

1.0 Performance Measure Title

Southern Estuaries Submerged Aquatic Vegetation

Last Date Revised: December 30, 2004

2.0 Justification

One of the main biological targets of CERP for the restoration of Florida Bay and Biscayne Bay is improved seagrass habitat. Seagrasses are the dominant estuarine communities to be affected by the CERP, and they provide the majority of the fisheries habitat. Continuation of existing seagrass monitoring programs and expansion of sampling into areas likely to be affected by CERP projects will provide an effective approach to track the net effects of CERP-related changes in critical ecosystem parameters (e.g., salinity, water quality, phytoplankton, etc.) on seagrass habitats. Seagrass-habitat assessment will also provide valuable verification data for current and future modeling efforts. Current conditions include various stages of seagrass die-off and recovery in Florida Bay, limited coverage and duration of seasonally-occurring SAV beds in the coastal lakes and basins of the Everglades-Florida Bay ecotone, and absence of seagrass in extensive areas of nearshore habitat along the western shoreline of Biscayne Bay, particular near canals mouths where extreme salinity variations occur. In Florida Bay, the goal is to recover seagrass beds over most of bay bottom, extending west along the Gulf of Mexico coastal shelf to Lostman's River and restore a diverse mosaic of *Thalassia*, *Halodule*, *Ruppia* and *Syringodium* seagrass communities in Florida Bay. For south Biscayne Bay, the goal is to increase cover of seagrass beds, consisting primarily of species tolerant of lower salinities, e.g., *Halodule*, in nearshore areas that are presently devoid of stable seagrass communities. For north Biscayne Bay, the goal is to maintain current seagrass communities. In the Everglades Mangrove Estuaries, the goal is to increase cover and seasonal duration of *Ruppia*, *Chara*, *Najas* and *Utricularia* in coastal lakes and basins.

The Florida Bay Florida Keys Feasibility Study approaches the assessment of seagrasses by looking at three critical components: species composition, community coverage, and biomass. Seagrasses are the dominant biological community in Florida Bay, historically covering over 90% of the 180,000 ha of subtidal mudbanks and basins in Florida Bay (Zieman et al. 1989). Seagrasses act as integrators of net changes in water quality variables, which tend to exhibit rapid and wide fluctuations. Thus, the status of seagrass communities reflects larger, landscape-scale processes, and can reflect underlying ecological problems (Durako et al. 2002). Seagrasses provide food and shelter to numerous fish and invertebrate species, including many of commercial importance within the region (Powell et al. 1989; Thayler and Chester 1989; Tilmant 1989; Chester and Thayer 1990). Therefore, in addition to being an indicator of some importance, the seagrass community is a resource on which numerous higher-order processes depend.

Selection of targets for seagrass performance measures is based on paleoecological studies, anecdotal history, and recent research and monitoring. A consensus exists that the extremely dense and largely monospecific *Thalassia* beds that were widespread in central and western Florida Bay prior to the initial die-off event (1987) were an anomalous community condition (Fourqurean et al. 2002). The cause of this condition is not well understood, but likely related to human activity in general and salinity alterations in particular. Based on paleoecological studies, seagrass communities in the central-eastern bay (near Bob Allen and Russell Keys) appear to have been less dense prior to the 1950s than currently. Based on empirical and experimental data on salinity tolerances and optimal ranges, it is likely that *Ruppia* and *Halodule* were far more common in Florida Bay prior to canal construction in the 20th century. As fresh water flow to Florida Bay increases, there could be an overall community decrease in biomass (particularly in Zones 1, 3, 4, and 5) in association with a structural shift from the dominance of *Thalassia* to more diverse seagrass beds that include *Halodule* and *Ruppia*. Thus, an explicit restoration target is an increase in the contribution of these species in the bay's seagrass community, with *Ruppia* becoming increasingly dominant near the northern bay boundary and *Halodule* becoming co-dominant with *Thalassia* through much of the bay.

Species Composition

The restoration target for community composition is an increase in species that are currently less dominant in the

bay's overall seagrass community. This response is projected to develop to differing degrees in different parts of the estuary, depending on the quantity and distribution of fresh water flow.

