Southern Coastal Systems Performance Measure
Juvenile Spotted Seatrout Habitat Quality

Last Date Revised: February 16, 2017

Acceptance Status: Accepted

1.0 Desired Restoration Condition

Restoration of natural salinity distributions in bays and estuaries should provide higher quality nursery habitat for juvenile sportfish over an expanded area. The expansion of high quality nursery habitat will result in increased recruitment success, survivorship, and growth. Thus, if adult sportfish populations are not adversely impacted by externalities outside of the control of the Comprehensive Everglades Restoration Plan (CERP) (e.g. increase in fishing pressure, climate change, etc.) their populations are likely to increase, translating into increased recreational fishery catch rates.

The spotted seatrout, *Cynoscion nebulosus*, is one of the most commonly caught recreational sportfish in Florida Bay (Tilmant, 1989). This species is an established indicator of estuarine health (Bortone, 2002) with juvenile stages found to be adversely affected by hypersalinity in north-central Florida Bay (Powell et al., 2007). This hypersalinity is more intense and ecologically damaging, because of reductions from historic freshwater runoff (Marshall, 2016). The anticipated increases in freshwater runoff and associated decreases in Florida Bay salinity due to CERP should increase the distribution, abundance, growth and survival of juvenile spotted seatrout in north-central and western Florida Bay. The targets described below use frequency of occurrence of juvenile spotted seatrout and its associated habitat suitability as both the evaluation and assessment metric. These targets and metrics will be refined based on continuing detailed analysis of CERP Monitoring and Assessment Plan (MAP) data and values derived from modeling efforts, particularly concerning the current paleo-Natural System Model (NSM) target for salinity in Florida Bay.

1.1 Predictive Metric and Target

The metric proposed to evaluate potential individual projects and to assess the progress of CERP implementation is the frequency of occurrence of juvenile spotted seatrout (defined as spotted seatrout from 30-200 mm total length, because this is the size range effectively sampled in the RECOVER MAP monitoring protocols) in otter trawls. For assessment of already implemented project effects and progress on CERP implementation, the frequency of occurrence is calculated from observed data and compared to the baseline and full restoration target. To evaluate the potential effect of proposed restoration projects, frequency of occurrence is predicted based upon predicted habitat suitability for 3 scenarios; 1) future with this project, 2) future without this project, and 3) full restoration. Each otter trawl samples approximately a 400m^2 area. For evaluations that require predictions, the frequency of occurrence metric is used to calculate area of suitable habitat. The suitability of the habitat is predicted from a logistic regression of frequency occurrence upon three habitat parameters (salinity, temperature, and in the future seagrass percent cover) expected to change in response to CERP or due to factors outside the control of CERP during CERP's lifetime (e.g., climate change). The target is for the distribution of suitable habitat for juvenile spotted seatrout to match the distribution that would occur if salinity and seagrass CERP performance measures were achieved.

1.2 Assessment Parameters and Targets

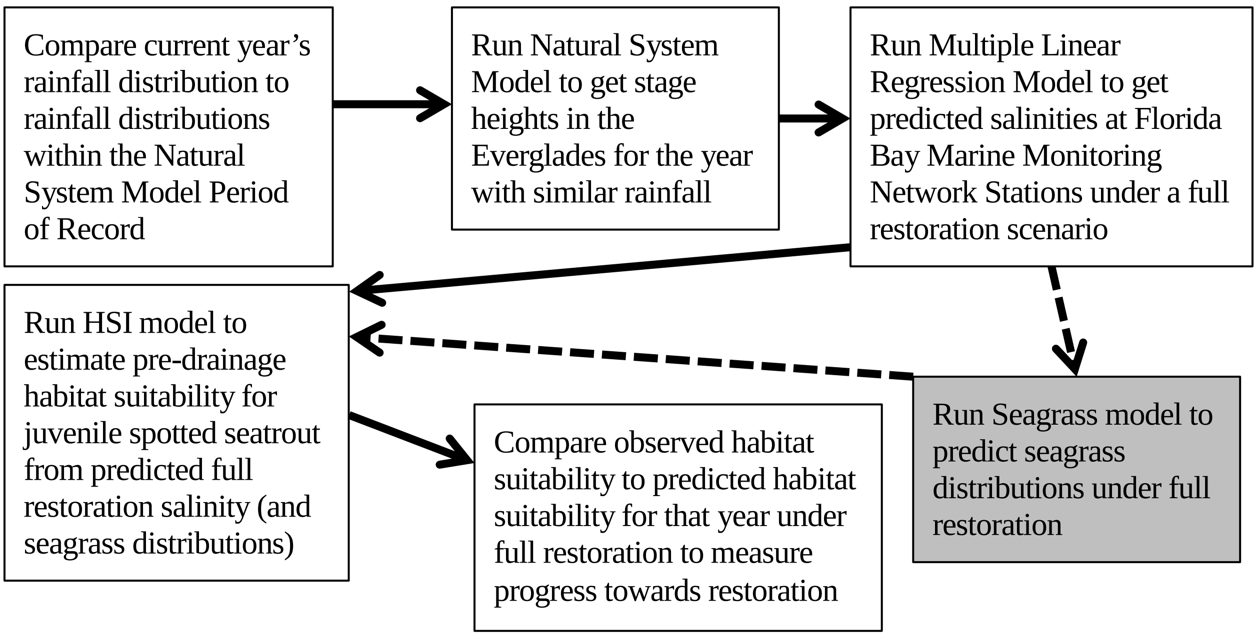

Figure 1. The above flow chart depicts the steps undertaken to use the juvenile spotted seatrout performance measure to assess progress towards full restoration of Florida Bay sportfish habitat. The grey box for the seagrass model indicates that there is currently not an approved seagrass model for use in this performance measure. Thus, for current applications we assume seagrass distributions will remain the same as currently observed. In the future, it is anticipated that a seagrass model will be developed and incorporated into the HSI to improve predictions of juvenile spotted seatrout habitat quality.

The operational objective for juvenile spotted seatrout in CERP is to restore juvenile spotted seatrout frequency of occurrence and habitat suitability to the conditions that would have existed if the hydrology of the Everglades ecosystem had not been anthropogenically altered (i.e., the "pre-drainage" condition). To assess how well we are achieving this objective, we will compare observational data to predicted pre-drainage juvenile spotted seatrout habitat suitability (i.e., target) for the same year using models (Fig. 1). Habitat suitability index models predict salinity in the pre-drainage Florida Bay by deriving historical salinity conditions using simulated historical hydrologic conditions. Resources include data from either the Natural Systems Model (NSM) Version 4.6.2 or Natural System Regional System Model (NSRSM) (South Florida Water Management District and Interagency Modeling Center, 2005) and multiple linear regression models that estimate salinity response at all Marine Monitoring Network (MMN) stations in Florida Bay (*sensu* Marshall et al. 2011). The NSM salinity time series values at each MMN station are adjusted based on paleo-salinity information provided by U.S. Geological Survey studies in Florida Bay (Marshall et al. 2009, Marshall and Wingard 2012, Wingard et al. 2007, Wingard et al. 2010, Wingard and Hudley 2011). These adjustments provide a more accurate historical salinity condition than the unadjusted NSM provides. See the Florida Bay salinity performance measure documentation sheet for additional information (http://141.232.10.32/pm/recover/perf_se.aspx). The output from these models is the predicted salinity distributions for each target if the hydrology of the

Everglades is fully restored. Modeled salinity output will be input into a juvenile spotted seatrout Habitat Suitability Index (HSI) model from which juvenile spotted seatrout habitat suitability without drainage of the upstream Everglades will be calculated. Observed juvenile spotted seatrout habitat suitability will be compared to juvenile spotted seatrout habitat suitability modeled to estimate the habitat quality if the Everglades hydrology had been fully restored.

