical expertise at hand, this is most likely the most cost effective and most reliable way to monitor and pinpoint changes in the marine and estuarine environment.

3.0 Scientific Basis

3.1 Relationship to Conceptual Ecological Models

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

Regional Models (RECOVER 2004b)

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

Ecological Model for Hypothesis Clusters (RECOVER 2005)

Benthic Infaunal Conceptual Ecological Model (see Figure 1 below)

3.2 Relationship to Adaptive Assessment Hypothesis Clusters

Ecological Premise: The predrainage Caloosahatchee, St. Lucie, Indian River Lagoon (post-inlet construction), Lake Worth Lagoon (post-inlet construction), and Loxahatchee River estuarine systems were characterized by freshwater inflow primarily from direct rainfall and basin runoff that was attenuated by vast watershed wetland systems. This resulted in a more stable salinity regime, and low nutrient and sediment inputs within the estuaries compared to present conditions.

RECOVER Northern Estuary Hypothesis cluster and linkage to assessment process:

Hypothesis 1 - Irregular and extreme shifts in salinity in the St. Lucie Estuary prevent the establishment of a natural healthy estuarine infaunal community

Rationale. In contrast to a natural estuary where the riverine input is relatively stable, and/or relatively predictable, throughout the year, resulting in a wedge-shape bottom layer of higher salinity (strong pycnocline), the irregular and massive freshwater releases from the primary SFWMD canals which drain the estuary's expanded basin and regulatory releases from Lake Okeechobee to both the Caloosahatchee and St. Lucie

Estuaries lead to sudden and dramatic drops in salinity in the entire water column. These unstable conditions prevent the establishment of a diverse and healthy estuarine benthic infaunal community (a very important food source for many fish and bird species). With increasing salinity, population distribution becomes more even, with a corresponding decrease in relative dominance and an increase in species richness and diversity (Livingston 2003). Benthic animals are directly or indirectly involved in most physical and chemical processes that occur in estuaries, processes that will be disturbed by the salinity changes.

Hypothesis 2 - The anthropogenically exacerbated accumulation of soft unconsolidated and strongly reducing sediments in the estuary inhibits the establishment of infaunal species resulting in an impoverished community characterized by low diversity and density.

Rationale. Abiotic factors, such as sediment grain size and quality and tidal currents, are responsible for determining broadscale benthic community patterns (Cabioch 1968, Warwick and Uncles 1980, Rees et al. 1999). Fine sediment deposits are a typical characteristic feature of most estuaries; however, wide-scale predominance of fine sediments at the expense of other typical estuarine sediment types, as is present in the St. Lucie estuary, constitutes a patently man-induced geologic imbalance that is necessarily reflected in both the benthic community and the higher trophic level species that rely on the benthos.

Hypothesis 3 - The frequent re-suspension of fine sediments in the St. Lucie Estuary severely impacts certain infaunal species, important for the ecosystem stability.

Rationale. Suspension feeders, such as many bivalves, tend to predominate in sandier sediments with sufficient current speed (Day et al. 1989). They feed and eliminate wastes by either pumping water through their burrows, where it is filtered out and pumped out, or by extending feeding structures above the bottom through which water is pumped and filtered. Benthic suspension feeders can therefore play a large role in nutrient recycling and in sedimentation and resuspension of particulate matter (Alongi 1998). The increase in suspended sediments likely clogs the filtering apparatus of the suspension feeders, resulting in a community dominated by deposit feeders, i.e., a community not in balance among functional groups. Popham (1966) also found that salinity and the increasing silt content in the water were the most significant factors limiting the upstream distribution of fauna in estuaries

Hypothesis 4 - Low oxygen concentrations, and at times significant concentrations of H_2S in the waters adjacent the bottom sediments often occurs. This results in mass mortality and prevents settling of larvae, adversely affecting the infaunal communities.

Rationale. The enrichment of coastal waters with excessive organic matter generally results from a variety of different sources and leads to a number of changes (Weis and Wilkes 1974, Graves et al. 2005). There are often very large changes in community structure and metabolism due to these changes. Inorganic nutrients from mineralization of the organic matter can stimulate algal blooms which provide another source of excessive organic matter (Day et al. 1989). As a result of widespread deposition of strongly reducing unconsolidated fine sediments in the St. Lucie Estuary, bottom waters are likely to exhibit depressed oxygen concentrations, and in some events contain significant quantity of sulfide from decomposition processes occurring in anaerobic sediments. Such conditions may likely be widespread and sustained on occasions when temperatures are higher (during the summer) or when wind induced mixing is low. Low oxygen concentrations have also been associated with freshwater discharge (Stanley and Nixon 1992). Such hypoxic, anoxic, and/or toxic conditions result in mortality of the sessile benthic communities, which is followed by a rapid establishment of opportunistic (r-strategist) species (Eagle and Rees 1973, Gray and Pearson 1982, Gray 1979, Wilson and Elkaim 1991). Overall these conditions result in a severe disturbance of the entire estuarine ecosystem.

