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Roseate spoonbill reproduction as an indicator for restoration of the Everglades and the Everglades estuaries

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in tracking trends. They are: nesting success, nest number, locations of nests, and prey fish community composition. Targets for these performance measures we established based on previous findings. The performance measures are then reported as suitability indices identified as stoplight colors with green indicating that targets have been met, yellow indicating that conditions are below the target but within a suitable range of it and red indicating the measure is performing poorly in relation to the target.

Roseate Spoonbills as an Indicator for Restoration of the Everglades and Florida Bay

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Abstract

Ecological monitoring is a key part of adaptive management and successful restoration. Not everything within an ecosystem can be monitored so it is important to select indicators that are representative of the system, integrate system responses, show clear responses to system change, can be effectively and efficiently monitored, and are easily communicated. Roseate Spoonbills are one of the indicators that meet these criteria within the Everglades ecosystem. Monitoring of Roseate Spoonbills in Florida Bay over the past 70 years has shown that this species responds to changes in hydrology and corresponding changes in prey abundance and availability. This indicator uses nesting location, nest numbers and nesting success in response to food abundance and availability. In turn, prey abundance is a function of hydrological conditions including depth, and salinity. These relationships have been well documented such that spoonbills responses can be directly related to changes in hydrology and salinity. The spoonbill indicator uses performance measures that have been shown to be both effective and efficient in tracking trends. They are: nesting success, nest number, locations of nests, and prey fish community composition. Targets for these performance measures we established based on previous findings. The performance measures are then reported as suitability indices identified as stoplight colors with green indicating that targets have been met, yellow indicating that conditions are below the target but within a suitable range of it and red indicating the measure is performing poorly in relation to the target.

Key words: ecological indicators, Everglades restoration, Roseate Spoonbill, Wading Birds, restoration assessment

1. Introduction and Background

Ecological monitoring is a key part of adaptive management (Williams et al., 2007, Lovett et al., 2007) and successful restoration. Not everything within an ecosystem can be monitored so it is important to select indicators that are representative of the system, integrate system responses, show clear responses to system change, can be effectively and efficiently monitored, and are easily communicated (Doren, 2006, Doren et al., intro chapter, Schiller et al., 2001).

Roseate Spoonbills are one of the indicators that meet these criteria within the Everglades ecosystem. Restoration of hydrology is a major part of the Comprehensive Everglades Restoration Plan (CERP, U.S. Army Corps of Engineers, 1999), and indicators used for tracking progress of Everglades restoration should have clear relationships to hydrologic conditions (Doren et al., intro. chapter, U. S. Army Corps of Engineers, 2004).

Monitoring of Roseate Spoonbills (*Platalea ajaia*) in Florida Bay over the past 70 years has shown that this species responds to changes in hydrology and corresponding changes in prey abundance and availability (Powell et al., 1989, Lorenz et al., 2002). This indicator uses nesting location, nest numbers and nesting success in response to food abundance and availability. In turn, prey abundance is a function of hydrological conditions including depth, and salinity (Lorenz and Serafy, 2006). These relationships have been well documented such that spoonbills responses can be directly related to changes in hydrology and salinity (Lorenz and Serafy, 2006).

Spoonbill nesting success is dependent on suitable environmental conditions. Correlations between biological responses and environmental conditions contribute to an understanding of the species' status and trends over time (Lorenz, 2000, Lorenz and Serafy, 2006). The positive or negative trends of this indicator relative to hydrological changes (Lorenz, 2000, Lorenz et al., 2002, Bartell et al., 2005) permit an assessment of positive or negative trends in restoration. Restoration success or failure would be evaluated by comparing recent and future trends and status of spoonbills with historical population data and model predictions, as stated in the CERP hypotheses related to the food web (CERP Monitoring and Assessment Plan section 3.1.2.4; U. S. Army Corps of Engineers, 2004).

The spoonbill indicator uses performance measures that have been shown to be both effective and efficient in tracking trends. They include: nesting success, nest number, locations of nests, and prey fish community composition. These parameters have been correlated with hydrologic conditions including water depth, hydroperiod, timing, spatial extent and salinity, which are influenced by water management practices.

Roseate Spoonbills are one of several charismatic megafauna found in the Everglades. They are both umbrella and flagship species to which the public can relate. In addition, the parameters used to track trends are easy to understand: How have the number of spoonbills changed through time? Are they as productive as they were historically? Are the animals in the places where they should be? Are their prey as abundant as under natural conditions?

1.1. Indicator History

There is a seventy year intermittent database of spoonbill nesting activity in Florida Bay (Figure 1). Lorenz et al., (2002) demonstrated that nesting patterns are highly dependant on hydrologic conditions on the foraging ground most proximal to the nesting colonies (Figure 2). Spoonbills primarily feed on wetland fishes (Dumas, 2000) and time their nesting with low water levels which result in the prey base fishes becoming highly concentrated into the remaining wetted areas (Loftus and Kushlan, 1987, DeAngelis et al., 1997, Lorenz, 2000). Studies suggest that tactile feeding wading birds, such as the Roseate Spoonbill, are particularly dependent on high prey density in order to successfully forage, probably more so than the visually oriented avian predators (Kahl, 1964, Frederick and Spalding, 1994, Gawlik, 2002). Tactile feeders are more efficient when prey density is very high and visual predators are more efficient at lower prey densities (Kahl, 1965). Gawlik (2002) experimentally demonstrated that two species of tactile feeders (wood storks and white ibis) abandoned foraging sites while prey was still abundant enough to attract visually oriented wading birds in high numbers. Although no spoonbills visited the study site, Gawlik's (2002) experimental approach lends empirical evidence to the idea that tactile feeders are more sensitive to prey availability. Because tactile foraging birds in general and roseate spoonbill in particular are more dependant on high prey concentration than other wading bird species (Kahl, 1964, Gawlik, 2002), they are more sensitive to changes in environmental conditions that determine fish concentrations, specifically water levels (Gawlik, 2002). The requirement for highly concentrated prey is exacerbated during nesting cycles when the high-energy demands of their offspring require a consistently available high density of prey items (Kahl, 1964, Lorenz, 2000, Dumas, 2000).

Beginning with the completion of a series of canals and water-control structures known as the South Dade Conveyance System (SDCS) in the early 1980's, water deliveries to Taylor Slough and northeastern Florida Bay (Figure 2) changed dramatically (Light and Dineen, 1994, McIvor et al., 1994, Lorenz, 2000). This canal system is immediately adjacent to Taylor Slough and just upstream from where the majority of spoonbills nested in Florida Bay at the time (Figure 2; Powell et al., 1989) and heavily impacted the coastal wetlands that were the primary feeding grounds for the spoonbill nesting population (Bjork and Powell, 1994). In 1979, 1,250 Roseate Spoonbill nests were located in Florida Bay, with more than half the nests located in the northeastern bay (Figure 1, Powell et al., 1989, Lorenz et al., 2002). Today, the number of nests is less than a third of that in 1979 and distribution of nesting by roseate spoonbills has shifted from northeastern Florida Bay to the northwestern region (Figure 2, Lorenz et al., 2002). The shift is attributed to the lack of nest production following the completion of the SDCS: Lorenz et al., (2002) calculated that prior to the SDCS northeastern Florida Bay produced an average of 1.38 chicks per nest attempt but dropped to 0.67 chicks per nest following its' completion. Lorenz (2000) demonstrated that this decline was the result of the SDCS causing changes in hydrology and salinity that affected the production (Figure 3) and availability of the spoonbill prey base.

In addition to a large nesting population in Florida Bay, spoonbills "nested in the thousands" along the southwest coast south of Cape Romano (Scott, 1889). Restoration of more historic hydrological conditions should promote greater prey abundance and availability in both Florida Bay and the southwestern estuaries of the Everglades, leading to an increase in the number of years spoonbills can successfully nest, defined as the survival of offspring to fledging. Therefore, roseate spoonbills are good indicators for evaluating the CERP's effectiveness at restoring estuarine conditions (Lorenz et al., 2002).

