Manuscript Number:

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

Article Type: Indicators for Restoration

Section/Category:

Keywords: ecological indicators, Everglades restoration, Roseate Spoonbill, Wading Birds, restoration assessment

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Manuscript Region of Origin:

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.

1   **<u>Roseate Spoonbills as an Indicator for Restoration of the Everglades and</u>**

2   **<u>Florida Bay</u>**

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24   **Abstract**

25   Ecological monitoring is a key part of adaptive management and successful

26   restoration. Not everything within an ecosystem can be monitored so it is important to

27   select indicators that are representative of the system, integrate system responses, show

28   clear responses to system change, can be effectively and efficiently monitored, and are

29   easily communicated. Roseate Spoonbills are one of the indicators that meet these

30   criteria within the Everglades ecosystem. Monitoring of Roseate Spoonbills in Florida

31   Bay over the past 70 years has shown that this species responds to changes in hydrology

32   and corresponding changes in prey abundance and availability. This indicator uses

33   nesting location, nest numbers and nesting success in response to food abundance and

34   availability. In turn, prey abundance is a function of hydrological conditions including

35   depth, and salinity. These relationships have been well documented such that spoonbills

36   responses can be directly related to changes in hydrology and salinity. The spoonbill

37   indicator uses performance measures that have been shown to be both effective and

38   efficient in tracking trends. They are: nesting success, nest number, locations of nests,

39   and prey fish community composition. Targets for these performance measures we

40   established based on previous findings. The performance measures are then reported as

41   suitability indices identified as stoplight colors with green indicating that targets have

42   been met, yellow indicating that conditions are below the target but within a suitable

43   range of it and red indicating the measure is performing poorly in relation to the target.

44

45   Key words: ecological indicators, Everglades restoration, Roseate Spoonbill,

46   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

69   have been well documented such that spoonbills responses can be directly related to

70   changes in hydrology and salinity (Lorenz and Serafy, 2006).

71

72   Spoonbill nesting success is dependent on suitable environmental conditions.

73   Correlations between biological responses and environmental conditions contribute to an

74   understanding of the species' status and trends over time (Lorenz, 2000, Lorenz and

75   Serafy, 2006). The positive or negative trends of this indicator relative to hydrological

76   changes (Lorenz, 2000, Lorenz et al., 2002, Bartell et al., 2005) permit an assessment of

77   positive or negative trends in restoration. Restoration success or failure would be

78   evaluated by comparing recent and future trends and status of spoonbills with historical

79   population data and model predictions, as stated in the CERP hypotheses related to the

80   food web (CERP Monitoring and Assessment Plan section 3.1.2.4; U. S. Army Corps of

81   Engineers, 2004).

82

83   The spoonbill indicator uses performance measures that have been shown to be

84   both effective and efficient in tracking trends. They include: nesting success, nest

85   number, locations of nests, and prey fish community composition. These parameters

86   have been correlated with hydrologic conditions including water depth, hydroperiod,

87   timing, spatial extent and salinity, which are influenced by water management practices.

88

89   Roseate Spoonbills are one of several charismatic megafauna found in the

90   Everglades. They are both umbrella and flagship species to which the public can relate.

91   In addition, the parameters used to track trends are easy to understand: How have the

92 number of spoonbills changed through time? Are they as productive as they were

93 historically? Are the animals in the places where they should be? Are their prey as

94 abundant as under natural conditions?

95

96 *1.1. Indicator History*

97 There is a seventy year intermittent database of spoonbill nesting activity in

98 Florida Bay (Figure 1). Lorenz et al., (2002) demonstrated that nesting patterns are

99 highly dependant on hydrologic conditions on the foraging ground most proximal to the

100 nesting colonies (Figure 2). Spoonbills primarily feed on wetland fishes (Dumas, 2000)

101 and time their nesting with low water levels which result in the prey base fishes

102 becoming highly concentrated into the remaining wetted areas (Loftus and Kushlan,

103 1987, DeAngelis et al., 1997, Lorenz, 2000). Studies suggest that tactile feeding wading

104 birds, such as the Roseate Spoonbill, are particularly dependent on high prey density in

105 order to successfully forage, probably more so than the visually oriented avian predators

106 (Kahl, 1964, Frederick and Spalding, 1994, Gawlik, 2002). Tactile feeders are more

107 efficient when prey density is very high and visual predators are more efficient at lower

108 prey densities (Kahl, 1965). Gawlik (2002) experimentally demonstrated that two

109 species of tactile feeders (wood storks and white ibis) abandoned foraging sites while

110 prey was still abundant enough to attract visually oriented wading birds in high numbers.

111 Although no spoonbills visited the study site, Gawlik's (2002) experimental approach

112 lends empirical evidence to the idea that tactile feeders are more sensitive to prey

113 availability. Because tactile foraging birds in general and roseate spoonbill in particular

114 are more dependant on high prey concentration than other wading bird species (Kahl,

115   1964, Gawlik, 2002), they are more sensitive to changes in environmental conditions that

116   determine fish concentrations, specifically water levels (Gawlik, 2002). The requirement

117   for highly concentrated prey is exacerbated during nesting cycles when the high-energy

118   demands of their offspring require a consistently available high density of prey items

119   (Kahl, 1964, Lorenz, 2000, Dumas, 2000).

120

121   Beginning with the completion of a series of canals and water-control structures

122   known as the South Dade Conveyance System (SDCS) in the early 1980's, water

123   deliveries to Taylor Slough and northeastern Florida Bay (Figure 2) changed dramatically

124   (Light and Dineen, 1994, McIvor et al., 1994, Lorenz, 2000). This canal system is

125   immediately adjacent to Taylor Slough and just upstream from where the majority of

126   spoonbills nested in Florida Bay at the time (Figure 2; Powell et al., 1989) and heavily

127   impacted the coastal wetlands that were the primary feeding grounds for the spoonbill

128   nesting population (Bjork and Powell, 1994). In 1979, 1,250 Roseate Spoonbill nests

129   were located in Florida Bay, with more than half the nests located in the northeastern bay

130   (Figure 1, Powell et al., 1989, Lorenz et al., 2002). Today, the number of nests is less

131   than a third of that in 1979 and distribution of nesting by roseate spoonbills has shifted

132   from northeastern Florida Bay to the northwestern region (Figure 2, Lorenz et al., 2002).

133   The shift is attributed to the lack of nest production following the completion of the

134   SDCS: Lorenz et al., (2002) calculated that prior to the SDCS northeastern Florida Bay

135   produced an average of 1.38 chicks per nest attempt but dropped to 0.67 chicks per nest

136   following its' completion. Lorenz (2000) demonstrated that this decline was the result of

6

137 the SDCS causing changes in hydrology and salinity that affected the production (Figure

138 3) and availability of the spoonbill prey base.

139

140   In addition to a large nesting population in Florida Bay, spoonbills "nested in the

141 thousands" along the southwest coast south of Cape Romano (Scott, 1889). Restoration

142 of more historic hydrological conditions should promote greater prey abundance and

143 availability in both Florida Bay and the southwestern estuaries of the Everglades, leading

144 to an increase in the number of years spoonbills can successfully nest, defined as the

145 survival of offspring to fledging. Therefore, roseate spoonbills are good indicators for

146 evaluating the CERP's effectiveness at restoring estuarine conditions (Lorenz et al.,

147 2002).