However, there is currently no overlap between our observational data set and NSM output. To overcome this lack of overlap, we compare monthly rainfall for the year of the observations (including the 6 months at the end of the previous year) to monthly rainfalls for the same time period (i.e., the current year and July through December of the preceding year) for years during which we have NSM output. The monthly rainfall data used in these analyses are from the NOAA National Climate Data Center's division 5 for Florida to identify similar rainfall distributions. NSM outputs for years with similar rainfall patterns can be used to estimate target salinities for each observational year. Rainfall similarities were determined by comparing absolute monthly differences in rainfall to net monthly differences in rainfall to determine the year with the lowest combined absolute and net monthly differences. For example, 1975 and 2009 were selected based on this analysis; anecdotally a visual comparison (Fig. 2) also suggests they had similar rainfall patterns.

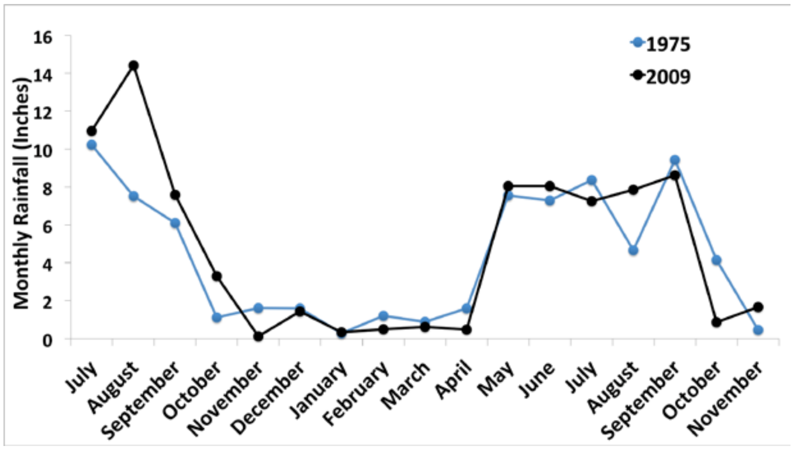

Figure 2. Monthly rainfall for 2009 and the preceding six months in 2008 compared to the same time period for 1975; the year determined to have the most similar rainfall pattern to 2009.

The first step in creating the HSI model was to develop the best model using MAP observational data for both environmental parameters and juvenile spotted seatrout occurrence collected from 2004-2012. The HSI was calculated using a logistic regression to quantify the impact of various water quality parameters (temperature, salinity, water depth, tow duration, turbidity) collected concurrently with juvenile spotted seatrout frequency of occurrence observations. The logistic regression was also calculated with data from Everglades marine monitoring network stations to see if using preceding salinity conditions (e.g. mean monthly salinity, maximum salinity in the preceding month, etc.) improved the predictive ability of the model. However, the salinity at time of collection was found to be a better predictor of habitat suitability for juvenile spotted seatrout than the marine monitoring network salinities. This may be due to the large degree of spatial heterogeneity displayed by water quality on Florida Bay (Boyer et al., 1997; Fourqurean et al., 1993; Kelble et al., 2007). The spatial heterogeneity might result in spatially co-located data being more informative than temporally resolved, but low spatial resolution marine monitoring network salinity data. The logistic regression based solely on water quality displayed significant dependencies on salinity, temperature, and depth ($p<0.05$). The dependency of the probability of observing a juvenile spotted seatrout on both depth and temperature could be a result of the tight correlation of these two variables. For simplicity, the relationship of the probability of observing a juvenile spotted seatrout with temperature and salinity is presented (Fig. 3).

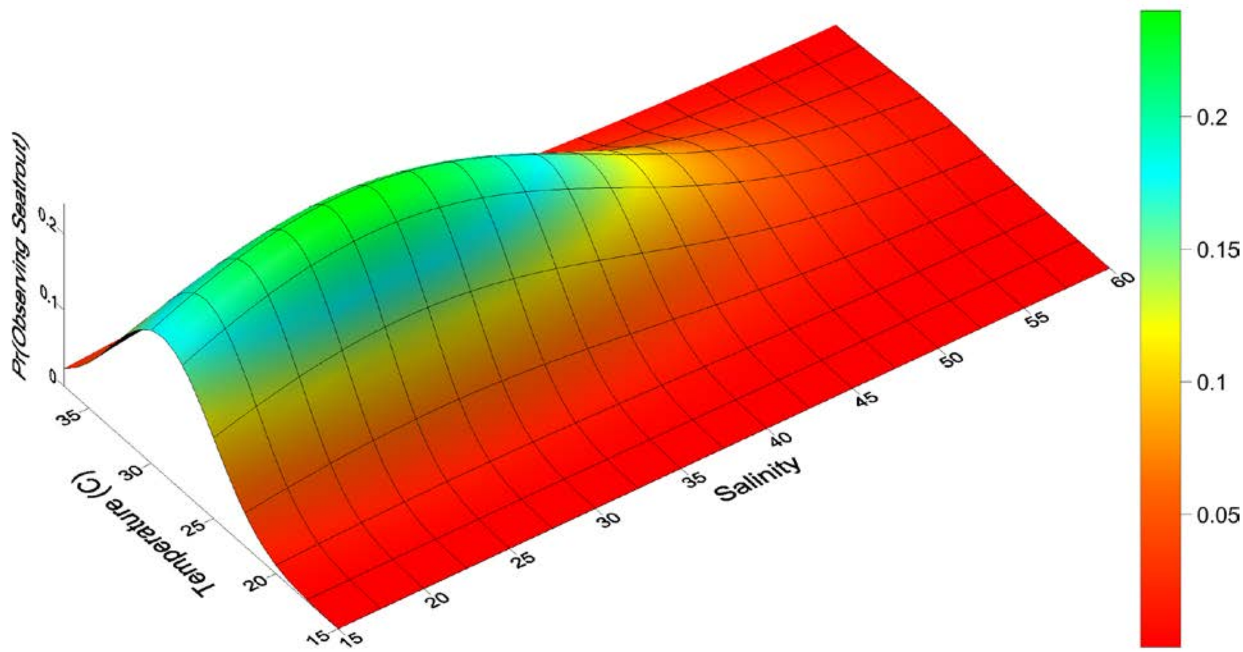

Figure 3. The probability of juvenile spotted seatrout observation across the range of salinity and temperatures in Florida Bay extracted from the logistic regression.