The major anthropogenic perturbations to spoonbill foraging grounds have been the filling of wetlands for urban development in the upper Florida Keys and the alteration of wetland type and function along the northeast coast of Florida Bay by water management practices (Lorenz et al., 2002). A striking implication of these findings is that current water management practices in the southern Everglades have resulted in the ecological degradation of the coastal wetlands in northeastern Florida Bay.

1.2 CERP Hypotheses for Spoonbills

A system-wide Monitoring and Assessment Plan (MAP) has been developed that describes the monitoring necessary to track ecological responses to Everglades restoration (U.S. Army Corps of Engineers, 2004). Included in that plan are descriptions of selected indicators, how those indicators are linked to key aspects of restoration (hypotheses), and performance measures (monitoring parameters). MAP hypotheses for Roseate Spoonbills are:

- Spoonbill's should experience successful nesting (defined as an average production of >1chick/nest) in 7 of 10 years and average 1.5 chicks/nest overall (initially using a five year running average for nest production and a ten year running average successful years).
- Restore nest numbers to pre-SDCS levels of 1250 nests with at least half in the northeastern region (as defined by Lorenz et al., 2002) of Florida Bay. Although specific numbers for the pre-plume hunting era are unknown for Florida Bay, anecdotal evidence suggests that the long term target should be in excess of 2000 nests bay wide.
- A return of significant nesting activity along the southwestern coast of Florida in the estuarine areas of Shark River and Lostman's sloughs (Figure 2).

1.3. Areas of the Everglades this Indicator Covers

Spoonbills are found throughout the Everglades landscape, however, the species is predominantly an indicator for the Florida Bay estuary (Figure 2) and cover the Greater Everglades and Southern Estuaries region. Spoonbills are included as attributes in the

Total System, Everglades Mangrove Estuaries, and Florida Bay conceptual ecological models. A monitoring and assessment plan has been developed for spoonbills nesting in Florida Bay. We perform a complete nest count of the entire bay, monitor nesting success at focal colonies in five regions of Florida Bay and perform quantitative assessments of the mangrove fish community which makes up the bulk of the spoonbill's diet while nesting in Florida Bay.

1.4. Significance of the Indicator to Everglades Restoration

1.4.1. The indicator is relevant to the Everglades ecosystem and responds to variability at a scale that makes it applicable to a large or portion of the ecosystem.

Spoonbills were abundant in Florida Bay and throughout the Southern Estuaries region prior to Everglades drainage activities and have responded negatively to water management activities. They are top predators that share a common prey base (small demersal fishes) and foraging habitat with myriad other species. Spoonbills feed by tactolocation rather than visual hunting; this makes them more sensitive to perturbations than the other species dependant on the same resource (i.e., they are an early warning indicator). Spoonbill nesting productivity is directly linked to hydrologic conditions within the Southern Estuaries and nest production is linked to hydrology through the impact of water management on primary producers (e.g. periphyton, submerged aquatic vegetation) and lower trophic level consumers (i.e., prey base fishes).

1.4.2. The indicator is feasible to implement and is scientifically defensible.

Research on Roseate Spoonbills has been conducted for over 70 years, providing a remarkable long-term data base. Currently, there are funded cooperative research and monitoring programs with U.S. Fish and Wildlife Service, Everglades National Park, U.S. Geological Service-Biological Resources Division, U.S. Army Corps of Engineers and the South Florida Water Management District. Reliable models from such research are available that determine the impacts of water management on nesting patterns. Pattern metrics (e.g. nest numbers and nesting success) are statistically correlated to Ecosystem Drivers, and a Spatially Explicit Species Index model is being developed as part of the Across Trophic Level System Simulation modeling effort. This research has provided numerous peer reviewed journal articles. This indicator is already part of the CERP RECOVER interim goals and Food-Web Monitoring Component of the CERP MAP.

1.4.3. The indicator is sensitive to system drivers (stressors).

Key environment drivers, such as water depth, hydroperiod and salinity, are statistically correlated to spoonbill nesting success (Lorenz, 2000, Lorenz et al., 2002). A causal link exists between hydropatterns, prey abundance and availability, and nesting success (Lorenz, 2000, Lorenz and Serafy, 2006). Nesting failure has been statistically linked to nest number and location in a given region such that persistent nesting failure results in a decline in nesting effort and a concurrent increase in other regions.

1.4.4. The indicator is integrative.

Spoonbill nesting success is linked to fish production and in turn, fish production is linked to periphyton and SAV production. Spoonbill nesting responses are representative of hydrological improvement (i.e. Water Management). Spoonbills are also included in the CERP Food-Web Monitoring Component that includes an index of food-web function and landscape connectivity ("intactness").

2. The Spoonbill Indicator Performance Measures

2.1. Indicator Metrics

The spoonbill indictor consists of four performance measures:

- Nesting success (average number of chicks fledged per nesting attempt and number of years out of the last ten in which production exceeded 1.0 chicks per nest fledged)
- Number of nests
- Distribution of nests (number of nests in northeastern Florida Bay and 10,000 islands area)
- Prey community structure (percent of total community that are considered freshwater species as defined by Lorenz and Serafy, 2006)

In addition there will be a metric for spoonbills nesting in the northwestern region of Florida Bay to act as a control metric for restoration efforts that will affect the northeastern region.

2.2. The Stoplight Restoration Report Card System Applied to Spoonbills

This communication tool is based on MAP performance measures (either by module or system-wide) and is expected to be able to distinguish between responses to restoration and natural patterns. A set of parameters (Table 1) has been developed for each performance measure. Answers are translated as suitability indices identified as stoplight colors with green indicating that targets have been met, yellow indicating that conditions are below the target but within a suitable range of it and red indicating the measure is performing poorly in relation to the target. Two questions are addressed using suitability indices: 1) have we reached the restoration target, or if not, 2) are we making progress toward targets?

Methods for producing suitability curves vary among performance measures. For example, a ten-year running average was used for percentage of years that spoonbills were successful. A five-year running average was used for average annual nest production and nest numbers. Fish community structure changes to a greater percentage of freshwater species only when salinity conditions have been favorable to these species for a two to three year period, therefore this parameter will be reported as an annual metric that covers a three year period. Nesting success will be reported annually because short-term water depth conditions dominate this parameter. By using this suite of performance measures this indicator covers time scales from annual to three, five and ten year cycles.

2.3. Calculation of Metrics and Thresholds for the Spoonbill Stoplight Restoration Report Card

2.3.1. Spoonbill nesting success. Lorenz et al., (2002) divided Florida Bay into five regions based on the primary foraging grounds for each of the colonies within each region (Figure 2). They also demonstrated that, under the SDCS operations, the nest productivity and nest number in the northeastern region have experienced a significant decline. The method used to calculate this metric is based on surveys of focal colonies (defined as the two largest colonies within the region) . These surveys entailed marking up to 50 nests shortly after full clutches had been laid and re-visiting the nests on an approximate 7-10d cycle to monitor chick development. The metric is the number of chicks per nest to survive to twenty-one days. After twenty-one days, the chicks become very active and move throughout the colony precluding accurate accounting of individual nest production. Since 2003, chicks have also been leg-banded so that individual chicks can be identified. By resighting these individuals later in the nesting cycle, we are able to use a second method to estimate nest production. Preliminary analysis of this mark-resighting technique generally confirms that the twenty-one day survival is an accurate method to calculate nest production..