148

149   The major anthropogenic perturbations to spoonbill foraging grounds have been

150 the filling of wetlands for urban development in the upper Florida Keys and the alteration

151 of wetland type and function along the northeast coast of Florida Bay by water

152 management practices (Lorenz et al., 2002). A striking implication of these findings is

153 that current water management practices in the southern Everglades have resulted in the

154 ecological degradation of the coastal wetlands in northeastern Florida Bay.

155

156 ***1.2 CERP Hypotheses for Spoonbills***

157

158   A system-wide Monitoring and Assessment Plan (MAP) has been developed that

159 describes the monitoring necessary to track ecological responses to Everglades

160   restoration (U.S. Army Corps of Engineers, 2004). Included in that plan are descriptions

161   of selected indicators, how those indicators are linked to key aspects of restoration

162   (hypotheses), and performance measures (monitoring parameters). MAP hypotheses for

163   Roseate Spoonbills are:

164

165   •   Spoonbill's should experience successful nesting (defined as an

166   average production of >1chick/nest) in 7 of 10 years and average 1.5 chicks/nest

167   overall (initially using a five year running average for nest production and a ten

168   year running average successful years).

169   •   Restore nest numbers to pre-SDCS levels of 1250 nests with at

170   least half in the northeastern region (as defined by Lorenz et al., 2002) of Florida

171   Bay. Although specific numbers for the pre-plume hunting era are unknown for

172   Florida Bay, anecdotal evidence suggests that the long term target should be in

173   excess of 2000 nests bay wide.

174   •   A return of significant nesting activity along the southwestern

175   coast of Florida in the estuarine areas of Shark River and Lostman's sloughs

176   (Figure 2).

177

178   *1.3. Areas of the Everglades this Indicator Covers*

179

180   Spoonbills are found throughout the Everglades landscape, however, the species

181   is predominantly an indicator for the Florida Bay estuary (Figure 2) and cover the Greater

182   Everglades and Southern Estuaries region. Spoonbills are included as attributes in the

183   Total System, Everglades Mangrove Estuaries, and Florida Bay conceptual ecological

184   models. A monitoring and assessment plan has been developed for spoonbills nesting in

185   Florida Bay. We perform a complete nest count of the entire bay, monitor nesting success

186   at focal colonies in five regions of Florida Bay and perform quantitative assessments of

187   the mangrove fish community which makes up the bulk of the spoonbill's diet while

188   nesting in Florida Bay.

189

190   **1.4. Significance of the Indicator to Everglades Restoration**

191   ***1.4.1. The indicator is relevant to the Everglades ecosystem and responds to***

192   ***variability at a scale that makes it applicable to a large or portion of the ecosystem.***

193

194   Spoonbills were abundant in Florida Bay and throughout the Southern Estuaries

195   region prior to Everglades drainage activities and have responded negatively to water

196   management activities. They are top predators that share a common prey base (small

197   demersal fishes) and foraging habitat with myriad other species. Spoonbills feed by

198   tactolocation rather than visual hunting; this makes them more sensitive to perturbations

199   than the other species dependant on the same resource (i.e., they are an early warning

200   indicator). Spoonbill nesting productivity is directly linked to hydrologic conditions

201   within the Southern Estuaries and nest production is linked to hydrology through the

202   impact of water management on primary producers (e.g. periphyton, submerged aquatic

203   vegetation) and lower trophic level consumers (i.e., prey base fishes).

204

205   ***1.4.2. The indicator is feasible to implement and is scientifically defensible.***

206

207   Research on Roseate Spoonbills has been conducted for over 70 years, providing a

208 remarkable long-term data base. Currently, there are funded cooperative research and

209 monitoring programs with U.S. Fish and Wildlife Service, Everglades National Park,

210 U.S. Geological Service-Biological Resources Division, U.S. Army Corps of Engineers

211 and the South Florida Water Management District. Reliable models from such research

212 are available that determine the impacts of water management on nesting patterns. Pattern

213 metrics (e.g. nest numbers and nesting success) are statistically correlated to Ecosystem

214 Drivers, and a Spatially Explicit Species Index model is being developed as part of the

215 Across Trophic Level System Simulation modeling effort. This research has provided

216 numerous peer reviewed journal articles. This indicator is already part of the CERP

217 RECOVER interim goals and Food-Web Monitoring Component of the CERP MAP.

218

219   *1.4.3. The indicator is sensitive to system drivers (stressors).*

220

221   Key environment drivers, such as water depth, hydroperiod and salinity, are

222 statistically correlated to spoonbill nesting success (Lorenz, 2000, Lorenz et al., 2002). A

223 causal link exists between hydropatterns, prey abundance and availability, and nesting

224 success (Lorenz, 2000, Lorenz and Serafy, 2006). Nesting failure has been statistically

225 linked to nest number and location in a given region such that persistent nesting failure

226 results in a decline in nesting effort and a concurrent increase in other regions.

227

228   *1.4.4. The indicator is integrative.*

229

230   Spoonbill nesting success is linked to fish production and in turn, fish production

231   is linked to periphyton and SAV production.   Spoonbill nesting responses are

232   representative of hydrological improvement (i.e. Water Management). Spoonbills are

233   also included in the CERP Food-Web Monitoring Component that includes an index

234   of food-web function and landscape connectivity ("intactness").

235

236   **2. The Spoonbill Indicator Performance Measures**

237

238   *2.1. Indicator Metrics*

239

240   The spoonbill indictor consists of four performance measures:

241   • Nesting success (average number of chicks fledged per nesting attempt and

242   number of years out of the last ten in which production exceeded 1.0 chicks per

243   nest fledged)

244   • Number of nests

245   • Distribution of nests (number of nests in northeastern Florida Bay and 10,000

246   islands area)

247   • Prey community structure (percent of total community that are considered

248   freshwater species as defined by Lorenz and Serafy, 2006)

249

250   In addition there will be a metric for spoonbills nesting in the northwestern region

251   of Florida Bay to act as a control metric for restoration efforts that will affect the

252   northeastern region.

253

254   *2.2. The Stoplight Restoration Report Card System Applied to Spoonbills*

255

256   This communication tool is based on MAP performance measures (either by

257   module or system-wide) and is expected to be able to distinguish between responses to

258   restoration and natural patterns. A set of parameters (Table 1) has been developed for

259   each performance measure. Answers are translated as suitability indices identified as

260   stoplight colors with green indicating that targets have been met, yellow indicating that

261   conditions are below the target but within a suitable range of it and red indicating the

262   measure is performing poorly in relation to the target. Two questions are addressed using

263   suitability indices: 1) have we reached the restoration target, or if not, 2) are we making

264   progress toward targets?