This is the best model to predict juvenile spotted seatrout habitat suitability when you have environmental measures for the point in time you are trying to predict. However, when attempting to predict from modeled salinity values we do not have salinity values on a time-scale or space-scale similar to these environmental observations. Rather the multiple regression models predict monthly mean salinity, maximum salinity, and minimum salinity at the marine monitoring network stations in Florida Bay (Marshall et al., 2011). Thus, instead of using instantaneous salinity we have to use monthly salinity and temperature metrics in the HSI and spatially interpolate these values to the rest of the study area to predict the restored habitat suitability.

Another aspect of assessing restoration impacts on juvenile spotted seatrout will focus on determining the effect of individual CERP projects during and after construction. In fact, the assessment of CERP project effects on juvenile spotted seatrout habitat has already begun with the assessment of impacts from the C-111 Spreader Canal Western Project. This assessment employs a Before-After-Control-Impact analysis with samples paired in time (BACIP) to determine if there was a significant difference (de Mutsert and Cowan, 2012) between juvenile spotted seatrout frequency of occurrence before and after the completion of construction. The BACIP assumes any natural variation in the impact site that is not due to the project being constructed will be accounted for by using a nearby control site with the same natural variability, but unaffected by the restoration project. The BACIP uses a paired t-test to determine if the differences between the impact and control site are significantly affected by the restoration project. This also enables one to quantify the mean change and variability in the differences between the two sites before and after project implementation. This allows for quantification of the effect of the restoration project with 95% confidence intervals.

While this assessment focused directly on the frequency of occurrence, the same BACIP analysis can be conducted on the predicted habitat suitability from the process described using the same model as used for predictive metric and target to evaluate potential restoration effects. This is necessary to capture increases in suitable habitat that may occur with no increase in juvenile spotted seatrout abundance, because the population was adversely affected by another external factor, such as fishing or extreme cold weather occurring outside the sampling period, thus, decreasing the adult population, or due to the lag between the creation of suitable habitat and the increase in juvenile spotted seatrout observations. This lag could potentially be as long as a decade given the life span of spotted seatrout is 7-10 years. The assessment would employ the BACIP test to determine if habitat for spotted seatrout had significantly changed.

2.0 Justification

Fish are important to humans, not only as a source of food and recreation, but also as an indicator of ecosystem function and health. Fish communities are interlinked and interdependent to the extent that environmental problems in an estuary may translate into adverse impacts on both local estuarine fish communities and fish communities offshore; for example, pelagic and reef fish may feed on fish and invertebrates produced in brackish to moderate salinity zones, or rely on such zones at some stage during their life cycle. Estuaries are responsible for a disproportionately large proportion of world fishery production (Houde and Rutherford, 1993). Those species inhabiting estuaries during some or all of their life cycle are especially vulnerable to anthropogenic influences (Beck et al. 2001), including changes in the volume, timing, and quality of freshwater inflow. Poor water quality resulting in depressed dissolved oxygen content or uncharacteristic salinity patterns (e.g. steep or inverse salinity gradients; abrupt salinity changes; inappropriate salinities for a given time of year; and frequent and intense hypersalinity events) may cause direct mortality, inhibit reproduction, reduce food production or cause fish to avoid an area for physiological reasons. Estuarine conditions that disrupt lower trophic level organisms such as shrimp, clams, or crabs may also adversely affect nearshore and offshore fish communities. Thus, fish are excellent indicators of ecosystem health (Hughes et al. 2002).

Spotted seatrout, *Cynoscion nebulosus*, is an important recreational sportfish in Florida Bay and spends its entire life history within the Bay (Rutherford et al., 1989). They are the second most commonly caught gamefish and, along with grey snapper, account for over 60% of the recreational catch in Florida Bay (Tilmant 1989). The recreational fisheries associated with Everglades estuaries account for approximately $880M per annum contribution to south Florida's economy and represent greater than 6,000 jobs (Fedler et al., 2009). Furthermore, spotted seatrout is a well-established indicator of estuarine health (Bortone et al., 2001).

Because CERP is anticipated to significantly improve water quality, particularly salinity, estuarine fish communities should benefit from these lower salinities and more specifically a reduction in hypersaline conditions and thus are appropriate indicators of ecosystem health.

2.1 Justification for Juvenile Spotted Seatrout as the Performance Measure

A variety of variables have been correlated with juvenile spotted seatrout distribution, density, growth, recruitment and survival, including salinity, temperature, dissolved oxygen, sediment organic content, submerged aquatic vegetation (SAV), and forage base of small prey fish and pink shrimp (Baltz et al. 1998, Rutherford et al 1989, Chester and Thayer 1990, Hettler 1989, Helser et al. 1993). Juvenile and larval seatrout have demonstrated particular sensitivity to salinity and variation of salinity in both field and laboratory settings (Johnson and Seaman 1986, Peebles and Tolley 1988, Gray et al. 1991, Alshuth and Gilmore 1994, Serafy et al 1997, Baltz et al. 1998). Tolerable salinity ranges cited in literature are broad and dependent on habitat. Florida Bay is no exception with juvenile spotted seatrout frequency of occurrence decreasing significantly with increasing salinity (Fig. 4).