It is expected that two factors will increase SAV diversity in the bay. First, the introduction of additional fresh water will expand the zone of favorability for species with tolerance for low salinity, increasing the penetration of these populations from the land margin toward the central bay. Because *Thalassia* can tolerate some reduction in salinity, existing populations of *Thalassia* will likely not be eliminated from some of the affected zones, but be reduced in density, having the effect of overall increasing diversity. Secondly, increased fresh water inputs, delivered on a natural seasonal hydrologic schedule, will increase environmental variability in the water column and osmotic stress in plants. This naturally pulsed stress will likely result in the expansion of ecological niches in various zones most influenced by fresh water flow (zones 13, 14, 1, 2, 15, 5, 3). Adjacent zones not as strongly impacted by salinity change, but influenced by secondary factors (water color, nutrients, turbidity) should experience pulsing stress and expansion of niche space as well. It is well-recognized that moderately perturbed systems often respond with increased community productivity and diversity. In general, anticipated changes are that *Ruppia* distributions will expand spatially, and become dominant in the transition zone basins (zones 1, 15) and along the northern bay boundary. *Halodule* is expected to become co-dominant with *Thalassia* and *Ruppia* through much of the northern and central bay. *Thalassia* is expected to become less dominant in all transition zone basins (zones 13, 1, 15), zones adjacent to the fresh water input (14, 2, 5, 16), the central bay (zone 3), and to a lesser extent in the western bay (zone 4). *Syringodium* is projected to be least affected by restoration activities as it is distributed farthest from the area of fresh water flow, possibly benefiting from pulsing stress in zones 4, 6, 7, 8, 9, 16.

Community Coverage

In 1987, a widespread die-off of the dominant seagrass species, *Thalassia testudinum* occurred in the central and western basins of Florida Bay (Robblee et al., 1991). By 1990, 4,000 ha were completely lost and 24,000 ha were affected by the primary die-off. Several years after the initiation of the primary die-off, Florida Bay started exhibiting chronic turbidity with concomitant decline (a "secondary die-off") in *Thalassia testudinum* in Johnson Key Basin and Rankin Lake (Stumpf et al., 1999). Increased turbidity was due to cyanobacteria-dominated microalgal blooms and resuspended sediments associated with the loss of seagrass. This resulted in a negative feedback loop in which the loss of seagrass cover from the die-off led to exposed, easily resuspended sediments diminishing light availability, and more, widespread loss of seagrass. Conceptual models have been developed to assess the mechanisms and conditions leading up to the die-off. Details are provided in a recent review of Florida Bay seagrass research (PMC 2003).

Accordingly, the fundamental target for total SAV community coverage is to maximize coverage by SAV beds at sustainable levels. It is expected that CERP activities will support SAV growth where sediment and water depth are appropriate for such growth. The absence of SAV in areas with soft sediments is considered highly detrimental because this enables sediments to be readily suspended, decreasing light penetration, and threatening the viability of nearby SAV beds. The targeted range of coverage varies through the Bay and is partially dependent on species composition. For areas that are expected to be dominated by *Thalassia* (particularly western and central Florida Bay), very high density for the total community is considered detrimental because high density *Thalassia* is considered to be a precursor of die-off events. However, the target range for these zones is set for maximum coverage (5) because the performance measures for species composition are designed to establish a mixed-dominance of species for each zone. If targets are not achieved, and coverage values of 5 are achieved for *Thalassia*, the seagrass community may be in an unsustainable condition. Thus, if targets are not achieved, then the targeted Braun-Blanquet coverage would be reduced to 4 for Florida Bay (Zones 3, 4, 5, 6, and 16).

Biomass

The overall target for SAV biomass in Florida Bay is to maximize seagrass biomass while preventing monoculture or overly dense growth. Seagrass meadows are well-known as among the most productive aquatic communities, often supporting up to 400 g dry weight m⁻² in biomass (Hemminga and Duarte, 2000). Standing stock varies among species, with *Thalassia* able to attain much greater biomass densities than *Halodule* or *Ruppia*. Species

composition is expected to change in response to restoration and increased fresh water input, and a decrease in biomass may result in some nearshore areas, depending on the target species. Both *Ruppia* and especially *Halodule* have far less biomass per plant and per m² than *Thalassia*. Even in some areas where *Thalassia* is targeted to continue as the dominant species, a reduction in biomass is expected (and desired) as the performance target due to three factors:

- 1) Although *Thalassia* may be dominant, a mix of species is ecologically important. Enhancement of species of lower biomass, at the expense of *Thalassia*, will reduce overall biomass within a zone
- 2) In an effort to prevent a dense and precarious overgrowth, a biomass target for *Thalassia* is established that is in some zones lower than current levels, and
- 3) In some zones close to fresh water sources (especially zones 15 and 5), during the wet season, natural environmental variability and osmotic stress may increase, resulting in greater variability and a reduction in seagrass biomass.