265

266   Methods for producing suitability curves vary among performance measures. For

267   example, a ten-year running average was used for percentage of years that spoonbills

268   were successful. A five-year running average was used for average annual nest

269   production and nest numbers. Fish community structure changes to a greater percentage

270   of freshwater species only when salinity conditions have been favorable to these species

271   for a two to three year period, therefore this parameter will be reported as an annual

272   metric that covers a three year period. Nesting success will be reported annually because

273 short-term water depth conditions dominate this parameter. By using this suite of

274 performance measures this indicator covers time scales from annual to three, five and ten

275 year cycles.

276

277 **2.3. Calculation of Metrics and Thresholds for the Spoonbill Stoplight Restoration**

278 **Report Card**

279

280   *2.3.1. Spoonbill nesting success.* Lorenz et al., (2002) divided Florida Bay into

281 five regions based on the primary foraging grounds for each of the colonies within each

282 region (Figure 2). They also demonstrated that, under the SDCS operations, the nest

283 productivity and nest number in the northeastern region have experienced a significant

284 decline. The method used to calculate this metric is based on surveys of focal colonies

285 (defined as the two largest colonies within the region) . These surveys entailed marking

286 up to 50 nests shortly after full clutches had been laid and re-visiting the nests on an

287 approximate 7-10d cycle to monitor chick development. The metric is the number of

288 chicks per nest to survive to twenty-one days. After twenty-one days, the chicks become

289 very active and move throughout the colony precluding accurate accounting of individual

290 nest production. Since 2003, chicks have also been leg-banded so that individual chicks

291 can be identified. By resighting these individuals later in the nesting cycle, we are able to

292 use a second method to estimate nest production. Preliminary analysis of this mark-

293 resighting technique generally confirms that the twenty-one day survival is an accurate

294 method to calculate nest production..

295

296   This stoplight uses two metrics for nest production. The number of successful

297   nesting years out of ten with success being defined as an average nest production of

298   greater than one chick per nest (c/n) for all nest starts. This metric uses only the

299   northeastern region of the Bay (Figure 2) as this has been demonstrated to be the region

300   most impacted by water management practices (Lorenz et al., 2002). Prior to the

301   establishment of the SDCS, spoonbills nesting in the northeastern region averaged 71%

302   successful years (Lorenz et al., 2002). Stoplight colors were based on this threshold

303   (Table 1, Figure 4).

304

305   The second metric of nest production is the five year mean of nest production in

306   the northeastern region. Lorenz et al., (2002) demonstrated that prior to the SDCS annual

307   mean spoonbill production in the northeast region was 1.38c/n and that this dropped to

308   0.67 post-SDCS. Initially we set this as the target for the stoplight metric where annual

309   production was divided by 1.5 c/n with greater than 67% set as the threshold for a green

310   rating. However, as can be seen in Figure 5, there are no trends in the data with rapid

311   changes occurring from one year to the next. This is due to the interannual differences in

312   hydrologic conditions that affect the ability of spoonbills to capture enough prey to

313   successfully raise young. Simply put, some years are naturally better than others. Taking

314   a multi-year running average smoothes this high variability into more interpretable trends

315   (Figure 5). By examining various time frames from previous data we concluded that by

316   using a five year running average, no single good or bad year out of the five skewed the

317   results into the red or green classification. A single good or bad year in either the two,

318   three or four year running averages could bias the mean, thus resulting in an inaccurate

319   stoplight color.

320

321   There are natural background conditions that can result in nest failure that are

322   unrelated to CERP or water management practices. Therefore, we need to control for

323   natural background variation in foraging conditions. We dealt with this problem by using

324   the northwestern region's success rate as control for natural background conditions.

325   While the northeastern region's production declined post SDCS, the northwestern regions

326   production remained relatively high (1.24c/n) even though there was still a great deal of

327   interannual variability. Lorenz and Frezza (2007) concluded that the interannual variation

328   in productivity of the northwestern colonies reflects the natural variation while the

329   variation in the northeast is affected by both this background and by water management

330   practices. Therefore, we propose that the metric used to gage success in the northeastern

331   region be tied to that of the northwestern, i.e., the metric should be calculated by dividing

332   annual northeastern production by that of the northwest thereby resulting in a percentage

333   (Figure 6). The thresholds for stoplight colors are presented in Table 1.

334

335   Although this metric solves the problem of natural interannual variation in nesting

336   success, it is also dependant on the continued high rates of success of the northwestern

337   colony. What happens if CERP or other issues begin to negatively affect the success of

338   the northwestern colonies? This would result in the metric receiving higher scores even

339   though there was actually a degradation of the bay for spoonbills. Therefore, stoplight

340   metrics were developed to examine the northwestern regions (explained below in section

341 2.3.5).   If all three of the metrics are yellow or red then the metric for northeastern

342 success should be based on the long term mean production rate of 1.5 c/n for northeastern

343 Florida Bay (Lorenz et al., 2002, Figure 5).

344

345   *2.3.2. Number of spoonbill nests in Florida Bay*. Spoonbill nest counts for

346 Florida Bay have been performed intermittently since 1935 (Powell et al., 1989). Over

347 that period, spoonbills have been recorded nesting on thirty-eight keys throughout the

348 Bay (Figure 2; Lorenz et al., 2002). Spoonbills typically establish nests in Florida Bay in

349 November or December of each year, however, nest initiation has started as early as

350 October and as late as March (Powell et al., 1989, Alvear-Rodriguez, 2001). All known

351 nesting keys are visited every twenty-one days during the nesting season. Our data show

352 that prior to the establishment of the SDCS, the peak number of nests was 1258 in 1978

353 (Figure 1, Lorenz et al., 2002). For this stoplight, annual nest counts are divided by 1258

354 to get the annual percentage of the historic peak number of nests (Figure 7) and assigned

355 the stoplight color as per Table 1.

356

357   *2.3.3 Spoonbill nesting location.* This stoplight indicator consists of two metrics:

358 a return to pre-SDCS nest numbers in the northeastern region and return of spoonbills to

359 nesting colonies along the southwest coast of the Everglades in the Shark River Slough

360 and Lostman's Slough estuaries. Powell et al., (1989) reported that in the peak year of

361 1978 more than half of the 1258 nests were located in the northeast region (688 nests).

362 Following the completion of the SDCS, this number dropped to approximately 100 nests

363 from 2000 to 2007. In 2008 there were a total of 47 nests in the region. For restoration

364 to be considered successful, we should expect a return to nesting numbers to pre-SDCS

365 numbers. This metric is the percentage of 650 nests that occur annually (Figure 8).

366 Similar to nest success and total nests for Florida Bay, the interannual variation can bias

367 individual years and a five year mean was used for this metric (Table 1).

368

369   According to Scott (1889), spoonbills "nested in the thousands" along the

370 southwest coast of the Everglades in the Shark River and Lostman's slough estuaries.