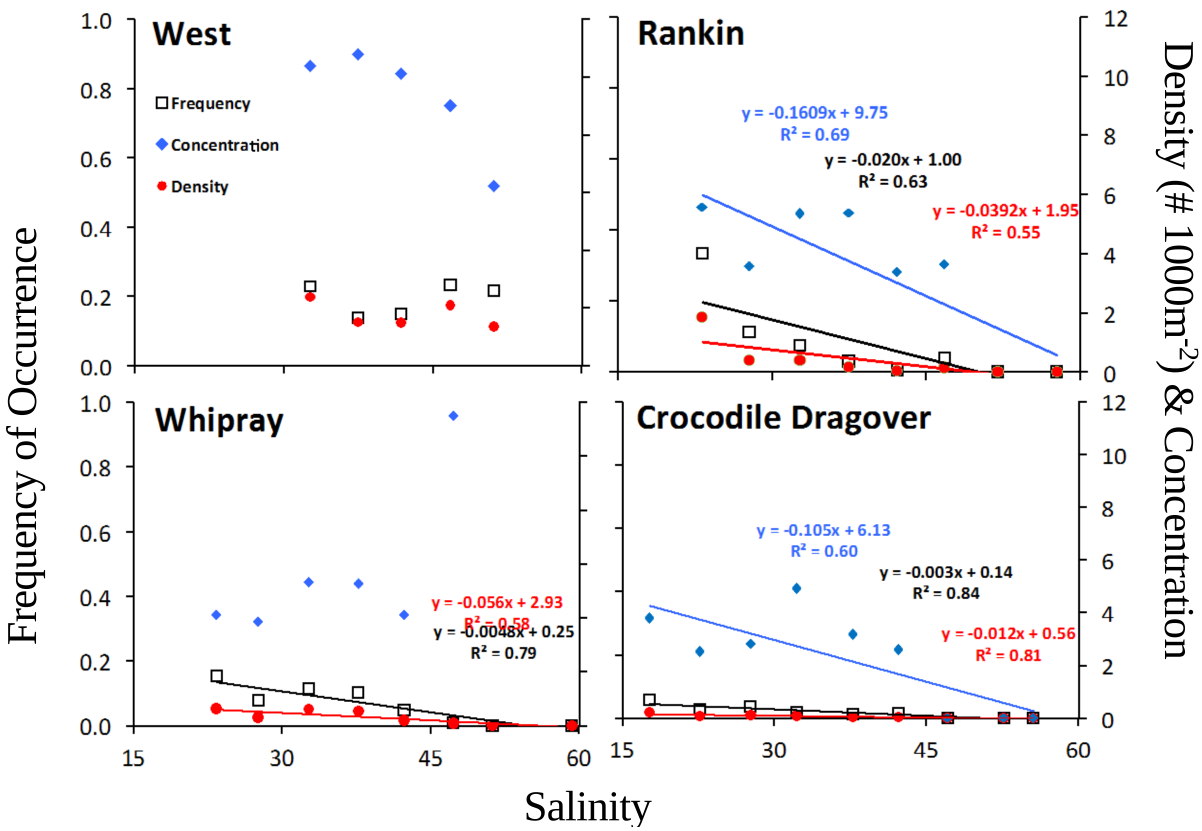

Figure 4. Scatter plots depict the relationship between the juvenile spotted seatrout population and salinity within each sub-region. The black boxes are frequency of occurrence, the blue diamonds are concentration and the red circles are density. Only significant linear regressions are depicted.

In work to support a bioenergetic model by Wuenschal (2002), salinities over 45 ppt appeared detrimental to the survival and growth of larval and juvenile seatrout in Florida Bay. Moreover, decreased metabolic rates detected at high temperatures (> 32°C) and higher salinities (> 35 ppt), suggest such conditions stress young seatrout (Wuenschal 2002). Conversely, very low salinities can detrimentally affect seatrout abundance. Serafy et al. (1997) found that freshwater pulses that induce large, rapid drops in salinity can cause mortality in juvenile seatrout.

In 1984-1985, seatrout were limited primarily to the western portion of the bay and absent from the north-central part of the bay, where hypersaline conditions prevailed. During 1994-1996, when hypersaline conditions in the north-central area of the bay were rare or absent, the spotted seatrout juveniles expanded into this area (Thayer et al. 1999). Moreover, Powell (2003) reported substantial numbers of larval spotted seatrout in Whipray Basin from 1994-1999, but few of these larvae survived to become juveniles except when seatrout-conducive salinities were present during 1994 and 1995.

Spotted seatrout generally spawn multiple times between March and October at temperatures between 27°C and 35°C (Powell, 2003). The geographic distribution of juvenile (20-100 mm SL, 35-100 days old) *Cynoscion nebulosus* varies in response to salinity conditions, seagrass characteristics, and sediment types in Florida Bay (Thayer and Chester 1989). Western Florida Bay is excellent habitat for juvenile spotted seatrout (Thayer et al., 1987; Thayer and Chester, 1989), whereas the north-central part of the bay is less suitable. In 1984-1985, seatrout distributions were limited primarily to the western portion of the bay and absent from the north-central part of the bay, where hypersaline conditions prevailed. Hypersaline conditions are characteristic of the north-central sub-region of Florida Bay (Orlando et al.1997, Kelble et al. 2007), although they are alleviated with increased freshwater inflow (Lee et al. 2008), as demonstrated by the period of unusually high rainfall beginning in 1994.

Hypersaline conditions routinely occur in the north-central sub-region of Florida Bay (Kelble et al. 2007), and alleviating hypersalinity frequency and duration is an interim goal of CERP (RECOVER 2005). Given the sensitivity of juvenile spotted seatrout to salinity, the distribution and abundance of the species was deemed an appropriate biological indicator for evaluating CERP-related changes in Florida Bay (RECOVER 2008). Accordingly, spotted seatrout are used as a component of the estuarine fish community performance measure for the Southern Coastal System. Field surveys conducted in Florida Bay since the mid-1980s demonstrate patterns in distribution of sub-adult seatrout and are used in CERP analyses for seatrout (Thayer et al. 1999, Powell 2003). Routine sampling of juvenile spotted seatrout as part of the MAP began in 2004 and has been ongoing. Power analyses have been conducted on both pre-MAP and MAP (2004-2010) data, and significant changes in the frequency of occurrence of seatrout in four sub-regions in Florida Bay were detected. A HSI, with salinity, temperature, and SAV as primary drivers, has been developed that can predict the habitat suitability distribution for juvenile spotted seatrout. This HSI and the MAP seatrout data are the basis for the predictive and assessment components of the performance measure described below.

3.0 Scientific Basis

3.1 Relationship to Conceptual Ecological Models

In the total system conceptual ecological model, juvenile spotted seatrout represent the nursery ground function of healthy, dynamically sustainable estuaries (Ogden et al., 2005). Spotted seatrout are also included as ecological indicators in both the Biscayne Bay and Florida Bay conceptual ecological models (Browder et al., 2005; Rudnick et al., 2005). To further capture our understanding of juvenile spotted seatrout and specifically their relationship to environmental variables, we developed a conceptual ecological model of the spotted seatrout population in south Florida (Fig. 5)