The restoration of hydrology toward Natural Systems Model (NSM) conditions within the Northern Estuaries will result in a more stable salinity regime, reduction in nutrient and sediment and loads from inflow structures at levels that provide water quality conditions that reduce the frequency and intensity of algal blooms and epiphytic plant growth and improve water clarity sufficient to promote establishment of seagrasses, and other SAV in the estuaries.

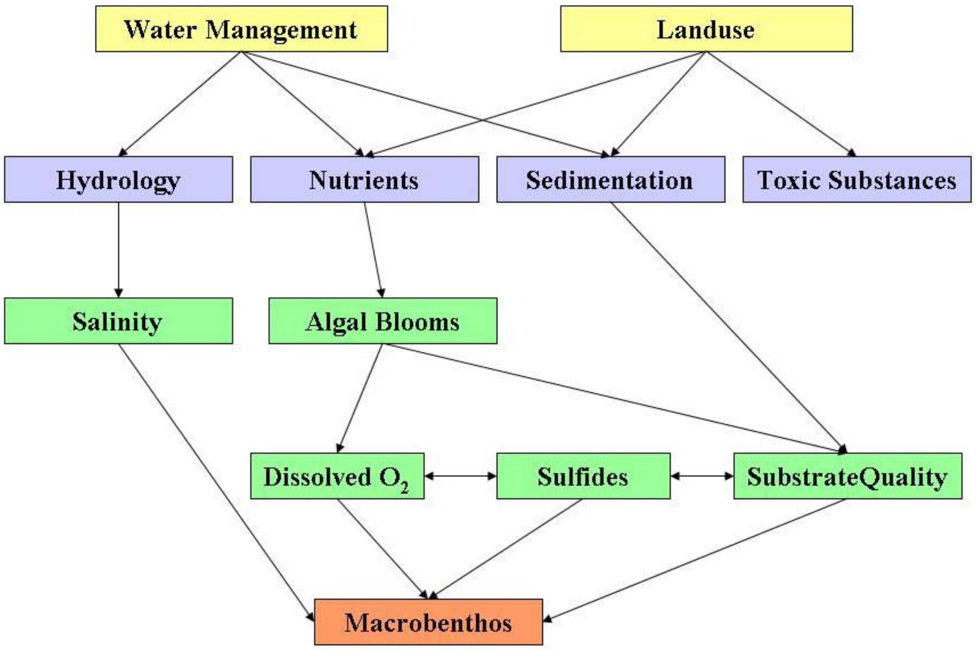

Figure 1 - BENTHIC INFAUNAL CONCEPTUAL ECOLOGICAL MODEL

4.0 Evaluation Application

4.1 Evaluation Protocol

Numeric predictive tools for macroinvertebrate assemblages currently do not exist.

4.2 Normalized Performance Output

NA

4.3 Model Output

NA

4.4 Uncertainty

NA

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 3.3.3.8 (RECOVER 2004a).

5.2 Assessment Approach

NA

6.0 Future Tool Development Needed to Support Performance Measure

6.1 Evaluation Tools Needed

Development of predictive tools will be facilitated by evaluating monitoring data as improvements occur. No specific model has been developed for the benthic communities of these estuaries, but instead there exist a large number of published estuarine benthic indices (condition indices), information concerning the trophic interactions between the benthos and the associated estuarine communities, and also on the effects from anthropogenic disturbance, such as eutrophication. This information will be used and evaluated and may be of great help for establishing a specific benthic "model" for the SLE-IRL system. A few examples of the extensive information available for this work include e.g: The Chesapeake Bay benthic community restoration goals (Ranasinghe et al. 1994), the Index for the northern Gulf of Mexico estuaries (Engle and Summers 1999), responses of tidal creek macrobenthic communities to the effects of watershed development (Lerberg et al. 2000), the biodiversity links above and below the marine sediment-water interface that may influence community stability (Austen et al. 2002), an approach to the intercalibration of benthic ecological status assessment in the North Atlantic ecoregion, according to the European Water Framework Directive (Borja et al. 2005, 2006), the covariation between physical factors and long-term variation of the marine soft bottom macrofauna (Hagberg and Tunberg 2000), and benthic response to pelagic fronts (Josefson and Conley 1997).

6.2 Assessment Tools Needed

The established customized database, the multivariate analysis software (PRIMER), and software for additional analyses (Systat 11) will be used as the primary assessment tools. Data management links to other databases (e.g., dbHydro water quality and hydrology) are under development

7.0 Notes

This Performance Measure supersedes and addresses NE-13 Northern Estuaries Benthic Macroinvertebrates (Last Date Revised: Sep 22, 2005).

8.0 Working Group Members

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