371 Restoration of more historic hydrological conditions should promote greater prey

372 abundance and availability in this region, potentially leading to a return of spoonbill

373 nesting in large numbers. In recent years, Everglades National Park has performed aerial

374 wading bird surveys of this area and has documented spoonbill nesting (Pers. Comm,

375 Sonny Bass, Supervisory Wildlife Biologist, Everglades National Park), however

376 accurate surveys of spoonbills nest number can not be performed from aircraft because

377 they tend to nest low in the canopy. Although it is imperative to get a baseline for pre-

378 CERP nesting in this critical region, no funds have been identified to pay for this effort.

379 As a result, no stoplight metrics can be established at the time of this publication.

380

381   *2.3.4 Prey Community Structure*. Spoonbills primarily feed on small demersal

382 fishes found throughout the Everglades system (Allen, 1942, Dumas, 2000). Lorenz et

383 al., (1997) developed a methodology that uniquely sampled fishes in the dwarf mangrove

384 foraging grounds that are the preferred feeding locations for spoonbills nesting in Florida

385 Bay. The sampling design uses a $9m^2$ drop trap at fixed locations at known spoonbill

386   feeding sites. Data collection began in 1990 at four sites. Currently, there are 14

387   sampling sites associated with Florida Bay's nesting spoonbill population (Figure 2)

388

389   Lorenz (1999) documented that these fish respond markedly to changes in water

390   level and salinity and these factors can be altered by water management practices.

391   Lorenz and Serafy (2006) performed a fish community analysis of eight years of these

392   data from six sites. During the eight-year span reported by this study, there were three

393   consecutive years of unusually high rainfall and freshwater flows to the estuary which

394   resulted in low salinity similar those believed to have occurred in the region prior to

395   water management influences. As part of their analysis, Lorenz and Serafy (2006),

396   placed individual species in one of four salinity categories (freshwater, oligohaline,

397   mesohaline or polyhaline) based on the Venice System of Estuarine Classification

398   (Bulger et al., 1993). To accomplish this, the authors used the mean salinity for the thirty

399   days prior to a given collection (based on the findings of Lorenz, 1999) to identify the

400   range of salinities in which each species was found. The median score of each species

401   salinity range was then used to classify the species into one of the four categories.

402   During the period of low salinity and high fish abundance, Lorenz and Serafy (2006)

403   found that more than 40% of the total fish community were freshwater affiliates (Figure

404   3). Furthermore, they demonstrated that it took two to three years of low salinity for the

405   freshwater populations to respond. Finally, they demonstrated these low salinity

406   communities were much more productive based on both number and biomass of the

407   standing stock (Figure 3). The stoplight for prey abundance will use the percentage of

408   the fish community that was classified by Lorenz and Serafy (2006) as freshwater species

409   as per Table 1. Although the stoplight will be reported on an annual basis, it is

410   integrative for the previous two years as well, i.e., this stoplight measures conditions on a

411   three year time scale.

412

413   *2.3.5 Monitoring nesting success in northwestern Florida Bay as a control*. As

414   stated above, comparing nesting success in the northeastern bay to that of the

415   northwestern bay accounts for background fluctuations on an interannual basis. For this

416   metric to work, however, there needs to be a control for any anthropogenically induced

417   reduction in nesting and productivity in the northwestern bay. We propose three stoplight

418   metrics to act as a control for the proposed comparison of the two regions. Lorenz et al.,

419   (2002) indicated that the mean production rate for spoonbill nests in the northeastern

420   region was 1.24 c/n. Based on this we expect the five year mean production rate to

421   remain above 1.25 c/n and the control stoplight will remain green so long as this criterion

422   is met (Figure 9, Table 1). Since the completion of the SDCS, the northwestern region of

423   Florida Bay has produced a mean of 218 nests annually. Based on this metric, we set the

424   control metric for nest number at 200 and use a five year running mean of the percentage

425   of 200 as the stoplight indicator (Figure 9, Table 1). Finally, spoonbills have averaged

426   success in more than six of every ten years in the northwest region. The percentage of

427   successful years (mean production of >1.0 c/n) will also be used as a control with any

428   metric above six of ten years receiving a green stoplight score (Figure 9, Table 1). If all

429   three of the control metrics are yellow and/or red, than the metric for the northeastern bay

430   should be re-evaluated based on the historic trends of the northeastern region (Figure 5).

431

432   **3. Longer-Term Science Needs**

433   Population dynamics of spoonbills in the Everglades and methods to monitor their

434   responses to hydrologic management effectively, are relatively well understood. The

435   techniques used to survey spoonbills is relatively well worked out, however, there are

436   components of their basic biology that are unknown. For example, life expectancy and

437   age at maturity are not known. Furthermore, migratory patterns are not well understood

438   and need to be assessed to determine if spoonbills nest in multiple locations annually or if

439   the nesting population in Florida Bay is distinct from other nesting locations around the

440   state. Also, our knowledge of the dispersal of fledglings from the nesting colony is

441   extremely limited. A banding program is underway to determine movements within the

442   state, however, further funding for this effort has not been identified and the program will

443   be eliminated without identification of funds. Furthermore, a satellite tagging program

444   would provide a great deal of information on international movements (e.g. Cuba,

445   Yucatan). This would also allow definitive data on local foraging flights. Currently, we

446   use inferences (such as flight line counts) to track where birds are feeding.

447

448   Currently there are no efforts to survey wading bird nesting colonies in the

449   estuaries of the southwestern coast of the Everglades even though this has been

450   documented as an important nesting area prior to the plume hunting era. A return to

451   nesting in this area has been identified as an important indicator for the restoration of

452   flows through Shark River and Lostman's sloughs. Funding for such surveys may be

453   expensive as they will require the use of a helicopter for access, however, it is imperative

454   that such funds be identified so as to maximize the use of this versatile indicator species

455   in the larger restoration plan.

456

457   Of the seventeen existing prey fish sampling sites, three critical sites in

458   northeastern Florida Bay are not funded through any restoration effort. Secure funding

459   for these sites needs to be identified to preserve the statistical integrity of this effort.

460

461   **4. Discussion and Conclusions**

462

463   *4.1 Effectiveness of spoonbills as an Indicator of Ecological Restoration*

464   Spoonbills provide information to assess restoration of the Everglades that are

465   unique from other wading bird indicators and require different methods of assessing their

466   population trends. Therefore, spoonbills were identified as a separate indicator from the

467   other wading bird species for two reasons. First, spoonbills nest cryptically within the

468   canopy of mangroves and are not conspicuous from the air requiring nesting surveys to

469   be performed on the ground rather than aerially. As a result, different parameters have

470   been used to monitor spoonbills. Since we have to enter the nesting colonies to monitor

471   nesting effort, we are able to get more accurate counts of total nests, what region of

472   Florida Bay the nests were located, and the success of individual nests is documented

473   through mark and revisitation of the nests.

474

475   In southern Florida, spoonbills show a distinct fidelity to estuarine habitats with

476   approximately 90% of all nests found within Florida Bay, Tampa Bay and Indian River

477   Lagoon (although in recent years spoonbills have begun nesting at such inland freshwater

478   habitats such as the Corkscrew Swamp, Water Conservations Areas and mainland

479   Everglades National Park). In contrast, other wading birds are much more plastic in there

480   selection of breeding sites with a well documented switch from coastal mangrove habitats

481   to the Water Conservation Areas in response to water management practices. Given

482   these differences, spoonbills are an indicator for Florida Bay, the southwest coastal

483   estuaries and, perhaps Biscayne Bay while other wading birds are indicators for central

484   Everglades habitats.

485

486   The RECOVER Conceptual Ecological Models identify three major stressors to

487   wetlands that are affecting the spoonbill nesting activities in Florida Bay: reduced

488   freshwater flow volume and duration (affecting hydrology and salinity, fish abundance

489   and availability); invasive exotic species (affecting primary producers and the prey base

490   fish community); and sea level rise (affecting habitat loss, wetland function and

491   geomorphology, preliminary and secondary production in the prey base) (Davis et al.,

492   2005; CERP Monitoring and Assessment Plan; U. S. Army Corps of Engineers, 2004).

