2008 Assessment Update

Pink Shrimp Indicator for the Southern Estuaries (SE)

Supported by
MAP activities 3.2.3.5 and 3.2.4.5

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Background

The pink shrimp, *Farfantepenaeus duorarum*, was chosen as a faunal indicator of the ecosystem status of southern estuaries because the species is abundantly represented, wide spread and is economically as well as ecologically important. Furthermore, it has been extensively studied in South Florida with previous work suggesting relationships with salinity, and long data series are available for some locations to help establish targets. South Florida's southernmost estuaries—Biscayne Bay, Florida Bay, and the mangrove estuaries of the lower southwest coast—provide critical nursery habitat for many species of fish and invertebrates that support ecological food webs and fisheries. Salinity patterns influence their habitat quality.

Salinity patterns are established and maintained by the volume and timing of freshwater inputs, controlled not only by weather but also by water management. Previous structural and operational changes in South Florida's water management system have altered salinity patterns and salinity fluctuations in the southern estuaries, deteriorating the quality and spatial extent of nursery habitat for pink shrimp and other species.

For the southern estuaries, ecosystem restoration in the Comprehensive Everglades Restoration Program (CERP) calls for a reduction in the frequency, intensity, duration, and spatial extent of hypersaline events, as well as a reduction in the frequency and intensity of low-salinity pulses. Achieving these restoration objectives is expected to lead to overall increases in densities of juvenile pink shrimp with subsequent benefits to higher trophic levels and the Tortugas fishery, although local abundances may decrease at the lower end of the salinity gradient. A laboratory study on young pink shrimp from Florida Bay indicated a wide salinity tolerance range with a broad optimum in the midrange (Browder et al. 2002). Both extreme high and extreme low salinities depress pink shrimp survival.

Hypotheses in the CERP Southern Estuaries Module that apply to pink shrimp (RECOVER 2007) are summarized as follows: Reestablishing a relatively persistent positive salinity gradient through CERP will increase the area of overlap of favorable salinities with favorable bottom habitat (especially SAV) and shoreline features, thereby increasing the distribution and abundance of species characteristic of estuaries, including pink shrimp. A positive salinity gradient is one in which salinities are lowest nearest to shore. The specific details of optimum habitat will differ by species, however it is inherent in this hypothesis that restoring a broad and positive salinity gradient will optimize the spatial extent of high quality habitat for many characteristic species.

Data Support for the Pink Shrimp Indicator

Under the Monitoring and Assessment Program (MAP) for the Comprehensive Everglades Restoration Program (CERP), the Fish and Invertebrate Assessment Network (FIAN) Project (MAP activities 3.2.3.5 and 3.2.4.5) currently samples pink shrimp and

other epibenthic fauna at 19 locations within three regions: Florida Bay, Biscayne Bay, and the southwest mangrove coast estuaries, including Whitewater Bay. Collections are made biannually at the end of the dry (April-May) and wet seasons (September-October). A 1-m^2 throw-trap is used in shallow, open water seagrass habitats to quantify abundance metrics for pink shrimp and other species associated with bottom vegetation. At each monitoring location, sampling occurs within a randomly sited grid of 30 equal-sized, tessellated hexagonal cells. A suite of habitat measurements is collected in conjunction with each faunal sample, including salinity, temperature, water depth, and turbidity, as well as biological habitat features such as taxonomic composition and coverage of bottom vegetation. For each collection, one throw-trap sample is taken at a randomly located site within each grid-cell at each monitoring location, resulting in a total of 570 samples collected each season. This sampling design ensures that sampling encompasses gradients of environment and habitat present in each monitoring location. Additional details of sampling design and sampling method are provided in Robblee and Browder (2007, 2008). Prior use of the throw-trap method in the study domain dates back to 1984, providing considerable historical data to help establish pre-CERP pink shrimp abundance, variability, assessment targets and trends.