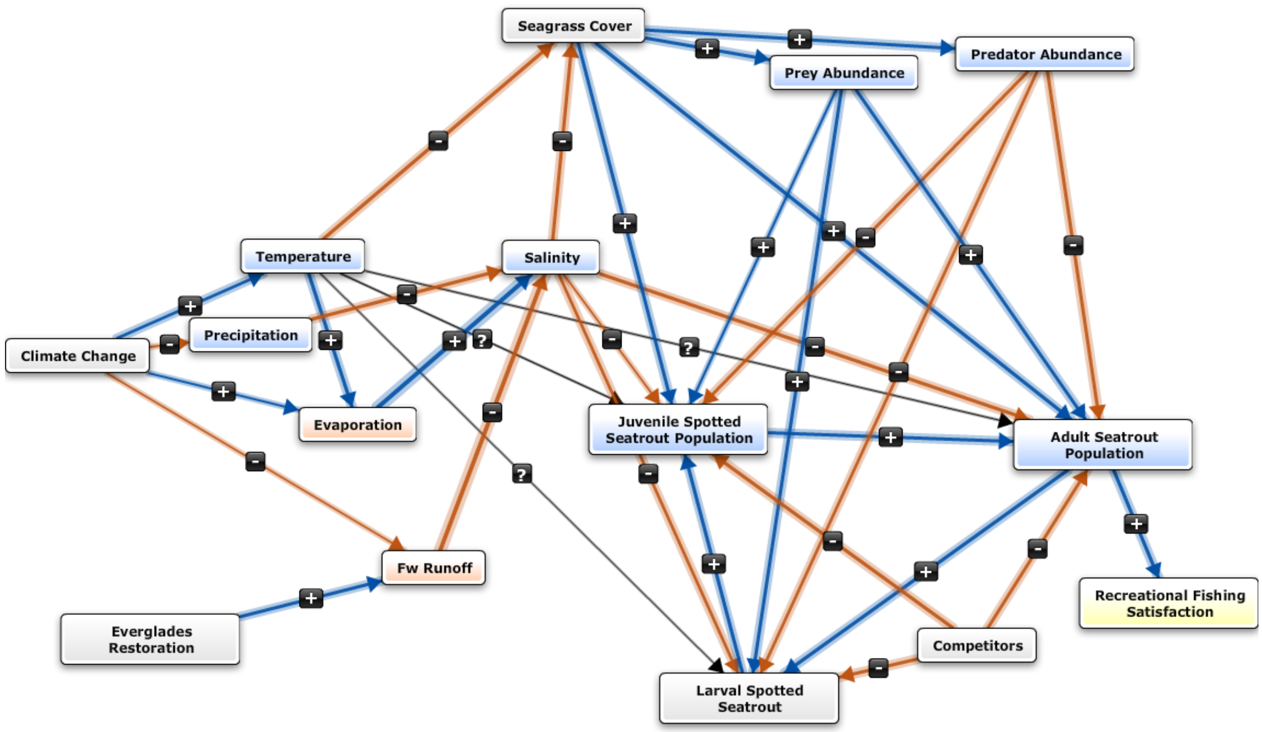

Figure 5. Spotted Seatrout Populations Conceptual Ecological Model with blue arrows depicting positive relationships, red for negative relationships, and black for parabolic relationships that have an optimal range and thus switch from positive to negative.

Ecological Premise: The estuaries downstream of the Everglades are Essential Fish Habitat, providing nursery grounds for many of the sportfish species that are essential to the ecology and economy of south Florida (Tilmant et al. 1989; Rutherford et al. 1989; Rubec et al., 1998). These estuaries experience elevated salinities and increased salinity variability due to the channelization of freshwater flow and the partial blockage of freshwater flow into Everglades National Park (Marshall 2016). Altered salinities have reduced the nursery habitat functions of these estuaries, adversely affecting sportfish populations dependent upon them.

3.2 Relationship to Adaptive Assessment Hypothesis Clusters

Hypothesis 1: Restoration will reduce the intensity, duration, and spatial extent of hypersaline conditions, thereby increasing the area of optimum (salinity) habitat for nearshore fish and invertebrates.

Hypothesis 2: Restoration will increase the area covered by seagrass, thereby increasing the area of optimum habitat for seagrass-associated fish and invertebrate species.

Rationale: Increased hypersalinity (>36), specifically in central Florida Bay (encompassing Whipray and Rankin subregions in figure 9), results in a double-dose of stress for juvenile sportfish in this area. First, there is the direct physiological stress on the reproduction of seatrout; seatrout larvae have an optimal salinity of 28 and do not survive at salinities less than 5 or greater than 50 (Holt and Holt, 2002). Moreover, seatrout respiration rates decrease at salinities greater than 40 when temperatures are at or above 30°C (Wuenschel et al. 2004). Stressed fish are in poor physiological condition, more susceptible to predation, and less likely to successfully capture prey.

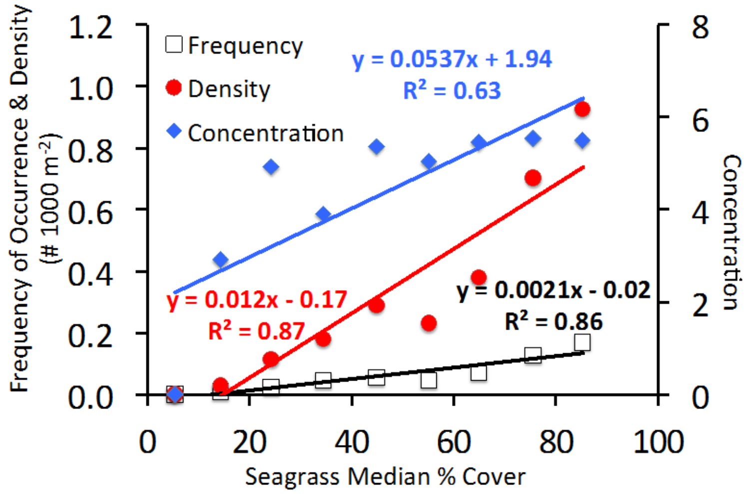

Figure 6. Scatter plots depict the correlation of the juvenile spotted seatrout population with Seagrass percent cover for all sub-regions combined. The open black boxes are frequency of occurrence, the blue diamonds are concentration and the red circles are density. Only significant linear regressions are depicted.

In addition to the direct physiological effects on seatrout, hypersaline conditions also affect juvenile seatrout indirectly by altering their SAV habitat. Specifically, if hypersalinity alters the percent cover of seagrass it will change juvenile spotted seatrout habitat quality, since a clear relationship has been established between seagrass percent cover and juvenile spotted seatrout population metrics (Fig. 6).

4.0 Evaluation Application

4.1 Evaluation Protocol

The juvenile spotted seatrout HSI model used to evaluate proposed projects should ideally examine the impact on spotted seatrout based upon the predicted changes in salinity, temperature, and seagrass. Juvenile spotted seatrout habitat suitability models and salinity prediction models have been developed that are capable of these evaluations (Fig. 1); however, we do not have a seagrass model that can be used to predict changes in seagrass distributions within Florida Bay in response to changes in salinity from proposed projects. The logistic regression model to predict the habitat suitability for juvenile spotted seatrout under different scenarios is based upon predicting salinity from an upstream hydrologic model that predicts stage and the multiple linear regression models applied in a similar way as used to set the target based upon predicting salinities for full restoration using NSM output in section 1.2 (Marshall et al. 2008; Fig. 3). As mentioned previously these salinity models do not produce salinities equivalent to the time of capture salinities used in the observational model; rather they predicts monthly salinity statistics at the marine monitoring network stations in Florida Bay. We interpolated these salinity predictions to the station locations where we sample juvenile spotted seatrout using inverse distance weighting interpolation. Thus, the logistic regression for juvenile spotted seatrout that uses monthly salinity statistics is applied. These salinity distributions are used as inputs into this habitat suitability model for juvenile spotted seatrout. The model then predicts habitat quality for any month for which predicted salinities are available. Temperature can then be assumed to be the same as observations if evaluating a short time-scale responses or temperatures can be increased to account for likely climate change impacts if predicting longer time scale effects.