493   Only the first of these stressors will be ameliorated by CERP and, therefore, the spoonbill

494   assessment tool only addresses issues for water flow, volume and duration.

495

496   Changes in salinity patterns reduces primary production (through stresses caused

497   by rapid and frequent fluctuations in salinity; Montague and Ley, 1993, Ross et al., 2000,

498   Frezza and Lorenz, 2003) and alter the prey base fish community to a state of lower

499   secondary production (Lorenz, 1999, Lorenz and Serafy, 2006). As a result, the overall

500   abundance of spoonbill prey items is reduced. The spoonbill assessment tool includes a

501   parameter that examines fish community structure which has been shown to have a direct

502   link to prey fish productivity thereby addressing this issue.

503

504   Changes in the timing and distribution of fresh-water deliveries, result in

505   increased water levels on the primary foraging grounds of spoonbills nesting in

506   northeastern Florida Bay (Lorenz, 2000). Studies performed in the mangrove foraging

507   grounds indicate that the prey base fishes begin concentrating into deeper creeks and

508   pools when water level on the wetlands drops to a certain depth threshold (Lorenz, 2000).

509   Spoonbills time nesting with falling water levels on these wetlands such that prey will be

510   concentrated at the time of egg hatching (Bjork and Powell, 1994). This provides a

511   highly available and consistent prey resource at a time when the energetic demands of

512   their rapidly growing young are highest. Out-of-season pulse releases resulting from

513   upstream water management activities rapidly raise water levels above the concentration

514   threshold and fish disperse across the surface of the wetland. This eliminates the needed

515   abundant and easily captured food resources for the spoonbills. Even brief reversal

516   events (3-5 days) can result in total failure of the spoonbill colonies. CERP and related

517   projects will alleviate this situation leading to higher nesting success and a return to

518   higher nest numbers in northeastern Florida Bay. The spoonbill metrics of nesting

519   success, location and number assess these components of the impacts of water

520   management practices.

521

522   The performance measure metrics chosen for spoonbills reflect current and

523   historic ecosystem conditions. The metrics used to evaluate spoonbills have been well

524 documented in the literature and are based on the best understanding of how the Florida

525 Bay estuary functioned historically, currently and how we expect it to function under

526 restored conditions. The metrics used provide both spatial and temporal metrics to assess

527 the state of recovery efforts. We conclude that the spoonbill assessment tool will provide

528 a powerful and integrative means to evaluate CERP activities.

529

530 *4.2. Communicating the Spoonbill Indicator*

531

532 Roseate spoonbills, being a species that Everglades visitors seek out and

533 appreciate provide a valuable social as well as natural indicator. They are also well

534 accepted by managers and policy makers as a species that is important to our

535 understanding of estuarine systems. This is an important feature for system-wide

536 integrative indicators and we can capitalize on these points with the spoonbill indicator.

537

538 Making environmental decisions requires both effective communication of

539 environmental information to decision makers and consideration of what members of the

540 public value about ecosystems (Schiller et al., 2001). As described above, spoonbills are

541 good indicators (well-established relationships with environmental parameters under

542 management control) and the metrics (nest number and location, nesting success, prey

543 species composition) are remarkably easy to understand and communicate. The first

544 MAP Annual Assessment Report for spoonbills and their prey summarizes the most

545 recent advancements for spoonbills (System Status Report, 2006). The concepts of low

546 nest numbers, nesting in less desirable habitats, declines in nest success and prey

547   abundance are all real concepts, with meaning to managers. Tracking improving or

548   declining conditions due to restoration activities with these metrics is easily

549   communicated and understood.

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667

668

679   Table 1. Decision rule targets and scores for forming performance measure/suitability

680   relationships for the Roseate Spoonbill indicator communication tool.

681

682   1. Northeastern Nesting Success: number of successful nesting attempts (average of >1 chick

683   fledged per nest attempt) out of the previous 10 years in northeastern Florida Bay. Target is 7

684   out of 10 successful years based on the pre-SDCS average (Lorenz et al., 2002)

685   a.   0 – 3   Red

686   b.   3 - 6   Yellow

687   c.   7 - 10   Green

688

689   2 Northeastern Nest Production:

690   A. Five year mean of northeastern Florida Bay nest production expressed as a percentage of

691   northwestern Florida Bay nest production. This metric will be used if any of the control

692   metrics for northwestern Florida Bay (number 7 below) are green. In the case of none of the

693   controls being scored green than 2B will be used.

694   a.   0 - 33   Red

695   b.   33 - 66   Yellow

696   c.   > 66   Green

697

698   B. Five year mean of the percentage of mean pre-SDCS nest production. Target is 1.5 chicks

699   per nest attempt is based on the mean nest production from 1962 to 1982 (Lorenz et al.,

700   2002). This metric will only be used when all of the northwestern Florida Bay control

701   metrics (number 7 below) are scored as yellow and/or red. In the case of any of the controls

702   being scored a green than 2A will be used.

703   a.   0 - 50   Red

704   b   50 - 100   Yellow

705   c. > 100   Green

706

707   3. Nest Number: five year mean of the percentage of pre-SDCS peak nest numbers found

708   throughout Florida Bay. Target is 1250 based on the peak number of nests found in 1978

709   (Powell et al., 1989).

710   a.   0 - 50   Red

711   b.   50 - 100   Yellow

712   c.   > 100   Green

713

714   4. Florida Bay Spoonbill Nesting Location: five year mean of the percentage of pre-SDCS peak

715   nest numbers found in northeastern Florida Bay. Target number is 625 based on the peak

716   number of nests found in 1978 (Powell et al., 1989).

717   a.   0 - 33   Red

718   b.   33 - 66   Yellow

719   c.   > 66   Green

720

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

722   time

723

724 6. Prey Community Structure: Annual percentage of prey base fish sampling that are classified as

725   freshwater species according to Lorenz and Serafy (2007). Target is that 40% of the total

726   annual catch collected at six sampling sites within the foraging grounds of spoonbills nesting

727   in northeastern Florida Bay (Figure 2: TR, EC, WJ, JB, SB, and HC) are freshwater species

728   using data. Note that this metric is integrative of three years.

729   a.   0 - 20   Red

730   b.   20 - 40   Yellow

731   c.   > 40   Green

732

733 7. Northwestern Florida Bay Control Metrics:

734   A: Five year mean of the percentage of mean post-SDCS nest production in northwestern

735   Florida Bay. Target is 1.24 chicks per nest attempt is based on the mean nest production

736   from 1982-2002 (Lorenz et al., 2002).