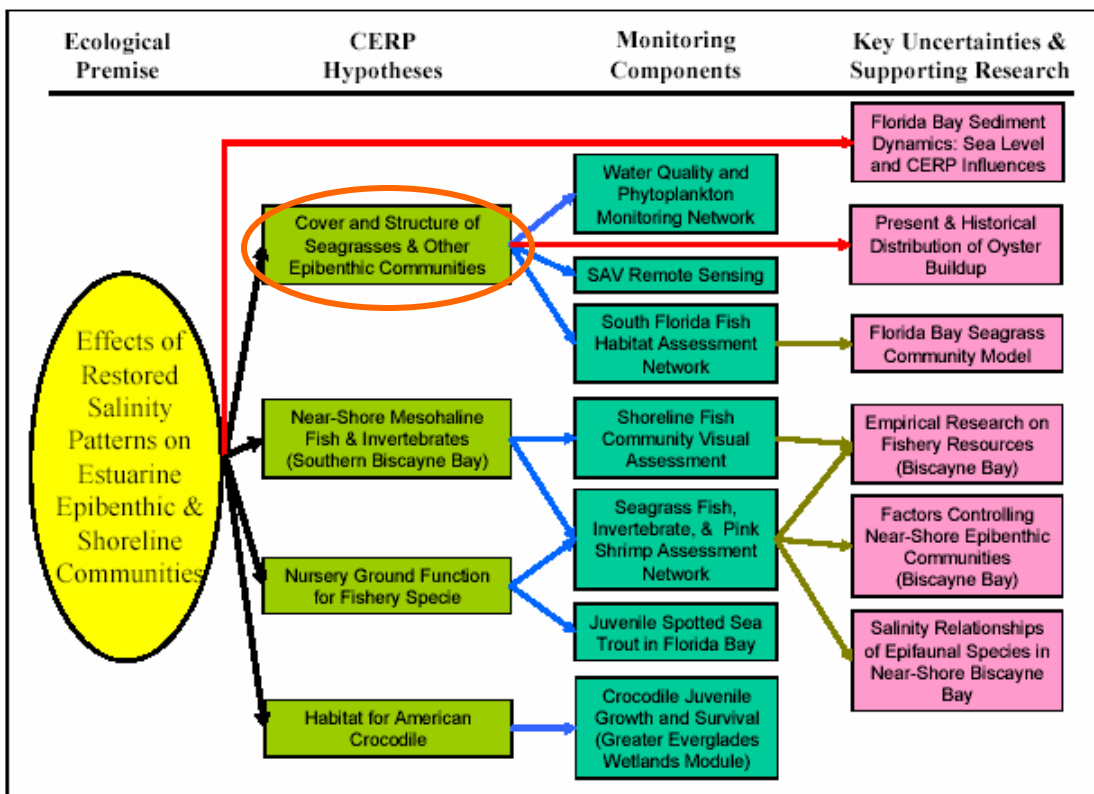
3.0 Relationship to CEMs and Adaptive Assessment Hypotheses

Everglades Mangrove Estuaries, Florida Bay, and Biscayne Bay Conceptual Ecological Models attribute (RECOVER 2004b)

Ecological Premise: Prior to upstream water management, mesohaline salinity conditions with fewer extremes in the coastal environments of Biscayne Bay, Florida Bay, and the southwest Florida coast supported broader coverage and higher diversity of seagrass and other epibenthic communities. These communities, in combination with prop-root habitats of mangrove shorelines, provided habitat for higher densities of valued estuarine fauna, including juvenile and adult stages of several economically important

CERP Hypotheses: The restoration of favorable flow and salinity regimes will result in the following:

- Extend the range of *Halodule* seaward into the near-shore environment of Biscayne Bay
- Increase seagrass cover and diversity in Florida Bay, reduce the region of *Thalassia* overdominance, and increase both *Halodule* and *Ruppia* cover
- Enhance the productivity of near-shore mesohaline fish and invertebrates in south Biscayne Bay, resulting in higher abundances of mesohaline forms and lower abundances of purely marine forms such as some reef fishes
- Extend the spatial extent of high concentrations of pink shrimp further south in Biscayne Bay
- Enhance the function of Florida Bay, the mangrove estuaries of the southwest coast, and Biscayne Bay as nursery grounds for fishery species, increasing the distribution and density of juvenile pink shrimp, spotted seatrout, and other species and resulting in higher yields in the pink shrimp
- Restore habitat for the endangered American crocodile