This stoplight uses two metrics for nest production. The number of successful nesting years out of ten with success being defined as an average nest production of greater than one chick per nest (c/n) for all nest starts. This metric uses only the northeastern region of the Bay (Figure 2) as this has been demonstrated to be the region most impacted by water management practices (Lorenz et al., 2002). Prior to the establishment of the SDCS, spoonbills nesting in the northeastern region averaged 71% successful years (Lorenz et al., 2002). Stoplight colors were based on this threshold (Table 1, Figure 4).

The second metric of nest production is the five year mean of nest production in the northeastern region. Lorenz et al., (2002) demonstrated that prior to the SDCS annual mean spoonbill production in the northeast region was 1.38c/n and that this dropped to 0.67 post-SDCS. Initially we set this as the target for the stoplight metric where annual production was divided by 1.5 c/n with greater than 67% set as the threshold for a green rating. However, as can be seen in Figure 5, there are no trends in the data with rapid changes occurring from one year to the next. This is due to the interannual differences in hydrologic conditions that affect the ability of spoonbills to capture enough prey to successfully raise young. Simply put, some years are naturally better than others. Taking a multi-year running average smoothes this high variability into more interpretable trends (Figure 5). By examining various time frames from previous data we concluded that by using a five year running average, no single good or bad year out of the five skewed the results into the red or green classification. A single good or bad year in either the two, three or four year running averages could bias the mean, thus resulting in an inaccurate stoplight color.

There are natural background conditions that can result in nest failure that are unrelated to CERP or water management practices. Therefore, we need to control for natural background variation in foraging conditions. We dealt with this problem by using the northwestern region's success rate as control for natural background conditions. While the northeastern region's production declined post SDCS, the northwestern regions production remained relatively high (1.24c/n) even though there was still a great deal of interannual variability. Lorenz and Frezza (2007) concluded that the interannual variation in productivity of the northwestern colonies reflects the natural variation while the variation in the northeast is affected by both this background and by water management practices. Therefore, we propose that the metric used to gage success in the northeastern region be tied to that of the northwestern, i.e., the metric should be calculated by dividing annual northeastern production by that of the northwest thereby resulting in a percentage (Figure 6). The thresholds for stoplight colors are presented in Table 1.

Although this metric solves the problem of natural interannual variation in nesting success, it is also dependant on the continued high rates of success of the northwestern colony. What happens if CERP or other issues begin to negatively affect the success of the northwestern colonies? This would result in the metric receiving higher scores even though there was actually a degradation of the bay for spoonbills. Therefore, stoplight metrics were developed to examine the northwestern regions (explained below in section

2.3.5). If all three of the metrics are yellow or red then the metric for northeastern success should be based on the long term mean production rate of 1.5 c/n for northeastern Florida Bay (Lorenz et al., 2002, Figure 5).

2.3.2. Number of spoonbill nests in Florida Bay. Spoonbill nest counts for Florida Bay have been performed intermittently since 1935 (Powell et al., 1989). Over that period, spoonbills have been recorded nesting on thirty-eight keys throughout the Bay (Figure 2; Lorenz et al., 2002). Spoonbills typically establish nests in Florida Bay in November or December of each year, however, nest initiation has started as early as October and as late as March (Powell et al., 1989, Alvear-Rodriguez, 2001). All known nesting keys are visited every twenty-one days during the nesting season. Our data show that prior to the establishment of the SDCS, the peak number of nests was 1258 in 1978 (Figure 1, Lorenz et al., 2002). For this stoplight, annual nest counts are divided by 1258 to get the annual percentage of the historic peak number of nests (Figure 7) and assigned the stoplight color as per Table 1.

2.3.3 Spoonbill nesting location. This stoplight indicator consists of two metrics: a return to pre-SDCS nest numbers in the northeastern region and return of spoonbills to nesting colonies along the southwest coast of the Everglades in the Shark River Slough and Lostman's Slough estuaries. Powell et al., (1989) reported that in the peak year of 1978 more than half of the 1258 nests were located in the northeast region (688 nests). Following the completion of the SDCS, this number dropped to approximately 100 nests from 2000 to 2007. In 2008 there were a total of 47 nests in the region. For restoration to be considered successful, we should expect a return to nesting numbers to pre-SDCS numbers. This metric is the percentage of 650 nests that occur annually (Figure 8). Similar to nest success and total nests for Florida Bay, the interannual variation can bias individual years and a five year mean was used for this metric (Table 1).

According to Scott (1889), spoonbills "nested in the thousands" along the southwest coast of the Everglades in the Shark River and Lostman's slough estuaries. Restoration of more historic hydrological conditions should promote greater prey abundance and availability in this region, potentially leading to a return of spoonbill nesting in large numbers. In recent years, Everglades National Park has performed aerial wading bird surveys of this area and has documented spoonbill nesting (Pers. Comm, Sonny Bass, Supervisory Wildlife Biologist, Everglades National Park), however accurate surveys of spoonbills nest number can not be performed from aircraft because they tend to nest low in the canopy. Although it is imperative to get a baseline for pre-CERP nesting in this critical region, no funds have been identified to pay for this effort. As a result, no stoplight metrics can be established at the time of this publication.

2.3.4 Prey Community Structure. Spoonbills primarily feed on small demersal fishes found throughout the Everglades system (Allen, 1942, Dumas, 2000). Lorenz et al., (1997) developed a methodology that uniquely sampled fishes in the dwarf mangrove foraging grounds that are the preferred feeding locations for spoonbills nesting in Florida Bay. The sampling design uses a $9m^2$ drop trap at fixed locations at known spoonbill feeding sites. Data collection began in 1990 at four sites. Currently, there are 14 sampling sites associated with Florida Bay's nesting spoonbill population (Figure 2)

Lorenz (1999) documented that these fish respond markedly to changes in water level and salinity and these factors can be altered by water management practices. Lorenz and Serafy (2006) performed a fish community analysis of eight years of these data from six sites. During the eight-year span reported by this study, there were three consecutive years of unusually high rainfall and freshwater flows to the estuary which resulted in low salinity similar those believed to have occurred in the region prior to water management influences. As part of their analysis, Lorenz and Serafy (2006), placed individual species in one of four salinity categories (freshwater, oligohaline, mesohaline or polyhaline) based on the Venice System of Estuarine Classification (Bulger et al., 1993). To accomplish this, the authors used the mean salinity for the thirty days prior to a given collection (based on the findings of Lorenz, 1999) to identify the range of salinities in which each species was found. The median score of each species salinity range was then used to classify the species into one of the four categories. During the period of low salinity and high fish abundance, Lorenz and Serafy (2006) found that more than 40% of the total fish community were freshwater affiliates (Figure 3). Furthermore, they demonstrated that it took two to three years of low salinity for the freshwater populations to respond. Finally, they demonstrated these low salinity communities were much more productive based on both number and biomass of the standing stock (Figure 3). The stoplight for prey abundance will use the percentage of the fish community that was classified by Lorenz and Serafy (2006) as freshwater species as per Table 1. Although the stoplight will be reported on an annual basis, it is integrative for the previous two years as well, i.e., this stoplight measures conditions on a three year time scale.

2.3.5 Monitoring nesting success in northwestern Florida Bay as a control. As stated above, comparing nesting success in the northeastern bay to that of the northwestern bay accounts for background fluctuations on an interannual basis. For this metric to work, however, there needs to be a control for any anthropogenically induced reduction in nesting and productivity in the northwestern bay. We propose three stoplight metrics to act as a control for the proposed comparison of the two regions. Lorenz et al., (2002) indicated that the mean production rate for spoonbill nests in the northeastern region was 1.24 c/n. Based on this we expect the five year mean production rate to remain above 1.25 c/n and the control stoplight will remain green so long as this criterion is met (Figure 9, Table 1). Since the completion of the SDCS, the northwestern region of Florida Bay has produced a mean of 218 nests annually. Based on this metric, we set the control metric for nest number at 200 and use a five year running mean of the percentage of 200 as the stoplight indicator (Figure 9, Table 1). Finally, spoonbills have averaged success in more than six of every ten years in the northwest region. The percentage of successful years (mean production of >1.0 c/n) will also be used as a control with any metric above six of ten years receiving a green stoplight score (Figure 9, Table 1). If all three of the control metrics are yellow and/or red, than the metric for the northeastern bay should be re-evaluated based on the historic trends of the northeastern region (Figure 5).