737   a.   0 - 50   Red

738   b   50 - 100   Yellow

739   c.   > 100   Green

740

741   B. Five year mean of the percentage of post-SDCS mean nest numbers found in northwestern

742   Florida Bay. Target number is 200 based on the number of nests from 1982-2002 (Lorenz et

743   al., 2002).

744   a.   0 - 50   Red

745   b   50 - 100   Yellow

746   c.   > 100   Green

747

748   C. Number of successful nesting attempts (average of >1 chick fledged per nest attempt) out of

749   the previous 10 years in northwestern Florida Bay. Target is 6 out of 10 successful years

750   based on the post-SDCS average (Lorenz et al., 2002)

751   a. 0 – 2   Red

752   b. 3 - 5   Yellow

753   c. 6 - 10   Green

754

755   8. Cumulative Spoonbill Stoplight Metric: the mean of the 6 (or 7 if nesting location on the

756   southwest coast of Florida can be calculated from future efforts) non-baseline

757   stoplights where red is scored 1, yellow is scored 0.5 and red is zero.

758   a. 0 - 33   Red

759   b. 33 - 66   Yellow

760   c. > 66   Green

761
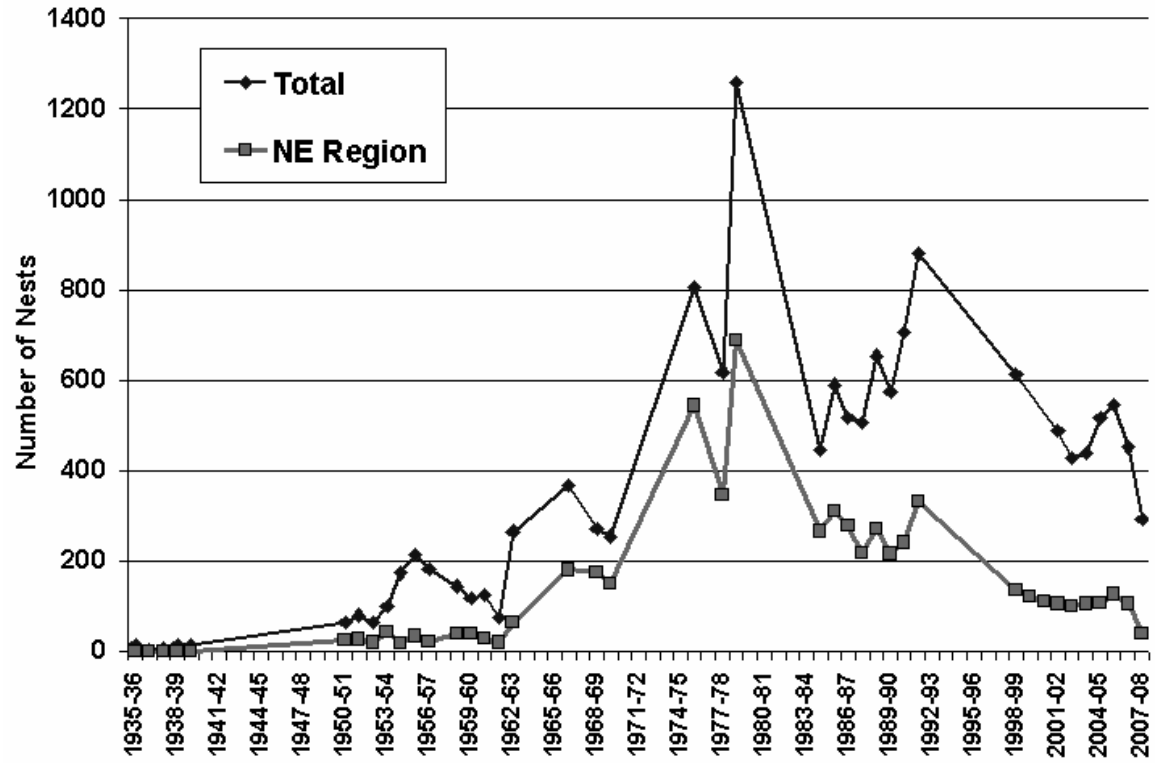
Figure 1. Annual number of roseate spoonbill nests for all of Florida Bay (Total) and for just the northeastern region of the bay from 1935 to 2008.
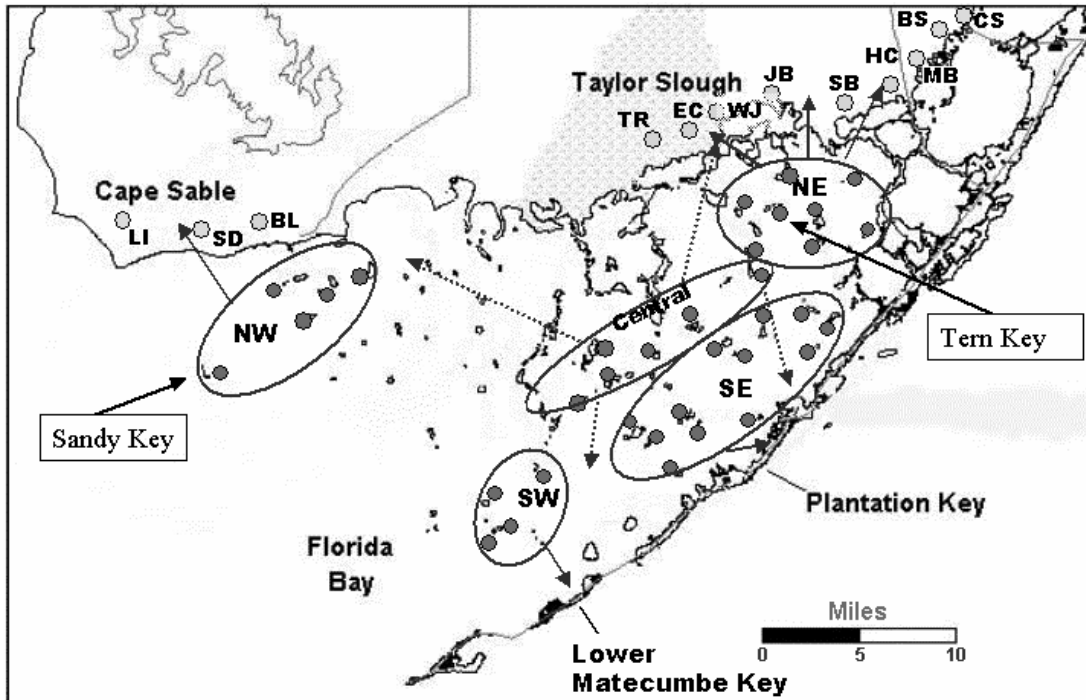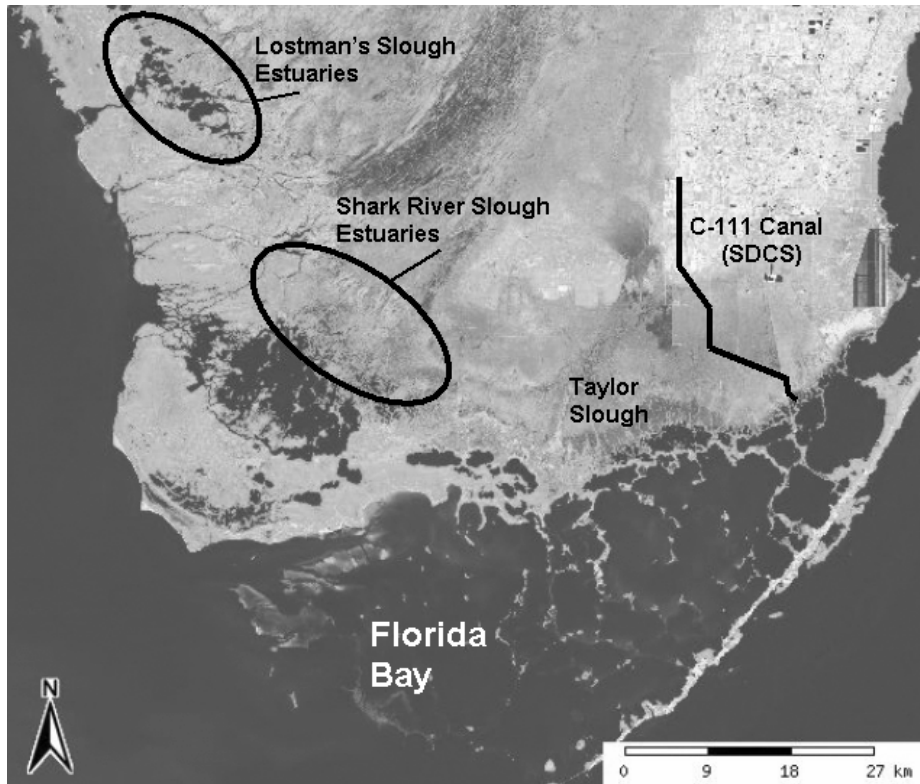
Figure 2. Top : Map of southern Florida indicating the major features discussed.
Bottom: Map of Florida Bay indicating all the nesting locations for spoonbills since 1935,
the primary foraging areas for five regions of Florida Bay and the fish sampling sites
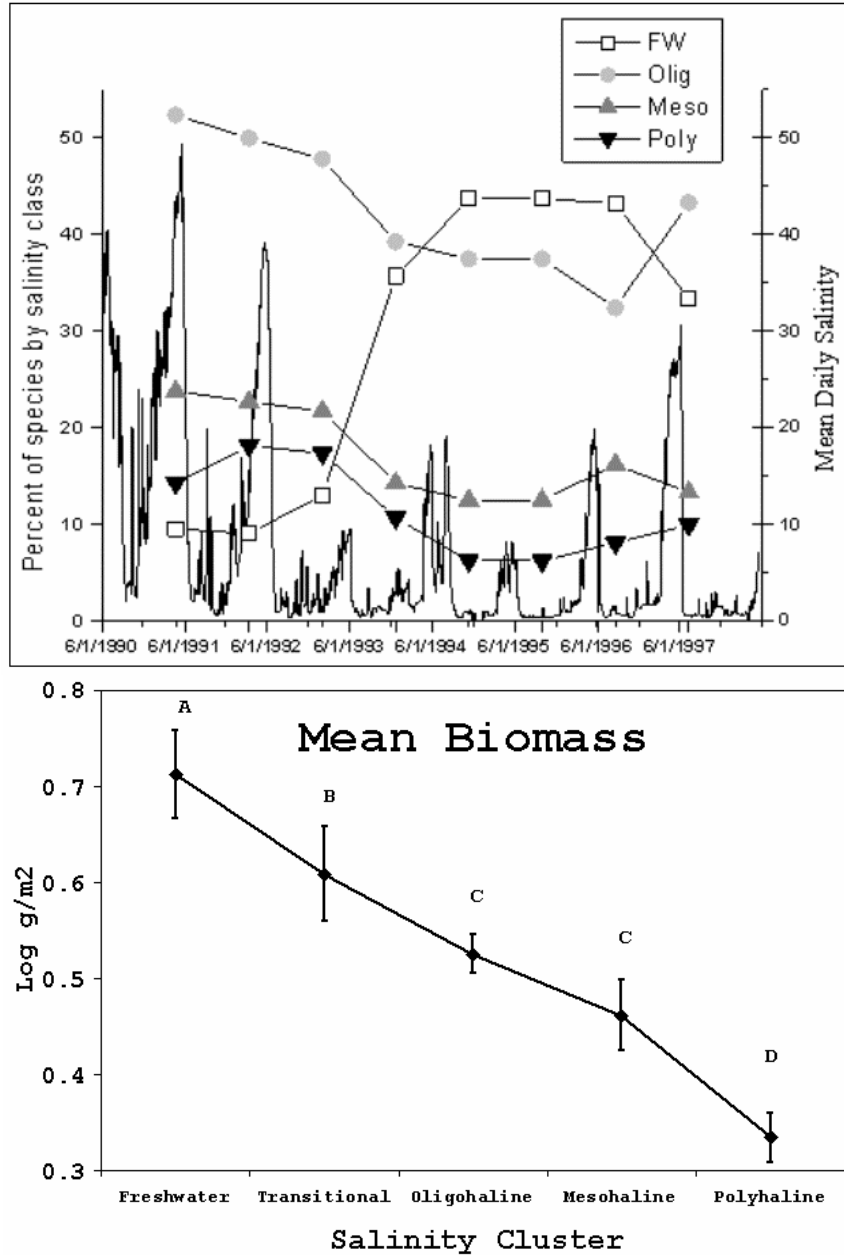used to evaluate the spoonbill's forage base.