4.0 Desired Restoration Condition

In Florida Bay, recover seagrass beds over most of bay bottom, extending west along the Gulf of Mexico coastal shelf to Lostman’s River and restore a diverse mosaic of *Thalassia*, *Halodule*, *Ruppia* and *Syringodium* seagrass communities in Florida Bay. For south Biscayne Bay, increase cover of seagrass beds, consisting primarily of species tolerant of lower salinities, e.g., *Halodule*, in nearshore areas that are presently devoid of stable seagrass communities. For north Biscayne Bay, maintain current seagrass communities. In the Everglades Mangrove Estuaries, increase cover and seasonal duration of *Ruppia*, *Chara*, *Najas* and *Utricularia* in coastal lakes and basins.

4.1 Predictive Metric and Target

4.2 Assessment Parameter and Target

Species Composition

The model metric for species composition will be based on spatial coverage by each species, quantified in Braun-Blanquet units, which are defined as follows:

B-B Score	SAV Cover
0	Absence
0.1	single individual ramet (less than 5% cover)
0.5	few individual ramets (less than 5% cover)
1	many individual ramets (less than 5% cover)
2	5-25% cover
3	25-50% cover
4	50-75% cover
5	75-100% cover

Community Coverage

It is considered that the most appropriate measure of bottom coverage is areal coverage. The metric chosen for assessment of areal coverage is the Braun-Blanquet index of per cent bottom cover. Most calibration data, field data and field monitoring programs in south Florida employ Braun-Blanquet for monitoring seagrass responses on a large spatial scale (Durako et al. 2001). The model metric for species composition will be based on spatial coverage by all seagrass, quantified in Braun-Blanquet units (above).

There are three components of community composition performance measure-

- 1) evaluates the areal coverage of the bed using Braun-Blanquet criteria. Units = Percent of bottom within a zone that is covered by submersed aquatic vegetation
- 2) evaluates the occurrence of die-back areas or blow-out holes. Units = Number of occurrences per zone per year of a die-back incident.
- 3) evaluates the intra-annual variability of seagrass coverage.

1. The concept of the coverage criterion measure derives from an understanding that it is desirable to maximize areal coverage of the rooted aquatic community, regardless of species. Having established conditions in the bay that support a seagrass community, assessment of the ecological balance required for a diverse species mix is further refined by the criteria detailed by SAV performance targets. Because nutrient limitation is and historically was likely to be operative in the northeast bay (Fourqurean 1992), it is expected that maximum Braun-Blanquet densities will be lower there than in other zones, and target values are established accordingly lower for zone 2 (score = 3) and zones 1, 13, and 14 (score= 4). It should also be noted that the coverage target has a dependence on species composition. For Florida Bay zones where die-off events are most likely (zones 3,4,5,6), maximum coverage should be lower (score = 4) when coverage is monospecific with *Thalassia testudinum* than when coverage is by multiple species (see Justification below). It should also be noted that the targets specified for 1 (above) are temporally (multiannual) and spatially averaged values.

2. Losses is a special case of 1, where the model is used to assess the cause of low Braun-Blanquet scores. Loss of seagrass by die-off is particularly undesirable because such loss is not simply a response to temporary stress, an above ground defoliation, or a transient reallocation of resources- it represents the death of the plant and behaves epidemiologically as a contagion. The prerequisites for invoking this performance measure are that the dominant species in the zone is *Thalassia testudinum* and that the loss of coverage is sudden and in response to meristem death, with initial coverage of at least 50% decreasing to less than 5% cover in less than one year.

3. Temporal variability tracks the seasonal variability of seagrass community coverage. Variability in the extent and density of seagrass distributions occurs naturally. Seasonally, areas dominated by *Ruppia maritima* seem to be highly variable, often going to zero and rapidly recovering in response to either climate or salinity variability. Though the exact nature of the oscillation is not known, a variability performance measure is established for each zone depending on the projected dominant species. In areas where *Thalassia* dominates, the target variability is set at 25% change in peak summer coverage between the wet and dry season. In zones where *Ruppia* dominates, the target variability is set at 100% change in coverage, with the target requiring re-growth to 50% of the previous maximum within one hydrologic cycle (wet-dry period).