3. Longer-Term Science Needs

Population dynamics of spoonbills in the Everglades and methods to monitor their responses to hydrologic management effectively, are relatively well understood. The techniques used to survey spoonbills is relatively well worked out, however, there are components of their basic biology that are unknown. For example, life expectancy and age at maturity are not known. Furthermore, migratory patterns are not well understood and need to be assessed to determine if spoonbills nest in multiple locations annually or if the nesting population in Florida Bay is distinct from other nesting locations around the state. Also, our knowledge of the dispersal of fledglings from the nesting colony is extremely limited. A banding program is underway to determine movements within the state, however, further funding for this effort has not been identified and the program will be eliminated without identification of funds. Furthermore, a satellite tagging program would provide a great deal of information on international movements (e.g. Cuba, Yucatan). This would also allow definitive data on local foraging flights. Currently, we use inferences (such as flight line counts) to track where birds are feeding.

Currently there are no efforts to survey wading bird nesting colonies in the estuaries of the southwestern coast of the Everglades even though this has been documented as an important nesting area prior to the plume hunting era. A return to nesting in this area has been identified as an important indicator for the restoration of flows through Shark River and Lostman’s sloughs. Funding for such surveys may be expensive as they will require the use of a helicopter for access, however, it is imperative that such funds be identified so as to maximize the use of this versatile indicator species in the larger restoration plan.

Of the seventeen existing prey fish sampling sites, three critical sites in northeastern Florida Bay are not funded through any restoration effort. Secure funding for these sites needs to be identified to preserve the statistical integrity of this effort.

4. Discussion and Conclusions

4.1 Effectiveness of spoonbills as an Indicator of Ecological Restoration

Spoonbills provide information to assess restoration of the Everglades that are unique from other wading bird indicators and require different methods of assessing their population trends. Therefore, spoonbills were identified as a separate indicator from the other wading bird species for two reasons. First, spoonbills nest cryptically within the canopy of mangroves and are not conspicuous from the air requiring nesting surveys to be performed on the ground rather than aerially. As a result, different parameters have been used to monitor spoonbills. Since we have to enter the nesting colonies to monitor nesting effort, we are able to get more accurate counts of total nests, what region of Florida Bay the nests were located, and the success of individual nests is documented through mark and revisitation of the nests.

In southern Florida, spoonbills show a distinct fidelity to estuarine habitats with approximately 90% of all nests found within Florida Bay, Tampa Bay and Indian River Lagoon (although in recent years spoonbills have begun nesting at such inland freshwater habitats such as the Corkscrew Swamp, Water Conservations Areas and mainland

Everglades National Park). In contrast, other wading birds are much more plastic in there selection of breeding sites with a well documented switch from coastal mangrove habitats to the Water Conservation Areas in response to water management practices. Given these differences, spoonbills are an indicator for Florida Bay, the southwest coastal estuaries and, perhaps Biscayne Bay while other wading birds are indicators for central Everglades habitats.

The RECOVER Conceptual Ecological Models identify three major stressors to wetlands that are affecting the spoonbill nesting activities in Florida Bay: reduced freshwater flow volume and duration (affecting hydrology and salinity, fish abundance and availability); invasive exotic species (affecting primary producers and the prey base fish community); and sea level rise (affecting habitat loss, wetland function and geomorphology, preliminary and secondary production in the prey base) (Davis et al., 2005; CERP Monitoring and Assessment Plan; U. S. Army Corps of Engineers, 2004). Only the first of these stressors will be ameliorated by CERP and, therefore, the spoonbill assessment tool only addresses issues for water flow, volume and duration.

Changes in salinity patterns reduces primary production (through stresses caused by rapid and frequent fluctuations in salinity; Montague and Ley, 1993, Ross et al., 2000, Frezza and Lorenz, 2003) and alter the prey base fish community to a state of lower secondary production (Lorenz, 1999, Lorenz and Serafy, 2006). As a result, the overall abundance of spoonbill prey items is reduced. The spoonbill assessment tool includes a parameter that examines fish community structure which has been shown to have a direct link to prey fish productivity thereby addressing this issue.

Changes in the timing and distribution of fresh-water deliveries, result in increased water levels on the primary foraging grounds of spoonbills nesting in northeastern Florida Bay (Lorenz, 2000). Studies performed in the mangrove foraging grounds indicate that the prey base fishes begin concentrating into deeper creeks and pools when water level on the wetlands drops to a certain depth threshold (Lorenz, 2000). Spoonbills time nesting with falling water levels on these wetlands such that prey will be concentrated at the time of egg hatching (Bjork and Powell, 1994). This provides a highly available and consistent prey resource at a time when the energetic demands of their rapidly growing young are highest. Out-of-season pulse releases resulting from upstream water management activities rapidly raise water levels above the concentration threshold and fish disperse across the surface of the wetland. This eliminates the needed abundant and easily captured food resources for the spoonbills. Even brief reversal events (3-5 days) can result in total failure of the spoonbill colonies. CERP and related projects will alleviate this situation leading to higher nesting success and a return to higher nest numbers in northeastern Florida Bay. The spoonbill metrics of nesting success, location and number assess these components of the impacts of water management practices.

The performance measure metrics chosen for spoonbills reflect current and historic ecosystem conditions. The metrics used to evaluate spoonbills have been well documented in the literature and are based on the best understanding of how the Florida Bay estuary functioned historically, currently and how we expect it to function under restored conditions. The metrics used provide both spatial and temporal metrics to assess the state of recovery efforts. We conclude that the spoonbill assessment tool will provide a powerful and integrative means to evaluate CERP activities.

4.2. Communicating the Spoonbill Indicator

Roseate spoonbills, being a species that Everglades visitors seek out and appreciate provide a valuable social as well as natural indicator. They are also well accepted by managers and policy makers as a species that is important to our understanding of estuarine systems. This is an important feature for system-wide integrative indicators and we can capitalize on these points with the spoonbill indicator.

Making environmental decisions requires both effective communication of environmental information to decision makers and consideration of what members of the public value about ecosystems (Schiller et al., 2001). As described above, spoonbills are good indicators (well-established relationships with environmental parameters under management control) and the metrics (nest number and location, nesting success, prey species composition) are remarkably easy to understand and communicate. The first MAP Annual Assessment Report for spoonbills and their prey summarizes the most recent advancements for spoonbills (System Status Report, 2006). The concepts of low nest numbers, nesting in less desirable habitats, declines in nest success and prey abundance are all real concepts, with meaning to managers. Tracking improving or declining conditions due to restoration activities with these metrics is easily communicated and understood.

Literature Cited

Allen, R. P., 1942. The Roseate Spoonbill. Dover Publications Inc., New York.

Alvear-Rodriguez, E.A., 2001. The use of nesting initiation dates of Roseate Spoonbills in northeastern Florida Bay as an ecosystem indicator for water management practices. MS Thesis, Florida Atlantic University, Boca Raton, Florida.

Bartell, S.M., Lorenz, J.J., Nuttle, W.K., 2004. Ecological models for ENP evaluation of CERP activities; Roseate Spoonbill Habitat Suitability Index model. Report to South Florida Research Center, Everglades National Park, Homestead FL.

Bjork, R. D. and Powell, G.V.N., 1994. Relationships between hydrologic conditions and quality and quantity of foraging habitat for Roseate Spoonbills and other wading birds in the C-111 basin. Final report to the South Florida Research Center, Everglades National Park, Homestead, Florida.