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).
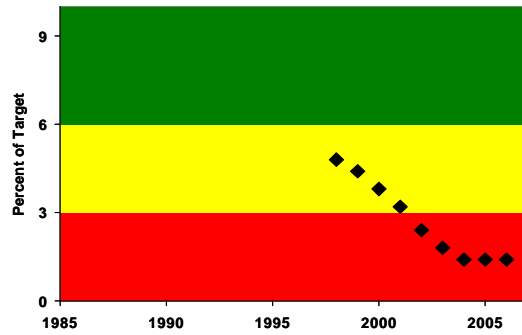
Figure 4. Decadal metric for percent of years nesting was successful. The percentage years out of the previous ten in which spoonbills nesting in northeastern Florida Bay were successful (>1 chick per nest fledged). These data demonstrate the declining number of successful years in spoonbill nesting 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.
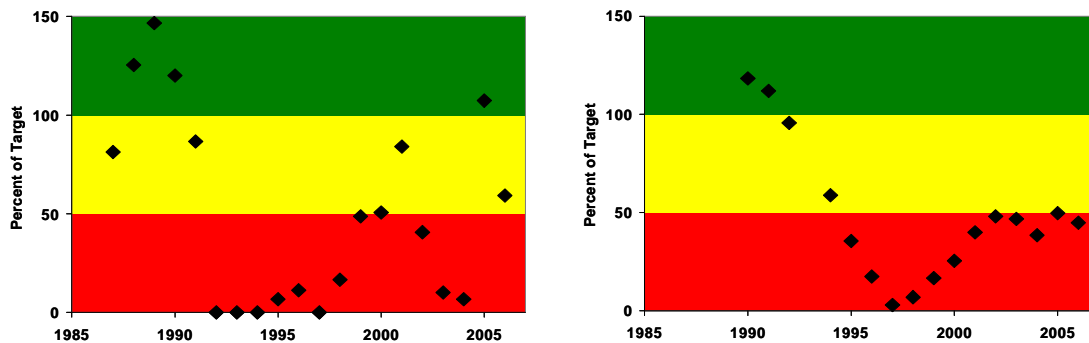