Biomass

The first component of the SAV biomass performance measure is mean annual biomass that is spatially averaged per zone or per sub-zone, as indicated. The second component is a metric that reflects seasonal variability, with the calculation of mean changes between wet and dry seasons. With restoration of freshwater flow to zones that have been deprived of natural flow (e.g. zones 15 and 5), greater seasonal salinity variability is likely and this is expected to induce greater variability in plant response, species composition and biomass within those zones. In contrast, some zones (e.g. zones 1 and 13) are likely to experience decreased salinity variability and may exhibit decreased variability in SAV biomass. Variability in seasonal biomass is to be measured as the percent change of the mean

seasonal biomass versus the mean annual biomass. The third component is a metric that will be used to track the frequency of die-off events, where a die-off event is considered to be an abrupt (month to month) loss of dense *Thalassia* to to zero g m⁻², forming bare patches that are larger than a specified minimum map unit (100 m²). Species other than *Thalassia* do not experience the die-off phenomenon in Florida Bay.

5.0 Evaluation Application

5.1 Evaluation Protocol

Species Composition

The model outputs for this performance measure are to be reported as the mean of an appropriate number of randomly selected simulated quadrats for each zone or sub-zone:

- 1) Identification of the dominant species by Braun-Blanquet areal coverage
- 2) Quantification of the relative Braun-Blanquet coverage for each species in a zone, expressed as four Braun-Blanquet scores in the order: Tt, Sf, Hw, Rm
- 3) Qualitative expression of the seasonally averaged transition from current community composition to a new composition, probably with the first 5 y of restoration. The trend targeted is for coverage by four target species in this order: Tt Sf Hw Rm, by indicating either: “+,” “0,” or “-“ to mean: increase, no change, decrease in Braun-Blanquet score from the initial structure.

Values are to be represented as calculated monthly means over a minimum ten-year period, and annual mean species composition scores are to be generated.

While variability occurs in the natural system, the intra-annual or monthly quantification of variability is not a useful index in the assessment of species composition. Assuming that the monthly performance targets are achieved, it is anticipated that variability in species composition is not relevant to this metric.

The targets for 1 and 2 are valid for the ten year projections. Because 3 is a trend analysis, and species compositions are expected to stabilize after some years of the simulation (assuming Year 1 is implementation of the alternative), the targeted changes will be expected to occur within the first five years. After Year 5, populations will be assumed to be in steady state and the target values for 3 for all zones will convert to: 0,0,0,0.

ZONE	Dominance	Coverage	Trend
		Tt Sf Hw Rm	Tt Sf Hw Rm
1	Rm	0,0,3,5	-,0,+,+
2	North: Rm South: Hw or Tt	North: 3,0,3,5 South: 4,0,4,1	North: -,0,+,+ South: 0,0,+,+
3	North: Rm or Hw South: Hw or Tt	North: 3,0,4,4 South: 4,0,4,1	North: -,0,+,+ South: 0,0,+,+
4	Tt	4,2,3,1	0,0,+,+
5	Rm or Hw	2,0,3,4	-,0,+,+
6	Tt	4,2,3,0	0,0,+,0
7	Tt or Sf	4,5,3,0	0,0,+,0
8	Tt or Sf	4,5,3,0	0,0,+,0
9	Tt or Sf	4,5,3,0	0,0,0,0
10	Tt	4, 3,2,0	0,0,0,0
11	Tt	4,3,2,0	0,0,0,0
12	Tt	4,3,2,0	0,0,0,0
13	North: Rm or Hw South: Hw or Tt	North: 2,0,3,4 South: 3,0,4,1	North: -,0,+,+ South: 0,0,+,+
14	North: Rm South: Tt or Hw	North: 2,0,3,4 South: 4,0,3,1	North: -,0,+,+ South: 0,0,+,+

15	Rm	0,0,1,5	0,0,0,+
16	Tt or Hw	4,3,4,1	0,0,+,+

Community Coverage

Values are to be represented as calculated monthly means over a minimum ten-year period; monthly, seasonal and annual mean coverage scores are to be generated.

Target performance metrics for the SAV PMs are presented here. The targets for SAV.SC.PM-1 and SAV.SC.PM-2 and SAV.SC.PM-3 for dry and wet seasons are valid for the ten year projections.