Bulger A.J., Hayden, B.P.,. Monaco, M.E., Nelson, D.M. McCormick-Ray, M.G., 1993. Biologically based estuarine salinity zones derived from multivariate analysis. Estuaries 16, 311-322.

Davis, S.M., Childers, D., Lorenz, J.J., Hopkins, T.E., 2005. A conceptual model of ecological interactions in the mangrove estuaries of the Florida Everglades. Wetlands 25, 832-842.

DeAngelis, D. L., Loftus, W.F., Texler, J.C., Ulanowicz, R.E., 1997. Modeling fish dynamics and effects of stress in a hydrologically pulsed ecosystem. J. Aqua. Ecosys. Stress Rec. 6: 1-13.

Doren, R.F. 2006. Indicators for Restoration: South Florida Ecosystem Restoration. Report to the South Florida Ecosystem Restoration Task Force.

Dumas, J., 2000. Roseate Spoonbill (Ajaia ajaja). *In:* A. Poole and F. Gill (Eds.) The birds of North America. The Academy of Natural Science, Philadelphia.

Frederick, P., Spalding, M.G., 1994. Factors affecting reproductive success of wading birds (Ciconiiformes) in the Everglades ecosystem. In: S. M. Davis and J. C. Ogden, (Eds.) Everglades. The Ecosystem and Its Restoration. St. Lucie Press, Boca Raton.

Frezza, P.E., Lorenz, J.J., 2003. Distribution and abundance patterns of submerged aquatic vegetation in response to changing salinity in the mangrove ecotone of northeastern Florida Bay. Florida Bay Program and Abstracts form the Joint Conference on the Science and Restoration of the Greater Everglades and Florida Bay Ecosystem. University of Florida, Gainesville FL.

Gawlik, D. E., 2002. The effects of prey availability on the numerical response of wading birds. Ecol. Monogr. 72, 329-346

Kahl, M.P., 1964. Food ecology of the wood stork (Mycteria amaricana). Ecol. Monogr. 34, 97-117.

Light, S.S., Dineen, J.W., 1994. Water control in the Everglades: a historical perspective. In Davis S.M. & J.C. Ogden (Eds), Everglades: the Ecosystem and Its Restoration, St. Lucie press, Delray Beach, FL.

Loftus, W. F., Kushlan, J.A., 1987. Freshwater fishes of southern Florida. Bull. Fla. State Mus. Biol. Sci. 31, 137-344.

Lorenz, J.J., 1999. The response of fishes to physicochemical changes in the mangroves of northeast Florida Bay. Estuaries 22, 500-517.

Lorenz, J.J., 2000. Impacts of water management on Roseate Spoonbills and their piscine prey in the coastal wetlands of Florida Bay. Ph.D. Dissertation, University of Miami, Coral Gables FL.

Lorenz, J.J., Serafy J.E., 2006. Subtropical wetland fish assemblages and changing Salinity regimes: implications of Everglades Restoration. Hydrobiologia 569, 401-422.

Lorenz, J.J., Ogden, J.C., Bjork, R.D., Powell, G.V.N., 2002. Nesting patterns of Roseate Spoonbills in Florida Bay 1935 -1999: implications of landscape scale anthropogenic impacts. In: Porter, J.W. & K. G. Porter (Eds), The Everglades, Florida Bay, and Coral Reefs of the Florida Keys: An Ecosystem Sourcebook, CRC Press, Boca Raton, FL.

Lovett, G.M., Burns, D.A., Driscoll, C.T., Jenkins, J.C., Mitchell, M.J., Rustad, L., Shanley, J.B.,Likens, G.E., Haeuber, R., 2007. Who needs environmental monitoring? Front. Ecol. Environ. 5(5), 253-260.

McIvor, C.C., J.A. Ley & R.D. Bjork, 1994. Changes in freshwater inflow from the Everglades to Florida Bay including effects on the biota and biotic processes: a review. In Davis S.M. & J.C. Ogden (eds), Everglades: the Ecosystem and Its Restoration, St. Lucie Press, Delray Beach, FL: 117-146.

Montague, C.L., Ley, J.A., 1993. A possible effect of salinity fluctuation on abundance of benthic vegetation and associated fauna in northeastern Florida Bay. Estuaries 16, 703-717.

Powell, G. V. N., Bjork, R.D., Ogden, J.C., Paul, R.T., Powell, A.H., Robertson, W.B., 1989. Population trends in some Florida Bay wading birds. Wils. Bull. 101, 436-457

Ross, M. S., Meeder, J.F., Sah, J.P., Ruiz, P.L., Telesnicki, G., 2000. The Southeast Saline Everglades revisited: a half-century of coastal vegetation change. J. Veg. Sci. 11, 101-112.

Scott W.E.D., 1889. A summary of observations on the birds of the gulf coast of Florida. Auk 6, 13-18.

Schiller, A., Hunsaker, C.t., Kane, M.A., Wolfe, A.K., Dale, V.H., Suter, G.W., Russell, C.S., Pion, G., Jensen, M.H., Konar, V.C., 2001. Communicating Ecological Indicators to Decision Makers and the Public. Cons. Ecol. 5(1), 19.

U. S. Army Corps of Engineers. 1999. CERP Central and Southern Florida Comprehensive Review Study. Final Integrated Feasibility Report and Programmatic Environmental Impact Statement. Jacksonville District, United States Army Corps of Engineers, Jacksonville, FL.

U. S. Army Corps of Engineers. 2004. CERP Comprehensive Monitoring and Assessment Plan http://www.evergladesplan.org/pm/recover/recover_map_2004.cfm

Williams, B.K., Szaro, R.C., Shapiro, C.D., 2007. Adaptive Management: The U.S. Department of the Interior technical guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

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Table 1. Decision rule targets and scores for forming performance measure/suitability relationships for the Roseate Spoonbill indicator communication tool.

1. Northeastern Nesting Success: number of successful nesting attempts (average of >1 chick fledged per nest attempt) out of the previous 10 years in northeastern Florida Bay. Target is 7 out of 10 successful years based on the pre-SDCS average (Lorenz et al., 2002)

a. 0 – 3 Red

b. 3 - 6 Yellow

c. 7 - 10 Green

2 Northeastern Nest Production:

A. Five year mean of northeastern Florida Bay nest production expressed as a percentage of northwestern Florida Bay nest production. This metric will be used if any of the control metrics for northwestern Florida Bay (number 7 below) are green. In the case of none of the controls being scored green than 2B will be used.

a. 0 - 33 Red

b. 33 - 66 Yellow

c. > 66 Green

B. Five year mean of the percentage of mean pre-SDCS nest production. Target is 1.5 chicks per nest attempt is based on the mean nest production from 1962 to 1982 (Lorenz et al., 2002). This metric will only be used when all of the northwestern Florida Bay control metrics (number 7 below) are scored as yellow and/or red. In the case of any of the controls being scored a green than 2A will be used.

a. 0 - 50 Red

b 50 - 100 Yellow

c. > 100 Green

3. Nest Number: five year mean of the percentage of pre-SDCS peak nest numbers found throughout Florida Bay. Target is 1250 based on the peak number of nests found in 1978 (Powell et al., 1989).

a. 0 - 50 Red

b. 50 - 100 Yellow

c. > 100 Green

4. Florida Bay Spoonbill Nesting Location: five year mean of the percentage of pre-SDCS peak nest numbers found in northeastern Florida Bay. Target number is 625 based on the peak number of nests found in 1978 (Powell et al., 1989).

a. 0 - 33 Red

b. 33 - 66 Yellow

c. > 66 Green

5. Nesting in Southwestern Everglades Estuaries: No targets or stoplight scores can be set at this time

6. Prey Community Structure: Annual percentage of prey base fish sampling that are classified as freshwater species according to Lorenz and Serafy (2007). Target is that 40% of the total annual catch collected at six sampling sites within the foraging grounds of spoonbills nesting in northeastern Florida Bay (Figure 2: TR, EC, WJ, JB, SB, and HC) are freshwater species using data. Note that this metric is integrative of three years.