Analysis Framework for Assessment Using the Pink Shrimp Indicator

The pink shrimp performance measure compares annual mean spring and fall pink shrimp density and variance estimated in FIAN with the historical period-of-record (Table 1) in six response areas (Figure 1), each encompassing one to two FIAN monitoring locations: Whitewater Bay, Johnson Key Basin (JKB), South-Central Florida Bay, North-Central Florida Bay, Eastern Florida Bay, and South Biscayne Bay (Figure 1). Because of frequency of use, throughout this document these regions are referred to as Whitewater, JKB, South-Central FB, North-Central FB, Eastern FB, and Biscayne. The JKB and Biscayne areas have substantial historical periods-of-record, ≈20 yrs and ≈6 yrs, respectively, but the period-of-record of available historical data consists of 2 or fewer years for the other four response areas; Eastern FB, North-Central FB, South-Central FB and Whitewater. The bases for establishing targets will strengthen with time as the MAP time series, now 3-years long, are lengthened. Available historical throw-trap data have been summarized as spring and fall density and variance estimates for each response area (Table 2); citations for these data are in footnotes to Table 1.

The delta-approach was applied to calculate pink shrimp density to overcome a common problem of faunal sampling, many zeros in the data due to absence of the species of interest in individual samples. Simply put, the delta approach calculates the mean density as the product of occurrence and concentration. Occurrence is the percent of samples in which the species occurs, and concentration is the mean of the samples in which the species occurs. If the concentration data are not normally distributed (which often is the case), the data are transformed (usually log transformed) to better approximate a normal distribution before calculating the concentration mean. Few of the pink shrimp datasets used in the assessment were normally distributed (based on Kolmogorov-Smirnov Distance tests [$p>0.05$]), even after the log transformation,

however log transformation strengthened the normality assumption. Of those datasets meeting the normality assumption, three were from JKB, one was from Biscayne, and all were data sets for the fall season, when pink shrimp were most abundant in south Florida estuaries. Log transformation of the concentration data for calculation of delta-density reduced variability, narrowed confidence intervals, and improved detection of differences. The gain from using the delta-density approach was most notable in the fall. Density, rather than occurrence or concentration, was the metric used in the assessment.

The current status of pink shrimp abundance was determined by comparison with quartiles of the distribution of historical spring and fall mean delta-densities over the available period-of-record. Mean pink shrimp densities less than the 25th quartile were scored as zero (poor), values between the 25th and 75th quartile received a score of 0.5 (neutral), and values equal to or exceeding the 75th quartile received a score of 1 (good). Status was determined for spring and fall of 2005, 2006, and 2007. The current assessment relates to 2007. The goal is to maintain, in each region for each season (dry and wet seasons), an annual observed pink shrimp density equivalent to good or a positive trend in density in that season. This goal recognizes that the greatest density attainable differs by assessment region.

Pink Shrimp Indicator Status

In Figures 3 and 4, zones are represented by red, yellow and green, respectively. The quartile density values defining the boundaries between zones are shown in Table 2. These boundaries represent thresholds across which change occurs from poor to neutral, neutral to good, and the converse. In Figures 3 and 4, solid black circles represent mean density values for each MAP year-season and the historical record. Confidence limits (CLs) around the mean density value can be used to determine whether the mean density of the current year is significantly different from that of previous MAP years or the mean of the historical record. Although density was the basis for the assessment, for added perspective, the same statistics (e.g., quartiles, means, confidence limits) for occurrence and concentration also were shown in Figures 3 and 4.

In the six response areas relatively few differences, based on overlap of 95% CL's, in occurrence, concentration or delta-density were observed between FIAN and period-of-record historical pink shrimp mean and variance. Differences were observed primarily in the fall when shrimp were most abundant (Figures 3 and 4). The short historical record in most locations (except JKB and to a lesser extent Biscayne) may in part account for these results. The few years in the period-of record for the other response areas may be too short to represent the weather cycles that affect freshwater runoff and estuarine salinities in South Florida and may not yield reliable thresholds for detecting change in pink shrimp status.

Pink shrimp did well in 2005, with average scores among the six response areas of 0.7 and 0.6, spring and fall, respectively (Table 3). In contrast, 2007 was an extremely poor year with scores among the six response areas averaging only 0.2 and 0.2, spring

and fall, respectively. The year 2006 was intermediate, averaging 0.6 and 0.4, spring and fall, respectively. In Johnson Key Basin the fall delta-density of 5.2 shrimp/m^2 (FIAN methods estimated 5.8/m^2) was the fourth lowest in a 20-year historical period-of-record. In 2007 poor pink shrimp status was noted everywhere but Johnson Key Basin in the spring and everywhere but South Biscayne in the fall. Details of assigning scores and associating them with green, yellow, and red stoplights were given in Browder and Robblee (in review).