ZONE	Cover	Die-back	Seasonal Variability
1	4	0	<100%
2	3	0	<100%
3	4 or 5	0	<25%
4	4 or 5	0	<25%
5	4 or 5	0	<25%
6	4 or 5	0	<25%
7	5	0	<25%
8	5	0	<25%
9	5	0	<25%
10	5	0	<25%
11	5	0	<25%
12	5	0	<25%
13	4	0	<25%
14	4	0	<50%
15	5	0	<25%
16	5	0	<25%

Biomass

Values are to be represented as calculated monthly means over a minimum ten-year period. The calculation of seagrass biomass should be iterated with a subdaily timestep (ideally 3 h), and the output averaged over one week to estimate mean above ground biomass (g m^{-2}) in several simulated one square meter quadrats for each species in each zone. Monthly, seasonal (dry: December-May; wet June- November) and annual mean biomass densities are to be generated.

Target performance metrics for the SAV biomass performance measures are presented here. The targets for SAV.B.PM-1, SAV.B.PM-2 and SAV.B.PM-3 are valid for a minimum of ten year projections. SAV.B.PM-1 units are mean annual biomass in dry weight m^{-2} ; SAV.B.PM-2 units are % deviation of mean wet and dry season biomass from the annual mean; SAV.B.PM-3 is the number of occurrences of die-off per zone for *Thalassia* only, per year. The SAV.B.PM-1 target range is $\pm 20\%$ of the stated criterion. Monthly values should not fall outside the target envelope more than two times consecutively or four times cumulatively per water year (June-June). SAV.B.PM-2 is a per cent difference between wet and dry season biomass means and as such, are calculated only one time per water year. The stated envelopes cover a fairly large range and values should not fall outside this range. For SAV.B.PM-3, biomass goes to zero according to the criteria established in PM components section above. The criterion for this PM (zero in all cases) should not be exceeded at all during the water year. For all three biomass performance measures, the annual quantity of the metric and the frequency of annual exceedences (years over the evaluation period) will be reported.

ZONE	Biomass	Variability	Die-off
1	50	Wet: 50 to 100% Dry: 50% to 100%	0
2	50	North Wet: 50 to 100% Dry: 50% to 100% South Wet: 25 to 50% Dry: 25% to 50%	0
3	North: 200 South:	North Wet: 50 to 100% Dry: 50% to 100% South Wet: 25 to 50% Dry: 25% to 50%	0
4	200	North Wet: 50 to 100% Dry: 50% to 100% South Wet: 25 to 50% Dry: 25% to 50%	0
5	150	Wet: 50 to 100% Dry: 50% to 100%	0
6	100	Wet: 25 to 50% Dry: 25% to 50%	0
7	200	Wet: 25 to 50% Dry: 25% to 50%	0
8	200	Wet: 25 to 50% Dry: 25% to 50%	0
9	200	Wet: 25 to 50% Dry: 25% to 50%	0
10	150	Wet: 25 to 50% Dry: 25% to 50%	0
11	150	Wet: 25 to 50% Dry: 25% to 50%	0
12	150	Wet: 25 to 50% Dry: 25% to 50%	0
13	North: 300 South:	Wet: 50 to 100% Dry: 50% to 100%	0
14	North: 50 South:	Wet: 50 to 100% Dry: 50% to 100%	0
15	75	Wet: 50 to 100% Dry: 50% to 100%	0
16	200	Wet: 50 to 100% Dry: 50% to 100%	0
5.2 Normalized Performance Output			

5.3 Model Output (example attached)	
5.4 Uncertainty	
6.0 Monitoring and Assessment Approach	
See <i>CERP Monitoring and Assessment Plan: Part 1 Monitoring and Supporting Research</i> - Southern Estuaries Module section 3.2.3.3 - 3.2.3.4 (RECOVER 2004a)	
See <i>The RECOVER Team's Recommendations for Interim Goals and Interim Targets for the Comprehensive Everglades Restoration Plan</i> – Interim Goal 4.2 Submerged Aquatic Vegetation in Southern Estuaries (RECOVER 2005)	
7.0 Future Tool Development to Support Performance Measure	
7.1 Evaluation Tools Needed	
7.2 Assessment Tools Needed	
8.0 Notes	
This Performance Measure supersedes and addresses SE-10 Southern Estuaries Submerged Aquatic Vegetation (Florida Bay and Biscayne Bay), (Last Date Revised: December 30, 2004).	
9.0 Working Group Members	
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ET	
AT	
Public Review	
Final Acceptance Date	
11.0 References	
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