a. 0 - 20 Red

b. 20 - 40 Yellow

c. > 40 Green

7. Northwestern Florida Bay Control Metrics:

A: Five year mean of the percentage of mean post-SDCS nest production in northwestern Florida Bay. Target is 1.24 chicks per nest attempt is based on the mean nest production from 1982-2002 (Lorenz et al., 2002).

a. 0 - 50 Red

b 50 - 100 Yellow

c. > 100 Green

B. Five year mean of the percentage of post-SDCS mean nest numbers found in northwestern Florida Bay. Target number is 200 based on the number of nests from 1982-2002 (Lorenz et al., 2002).

a. 0 - 50 Red

b 50 - 100 Yellow

c. > 100 Green

C. Number of successful nesting attempts (average of >1 chick fledged per nest attempt) out of the previous 10 years in northwestern Florida Bay. Target is 6 out of 10 successful years based on the post-SDCS average (Lorenz et al., 2002)

a. 0 – 2 Red
b. 3 - 5 Yellow
c. 6 - 10 Green

8. Cumulative Spoonbill Stoplight Metric: the mean of the 6 (or 7 if nesting location on the southwest coast of Florida can be calculated from future efforts) non-baseline stoplights where red is scored 1, yellow is scored 0.5 and red is zero.

a. 0 - 33 Red
b. 33 - 66 Yellow
c. > 66 Green

Figure(s)

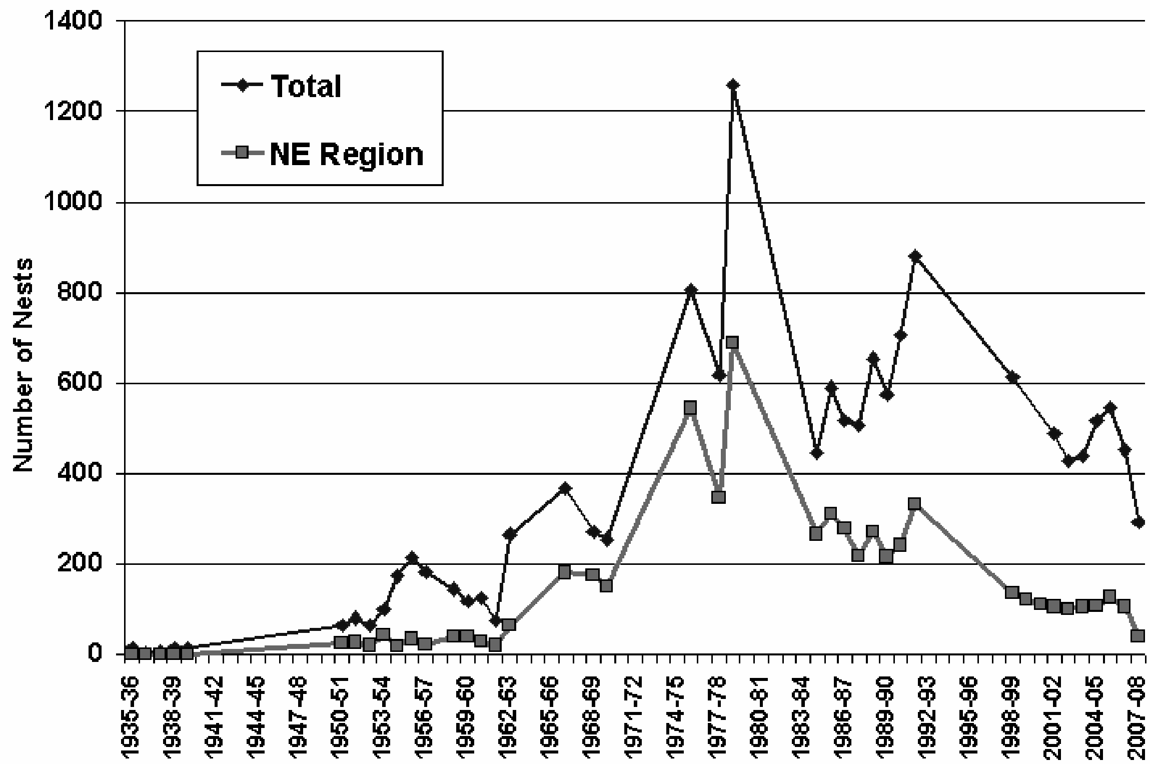

Figure 1. Annual number of roseate spoonbill nests for all of Florida Bay (Total) and for just the northeastern region of the bay from 1935 to 2008.

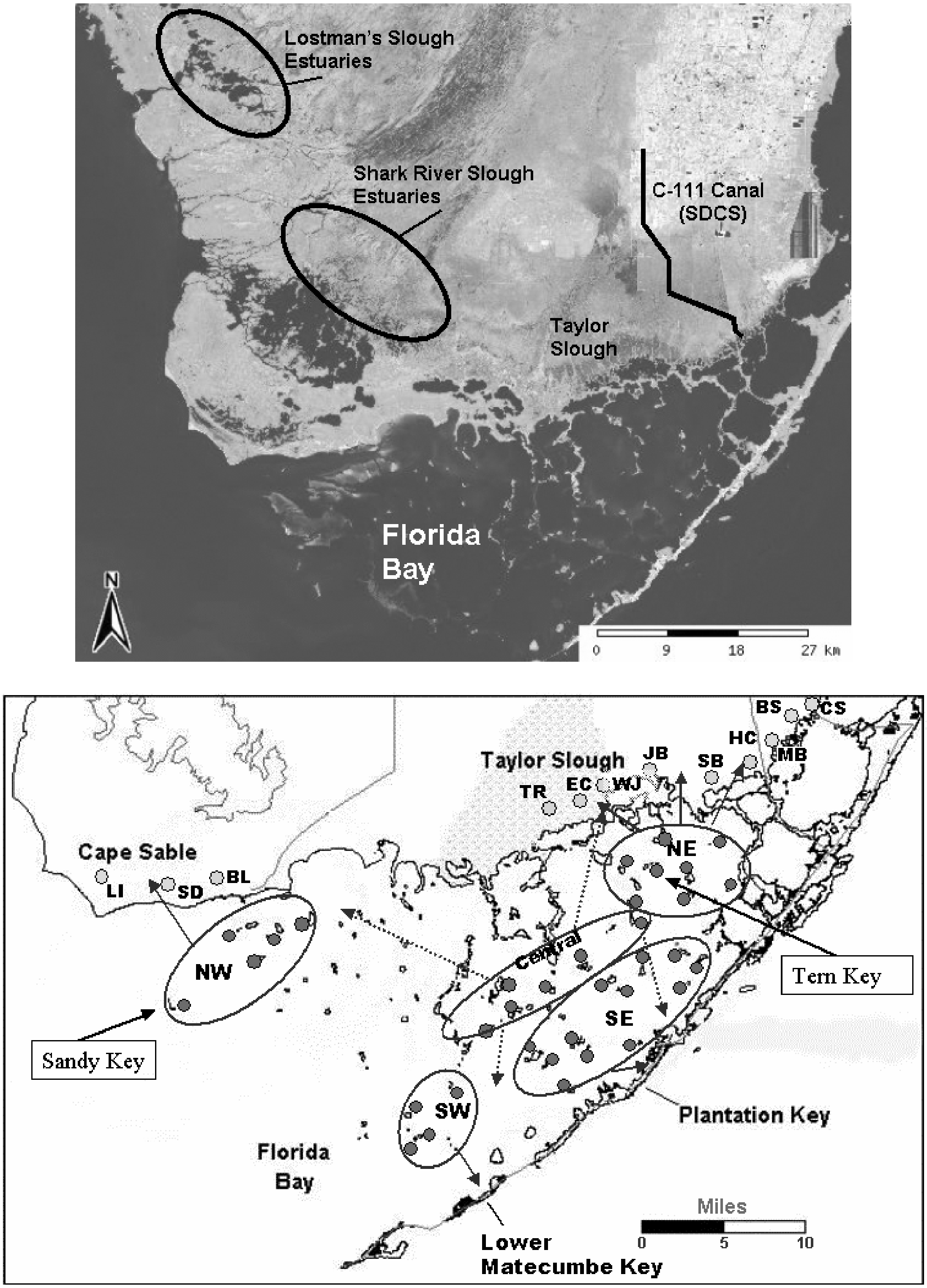

Figure 2. Top : Map of southern Florida indicating the major features discussed. Bottom: Map of Florida Bay indicating all the nesting locations for spoonbills since 1935, the primary foraging areas for five regions of Florida Bay and the fish sampling sites used to evaluate the spoonbill's forage base.