4.2 Model Output

Habitat suitability is a measure of how favorable a habitat is for a faunal species to inhabit it. Habitat suitability index models have been used widely and are empirically based typically using statistical relationships between environmental factors and population metrics for the species of interest to predict the suitability of an area to that specific faunal species of interest. For fisheries independent sampling programs investigating the effects of environmental factors on fish population parameters, logistic regressions that predict the frequency of occurrence of the fish species of interest have been successfully employed (McManus et al., 2014). The HSI model is used to predict the quality of juvenile spotted seatrout habitat at each of the 81 stations that are sampled as part of the monitoring and assessment protocol described in Section 5 below (Figure 7). This is done using a logistic model that predicts the probability of observing a juvenile spotted seatrout, if you were to do a trawl. Because the HSI predicts the probability of observing a juvenile spotted seatrout, the output is lower than the 0 to 1 distributions of typical HSI models. This is, because for our entire MAP dataset from 2004 through 2012 we observed juvenile spotted seatrout at less than 10% of the 3,615 samples (Kearney et al., 2015).

Specifically, the HSI model was developed via backward stepwise regression using a Generalized Linear Model with logit link function. This enabled the inclusion of linear, quadratic, and paired product interaction terms. The Akaike Information Criterion was employed to determine the parameters that contributed significantly to the logistic regression. The final model predicted the likelihood of observing a juvenile spotted seatrout from the maximum monthly salinity, mean monthly salinity, mean monthly temperature, and the area sampled in the otter trawl.

$$\begin{aligned}\text{Logit}(H) \quad = \quad & -69.93 - 0.5542{*}S_a + 0.1837{*}S_m + 5.265{*}T_a + 0.01749{*}A \\ & - 0.04256{*}S_a{*}T_a + 0.01716{*}S_a^2 - 0.06040{*}T_a^2 - 0.000032756{*}A^2\end{aligned} \tag{1}$$

Where S_a is monthly mean salinity, S_m is monthly maximum salinity, T_a is monthly mean temperature, and A is the area towed which is held at 400m^2 for predictions.

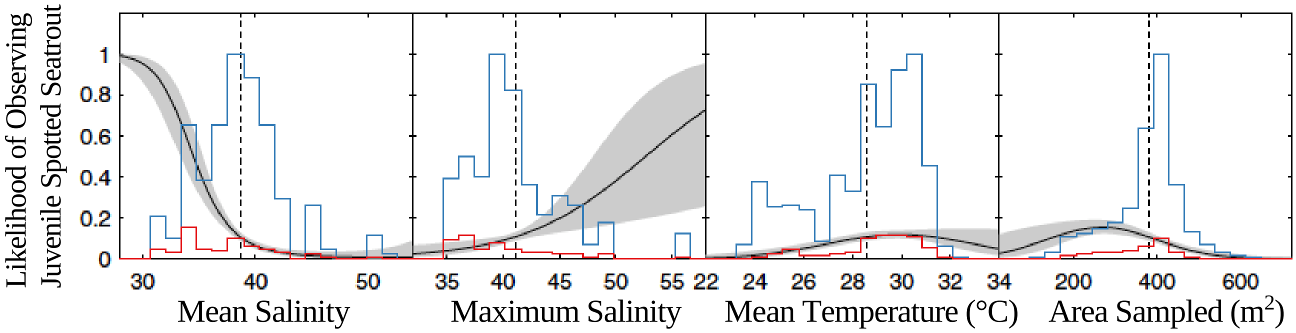

Figure 7. The HSI output versus monthly mean salinity, monthly maximum salinity, monthly mean temperature, and area sampled. The HSI prediction is shown in black, with the shaded gray region depicting the 95% confidence interval for the predictions. The blue histogram indicates the distribution of observations in the entire dataset and the red histogram indicates the distribution of observations for the subset of data in which juvenile spotted seatrout were observed. The dotted black line indicates the mean value of each predictor variable in the observation dataset; this indicates the value where the other predictor variables are set (e.g. the average salinity vs. HSI curve shows the predictions and confidence intervals when maximum salinity, average temperature, and sampling area are set to their mean-observed values).

It is difficult to visualize the response curves for an HSI with more than 2 terms. The final model had 6 terms meaning it would need to be depicted on 7 dimensional space to fully show the multitude of interactions between the terms. To help understand these relationships, all other parameters were held at their mean values and the HSI output was examined versus each input parameter individually (Fig. 7). These analyses showed that HSI was most sensitive to mean salinity, increasing non-linearly as salinity decreased, with likelihood of observing juvenile spotted seatrout increasing from near zero at mean monthly salinity just above 40 to near 1 when the mean monthly salinity dropped to 30 (Fig. 7). Maximum monthly salinity had less of an effect, but the HSI increased as maximum salinity increased when mean monthly salinity was kept at its mean value for the entire period of record. This is likely an artifact of keeping mean salinity at its average and not reflective of a true relationship between the occurrence of juvenile spotted seatrout and maximum salinity, because the difference between mean and maximum salinity is a proxy for variability which may be what drives this counterintuitive result. The effect of mean monthly temperature also was not as strong as mean monthly salinity. Mean temperature was optimal at approximately 30°C with decreasing values on either side of 30°C. The area sampled in the otter trawl also had a significant contribution to the model; however, this is most likely an artifact with the area sampled acting as a proxy for benthic vegetation and detritus. Originally, benthic macroalgae and detritus were not observed when doing the tows, but they have now been added as part of the regular sampling procedure to improve these analyses going forward. An overabundance of detritus and macroalgae causes us to sample a smaller area and the likelihood of observing a seatrout increases with decreasing sample area until it gets below about 250 square meters. There is no mechanistic reason that a smaller sample area itself should increase the likelihood of observing juvenile spotted seatrout. In fact, it should decrease the likelihood of observing a juvenile spotted seatrout. Thus, the increase in likelihood of observing a spotted seatrout is more likely reflective of there being better benthic habitat in areas where we sampled a smaller area.

The HSI values at the sampling stations were then spatially interpolated throughout the entire sampling domain using inverse distance weighting interpolation to calculate areas of habitat quality categories under different scenarios. These outputs can then be used to determine areal extent of different habitat qualities (e.g. to quantify the increase in areal extent where the HSI output is greater than specific value). The outputs can also be used to examine the increase in HSI at each point individually or at all points as numbers in a population to determine if increases are significant from a proposed project. The basic approach applied here is described in McManus et al. (2014).