Figure 5. Five year metric used for nest production in northeastern Florida Bay. Left: Percentage of the target production rate of 1.5 chicks per nest fledged in northeastern Florida Bay since the completion of the South Dade Conveyance System (SDCS). The target is based on pre-SDCS nest production data 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.
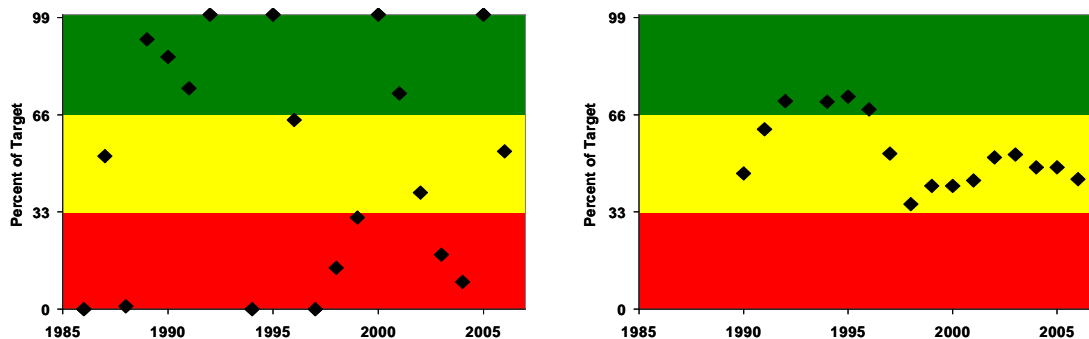

Figure 6. Five year metric used for nest production in northeastern Florida Bay. Left: Northeastern Florida Bay nest production (in chicks fledged per nest attempt) as a percentage of northwestern Florida Bay production since the completion of the South Dade Conveyance System. Right: The five year running 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
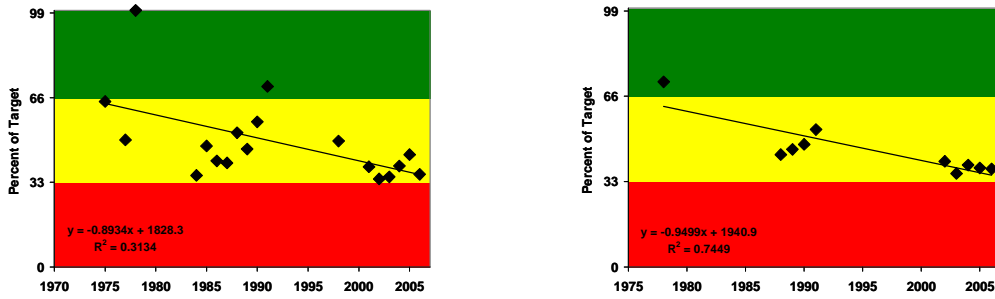
Figure 7. Bay wide nest number metric. Left: Number of nests bay-wide as a percentage of a target of 1250 nests. The target was set based on the maximum number of nests in Florida Bay prior to the completion of the South Dade Conveyance System (SDCS) as reported by Powell et al (1989). . Right: Five 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.
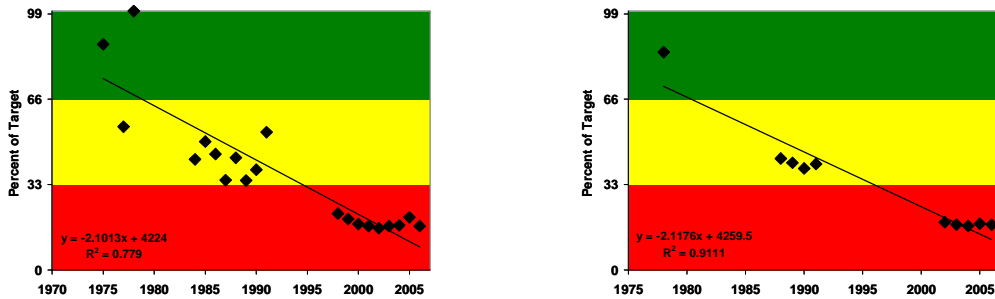

Figure 8. Nest location metric for northeastern Florida Bay. Left: Number of nests in northeastern Florida Bay as a percentage of a target of 625 nests. The target was set based on the maximum number of nests in northeastern Florida Bay prior to the completion of the SDCS as reported by Powell et al (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.
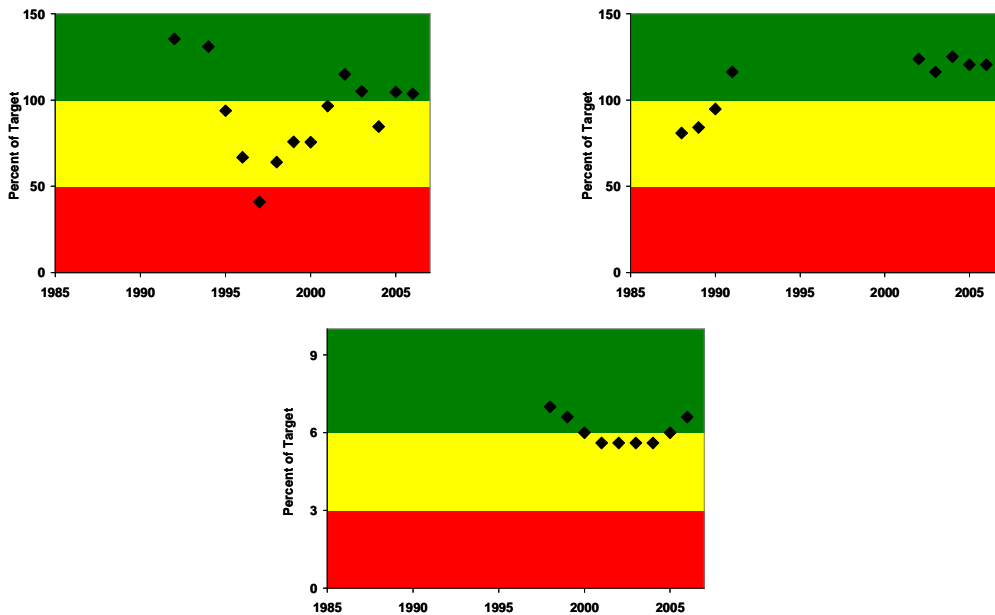

Figure 9 Control metric for using northwestern Florida Bay production as the standard for calculating the stoplight metric in northeastern Florida Bay (Figure ^). Top Right: Percentage of the target production rate of 1.25 chicks per nest fledged in northwestern Florida Bay since the completion of the 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.