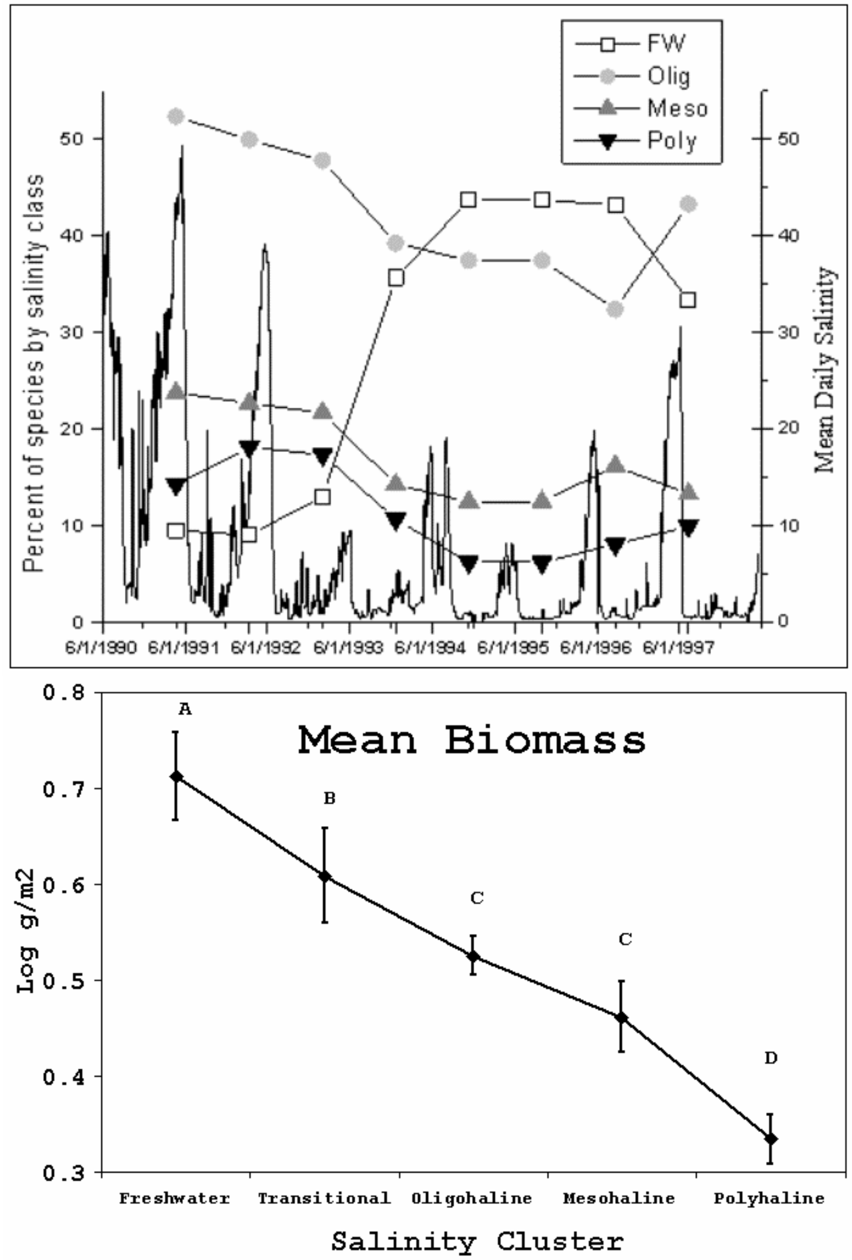

Figure 3. Top: Left Axis : Percent of total species collected annually at the three estuarine fish sampling sites (Figure : TR, JB, HC) by each salinity category as defined by Lorenz and Serafy 2006. Right Axis: Mean daily salinity from the three sites for the period of record. Note that years following a high salinity dry season have lower representation of freshwater species and higher representation of mesohaline and polyhaline species. The figure also indicates that it takes 2 to 3 consecutive years of low salinity for the freshwater species to become the dominate fish category. (Copyright: Hydrobiologia). Bottom: Differences in fish biomass between salinity categories as defined by Lorenz and Serafy (2006) using Non-Metric Multidimensional Scaling from eight years of fish collections at 6 sites. Their results show that samples dominated by lower salinity species have significantly higher biomass than those dominated by higher salinity species. (Copyright: Hydrobiologia).

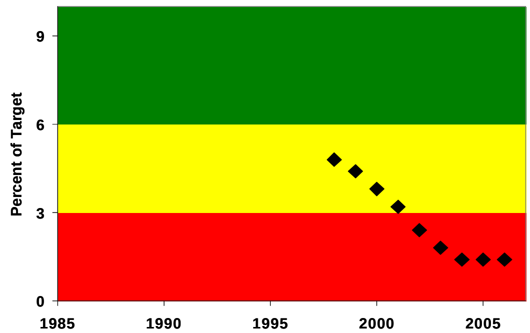

Figure 4. Decadal metric for percent of years nesting was successful. The percentage years out of the previous ten in which spoonbills nesting in northeastern Florida Bay were successful (>1 chick per nest fledged). These data demonstrate the declining number of successful years in spoonbill nesting since 1998. Note that due to data limitations we used the five year average in the figure, however, the ten year mean will be used for the actual stoplight metric.

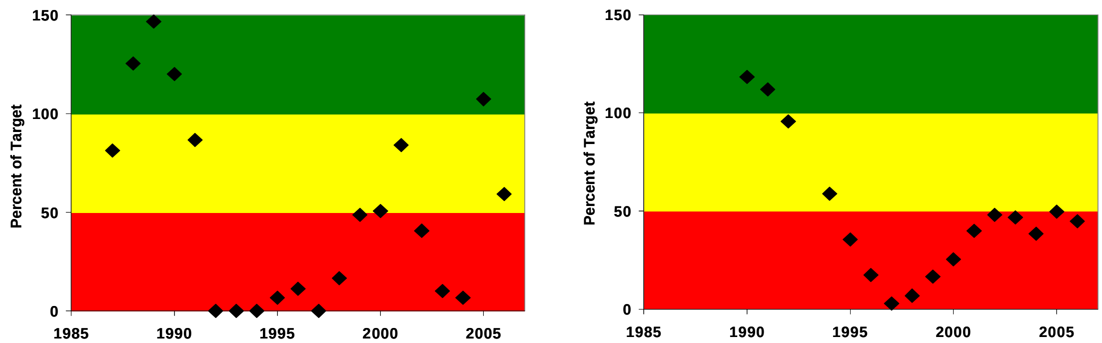

Figure 5. Five year metric used for nest production in northeastern Florida Bay. Left: Percentage of the target production rate of 1.5 chicks per nest fledged in northeastern Florida Bay since the completion of the South Dade Conveyance System (SDCS). The target is based on pre-SDCS nest production data presented by Lorenz et al (2002). Right: The five year running mean of data presented in the figure on the left. Note that due to data limitations the first 3 data points are four year averages, however, the five year mean will be used for the actual stoplight metric. This metric will only be used if the three control metrics for northwestern Florida Bay (Figure) are scored yellow and/or red.