4.3 Example Application

This approach was used to evaluate the ecological impact of the Central Everglades Planning Project (CEPP). Specifically, the Juvenile Spotted Seatrout HSI model was run using mean monthly salinities estimated from the model output for all seven CEPP scenarios (May through November only). The HSI model output from the sampling stations in Florida Bay was gridded with 0.01 degrees of latitude and longitude (approximately every 1,100 m) between each grid-point to produce spatial distributions of HSI scores throughout the sampling domain for each month. These spatially explicit HSI scores were then used to calculate the area of optimal juvenile spotted seatrout habitat using Surfer Software. Optimal Habitat was defined to be where the probability of observing a juvenile spotted seatrout was greater than 15%. The mean area of optimal juvenile spotted seatrout for each scenario over the entire period of record is shown in Figure 8 (left panel). The error bars reflect the standard error of the mean over the period of record. In other words, it is the variability about the mean over the months and years analyzed and does not account for model uncertainty. The natural system model serves as the target for this analysis and had the largest mean area of optimal juvenile spotted seatrout habitat at 368 km^2. The future without project (FWO) was the lowest mean area of optimal habitat followed by existing conditions baseline (ECB). All four CEPP alternatives showed improvements over FWO and ECB. A Mann-Whitney U-test was applied to conduct pair-wise comparisons among all of the scenarios. All four CEPP alternatives had significantly higher areal extents of optimal habitat for juvenile spotted seatrout than FWO ($p<0.1$). However, there were no significant differences among any of the alternatives ($p<0.1$).

The percent increase in area of optimal juvenile spotted seatrout relative to the future without project is depicted in Figure 8 (right panel). The four CEPP alternatives showed increases from 44% for Alternative 1 up to 65% for Alternative 4. Alternatives 2 and 3 were in the middle showing 49% and 52% increases respectively.

This approach will be used to evaluate all future CERP projects expected to affect juvenile spotted seatrout habitat quality in Florida Bay.

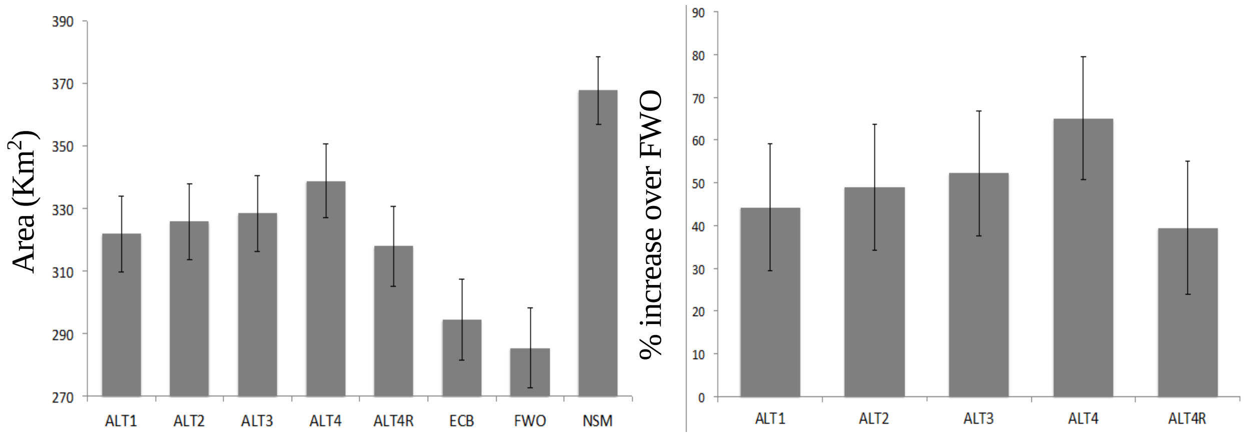

Figure 8. Depicted are mean optimal habitat (across months and years) areas for each CEPP scenario (left panel), and the mean percent increase over FWO towards the target CEPP scenario (NSM) (right panel). The optimal habitat was only calculated from May through October to correspond to the months with significant observations of *C. nebulosus* in Florida Bay. This output was calculated for a 36-year period under each scenario.

4.4 Uncertainty

Model uncertainty needs to be understood and accounted for when using ecological models to make predictions for evaluating projects. A particular problem in ecology is the tendency for a model to have minimal predictive value outside of the data set used to parameterize the model. This is unavoidable in cases where you are trying to predict climate change impacts or the future including the impacts of climate change, since there is no way to sample temperature and precipitation regimes that we have yet to experience. For example, temperature increases will necessarily push the model outside the range of temperatures used to develop the model. This is not a problem when doing the CEPP scenario analysis described above, since the values remained within the range of observations and temperature was assumed to be the same as today. To account for this problem and to develop the most robust model possible, the juvenile spotted seatrout HSI model has undergone the important, separate steps of model parameterization, calibration, and validation. The validation step is particularly important, because this step examines how well the proposed model predicts the observations seen in a sub-set of data not used to parameterize or calibrate the model. Thus, it replicates how much skill the model has in predicting future changes in juvenile spotted seatrout from data that is yet to be collected or replicated and thus not part of the observations used to calibrate and parameterize the model. To ensure our model was robust and had significant skill in predicting future changes in juvenile spotted seatrout habitat, we validated the model using two different methods. First, we validated potential models by randomly withholding ten percent of the observations. Second, we validated the potential models by withholding an entire year of data and examining how well the proposed model predicted that year of observations. The second validation method was found to be far more restrictive and difficult than the first method. Thus, a model that passed this second validation method is more robust and more skilled in predicting the effect of proposed restoration projects. This is not to say it does not still have uncertainties. The biggest uncertainty is the inability to predict seagrass responses to proposed projects, because seagrass habitat has a significant influence on seatrout populations and frequency of occurrence (Kelble et al., 2014). The model is still useful without seagrass and the analysis and example application show it has significant skill utility, however, it would only be made better by incorporating a seagrass model for input.

5.0 Monitoring and Assessment Approach

5.1 MAP Module and Section

See CERP MAP: Part 1 Monitoring and Supporting Research Southern Estuaries Module section 3.2.3.7 (RECOVER 2004a)

See CERP MAP 2009 Southern Coastal Systems Module Section 3.4.7 (RECOVER 2009)

5.2 Monitoring and Assessment Methods

Juvenile spotted seatrout are monitored following a stratified random sampling design focused on four sub-regions in the northern half of western and central Florida Bay (Figure 9). Sampling is conducted with an otter trawl. The trawl has a 3.4 m head rope, 3.8 m foot rope equipped with a 3 mm galvanized tickler chain, 6 mm mesh in the body, and a 3 mm mesh tail bag. The mouth opening has an effective width of 2.1 m. The trawl is towed at a speed of approximately 2.0 m s^{-1} for 2 min (to sample an area of about 400 m^2), unless the net gets clogged with detritus. When the net becomes clogged, the sample is counted if the tow is longer than a minute or redone if the tow is less than 1 minute. The sampling takes place from May through October to coincide with the peak of juvenile spotted seatrout abundance in Florida Bay. The four sub-regions in which spotted seatrout are monitored were selected based upon two criteria:

1) Historical data indicate juvenile spotted seatrout were previously collected in the sub-region; and
2) The sub-region is likely to be affected by water management changes associated with CERP.