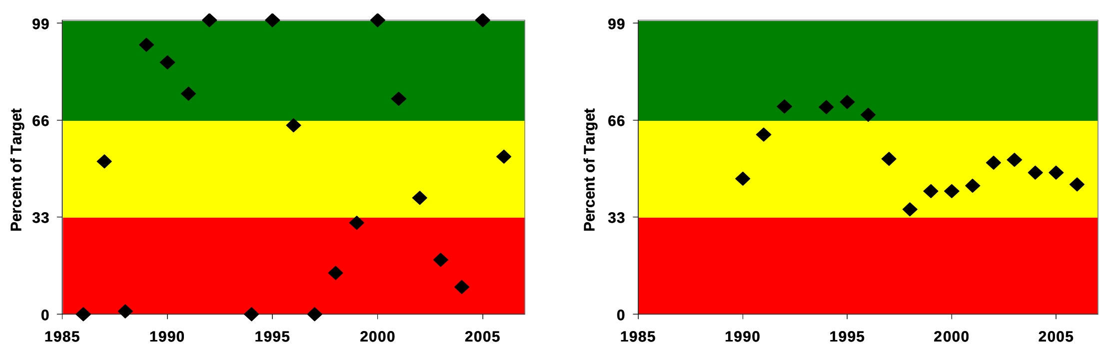

Figure 6. Five year metric used for nest production in northeastern Florida Bay. Left: Northeastern Florida Bay nest production (in chicks fledged per nest attempt) as a percentage of northwestern Florida Bay production since the completion of the South Dade Conveyance System. Right: The five year running mean of data presented in the figure on the right. This metric will be used as the stoplight metric for nest productivity unless the three control metrics for northwestern Florida Bay (Figure) are scored yellow and/or red

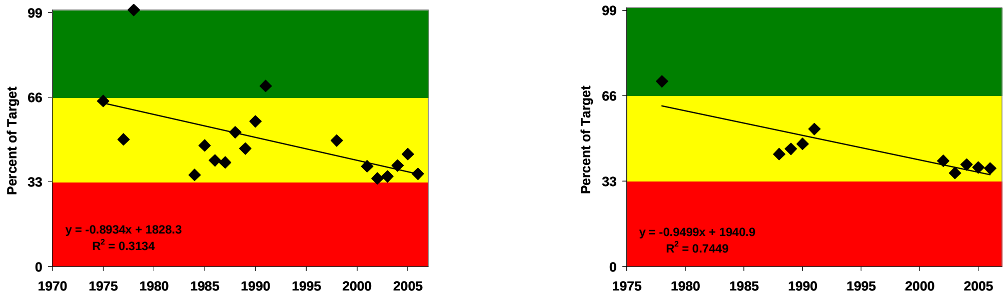

Figure 7. Bay wide nest number metric. Left: Number of nests bay-wide as a percentage of a target of 1250 nests. The target was set based on the maximum number of nests in Florida Bay prior to the completion of the South Dade Conveyance System (SDCS) as reported by Powell et al (1989). . Right: Five year running mean of the data presented to the right. Note that due to data limitations the earliest data point was a mean of only 3 years, however, the five year mean will be used for the actual stoplight metric.

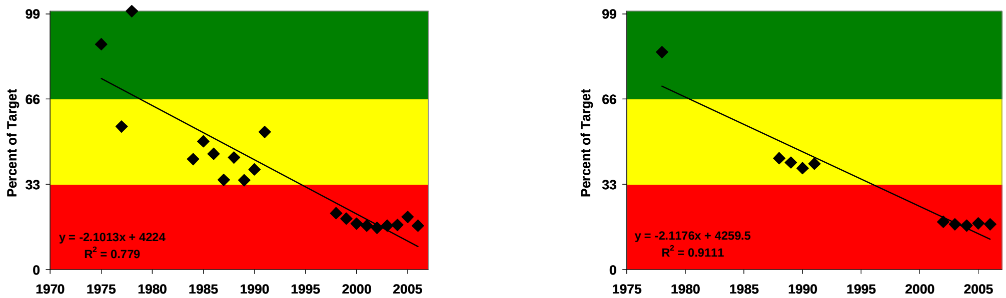

Figure 8. Nest location metric for northeastern Florida Bay. Left: Number of nests in northeastern Florida Bay as a percentage of a target of 625 nests. The target was set based on the maximum number of nests in northeastern Florida Bay prior to the completion of the SDCS as reported by Powell et al (1989). Right: Five year running mean of the data presented to the right. Note that due to data limitations the earliest data point was a mean of only 3 years, however, the five year mean will be used for the actual stoplight metric.

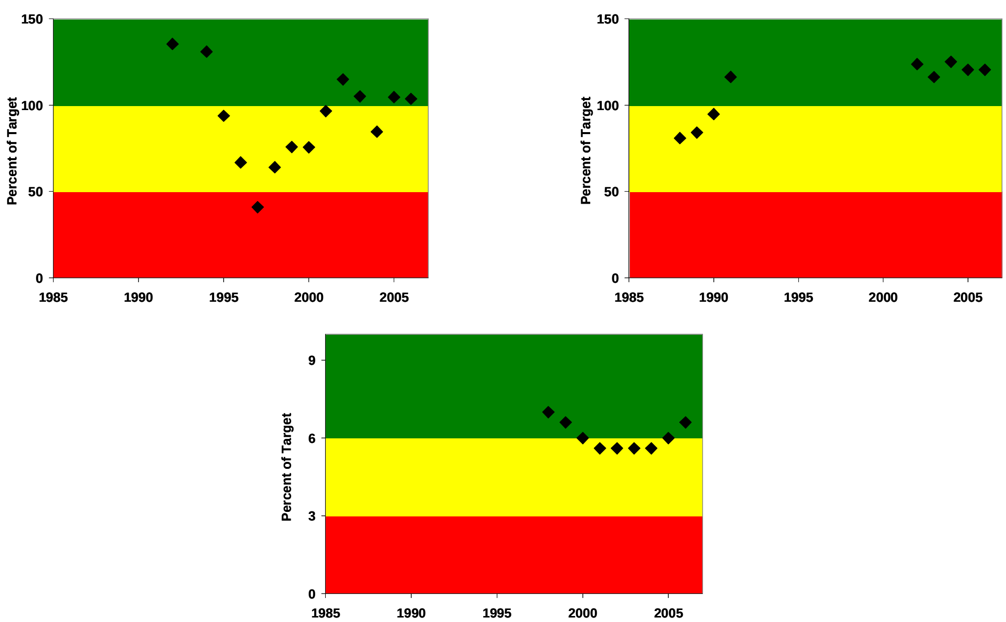

Figure 9 Control metric for using northwestern Florida Bay production as the standard for calculating the stoplight metric in northeastern Florida Bay (Figure ^). Top Right: Percentage of the target production rate of 1.25 chicks per nest fledged in northwestern Florida Bay since the completion of the SDCS. The target is based on the post-SDCS nest production data presented by Lorenz et al (2002). Top Left: Five year mean of the number of nests in northwestern Florida Bay as a percentage of a target of 200 nests. The target was set based on the average number of nests in northwestern Florida Bay since the completion of the SDCS as reported by Lorenz et al (2002). Bottom: The percentage years out of the previous ten in which spoonbills nesting in northeastern Florida Bay were successful (>1 chick per nest fledged). Note that due to data limitations we used the five year average in the figure, however, the ten year mean will be used for the actual stoplight metric.