Sampling is undertaken in a manner consistent with the Environmental Monitoring and Assessment Program Estuaries approach (Summers et al. 1995). The sampling location must have a minimum depth of 2 feet below the boat bottom and the boat motor is trimmed up to minimize disturbance of the benthos. Each sub-region has been divided into cells (macrocells) measuring 1800 m on a side, which were further divided into four smaller cells (microcells). Hence, there are four potential sampling sites per macrocell. Macrocells are randomly selected within each sub-region, and a microcell (900 m on a side) is then randomly selected within the randomly selected macrocell. A sample is collected at the center of this microcell. Because of the presence of shallow mud banks, islands, and variable tides, many macrocells contain less than four trawlable microcells. If a microcell not suitable for trawling is initially selected, then another microcell within the macrocell is randomly chosen. If there are no suitable microcells within a macrocell, an alternate macrocell within the same sub-region is randomly selected. Juvenile spotted seatrout are identified on site, measured, and preserved in ethanol for verification, and more precise measurement back in the laboratory.

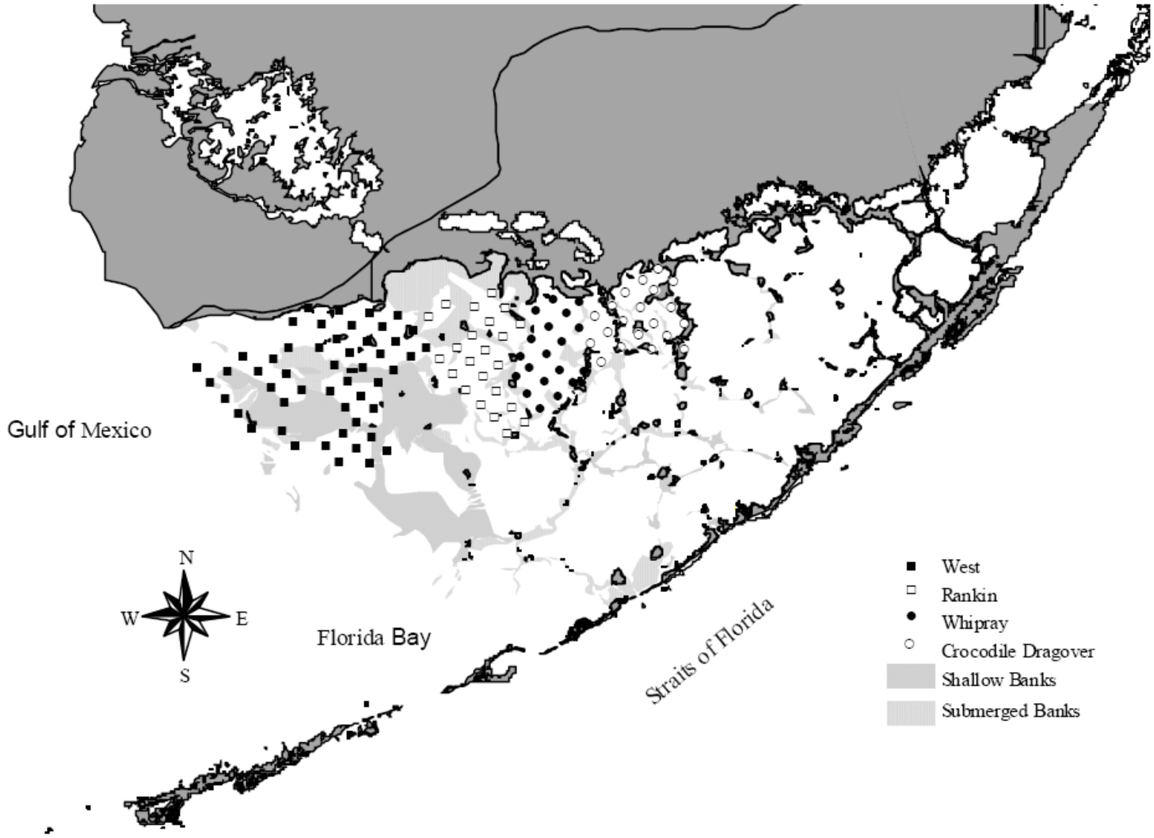

Figure 9. Location of all potential sampling stations by subregion in Florida Bay. Symbols are centered in the macrocell that is 1800 m on a side.

6.0 Future Tool Development and Data Needs

6.1 Evaluation Tools Needed

The logistic regression was modified for use as a two-stage HSI model with water quality as its first basis and SAV as the second. First, a logistic regression was calculated to determine the likelihood of observing a spotted seatrout from water quality parameters and then a second logistic regression was used to calculate the probability of observing juvenile spotted seatrout from seagrass percent cover. This was done in order to allow calculation of the HSI without using seagrass as an input, because there is not currently a model for seagrass in Florida Bay that could be used as an input into the HSI model. Without using seagrass as an input, the implicit assumption in the model is that seagrass distributions and coverage will be similar to those currently observed in the study site. The goal was to build the juvenile spotted seatrout model and associated performance measure to be usable without a seagrass model, but able to account for seagrass should such a seagrass model be developed.

Due to the lack of a current seagrass model in Florida Bay, we did not discuss how a potential seagrass model could fit into this HSI. This would depend in large part on the metrics output from the seagrass model, but we have established a significant relationship between the juvenile spotted seatrout frequency of occurrence and percent cover of seagrass (Fig. 6). This relationship will easily form the basis for the incorporation of seagrass into a second stage of this HSI.

Thus, the juvenile spotted seatrout evaluations would be most improved by the development and application of a SAV model able to predict changes in SAV from proposed restoration projects. In addition, the development of a hydrodynamic model in Florida Bay waters with daily salinity outputs would greatly improve our evaluation.

6.2 Assessment Tools Needed

Systematic, long-term data on juvenile spotted seatrout abundance, body condition, and frequency of occurrence are needed along with systematic long-term monitoring of salinity, temperature, and SAV to conduct assessments and validate the model and to refine model parameters.

7.0 Notes

This Performance Measure is a predictive tool focusing specifically on juvenile spotted seatrout and their preferred habitat requirements and can be used to assess existing or past habitat conditions as well as evaluate future restoration scenarios. The existing Southern Coastal Systems Fish Community Performance Measure has not been fully developed and is a precursor to the Juvenile Spotted Seatrout PM. When completed it is intended to focus more broadly on fish diversity and density among fish assemblages, especially the mangrove fish community. Therefore, the Juvenile Spotted Seatrout Performance Measure will stand separately and is not intended to replace the Southern Coastal Systems Fish Community Performance Measure (RECOVER 2007).

8.0 Working Group Members

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