Reflecting the scores in Table 3, the status of the pink shrimp indicator in 2005, 2006, and 2007 is portrayed in stoplight format in Figure 5 with a time-series of colored circles for each response area. The number of green circles decreases and the number of red circles increases from 2005 to 2007. The geographic distribution of green, yellow, and red circles can be seen in Figures 6 (spring) and 7 (fall).

Interpretation and Evaluation of the Assessment

The basis for the high number of red circles in 2007 needs further investigation with regard to causality. Inshore salinity conditions and/or offshore spawning success may account for the poor showing of pink shrimp in 2007, especially in Florida Bay. Salinity patterns characterizing the six response areas differ, reflecting freshwater inflows and mixing with Gulf of Mexico and Atlantic waters (Figure 8). In South Florida, with distinct dry and wet seasons, it is typical for salinities to increase approaching April and May, and decline approaching September and October. The salinity gradient may facilitate or enhance the movement of postlarval pink shrimp into nearshore nursery grounds, and a positive gradient may be more effective than one that is negative. Hughes (1969a, b) studied movement of postlarval and juvenile pink shrimp in relation to a vertical salinity gradient in a laboratory setting. Although he did not specifically examine the relative effect of positive vs. negative horizontal salinity gradients on pink shrimp movement toward and within estuaries, his results suggest that a negative salinity gradient may not provide the same support. Peak pink shrimp postlarval immigration to western Florida Bay occurs in the fall (Criales et al. 2006). Among the 3 years available for assessment, positive estuarine conditions occurred in the fall of 2005 and 2006 (Figure 5). In contrast, salinities increased through the wet season in JKB and North- and South-Central FB in the fall of 2007, leading to hypersaline conditions in central Florida Bay and a negative salinity gradient. Hypersalinity, which establishes a negative salinity gradient, may have limited pink shrimp immigration into Florida Bay and contributed to the exceptionally low pink shrimp abundance observed in the fall of 2007. A negative salinity gradient in Florida Bay is typical in the spring and may be at least partially responsible for the low abundance of pink shrimp in Florida Bay in the spring relative to the fall.

Weak spawning and postlarval immigration in 2007 relative to 2005 and 2006 is an alternative reason for the low pink shrimp abundance in 2007. With spawning occurring in the vicinity of the Tortugas (Costello and Allen 1966), spawning strength

should be best reflected in pink shrimp status in JKB, where immigrating postlarvae first enter the bay. In the absence of other environmental factors such as hypersalinity, pink shrimp status in western Florida Bay should be reflected broadly among the six response areas similar to the pattern observed in 2007. Whenever status is consistent across response areas (e.g., all low or all high), as in 2007, the possibility that offshore spawning strength affects pink shrimp status cannot be discounted. However, the conclusions of Ehrhard and Legault (1999) are relevant to this issue. On the basis of their cohort analysis of fishery catch and effort data, they concluded that environmental factors rather than a spawning stock-recruitment relationship determined year-class-strength.

Lessons Learned

Interpreting pink shrimp status in a response area or among response areas is dependent on the reliability of the historical (reference) condition. Periods-of-record (POR) for historical data sets against which "status" was determined were only 2 years long for four reference areas: Eastern, North-Central, and South-Central FB and Whitewater. Except for JKB, prior-year data are not sufficiently extensive to reliably estimate the 75th percentile of the past distribution of pink shrimp density. The potential of the six response areas to provide a strong basis for assessment of pink shrimp status is evident but more data is needed.

As demonstrated above, assessing several response areas at the same time helps to separate the effect of local conditions from the effect of recruitment success. However, to make such comparisons, it is essential to have strong concurrent time series of data for each response region. The FIAN sampling for MAP is building these time series.

Longer time series of data also are critical to allow assessments to be based on 3-yr running means rather than annual means. Assessments based on annual means are overly sensitive to year-to-year natural variation in rainfall and other climatic conditions. Time series from which to develop thresholds for determining status should be long enough to encompass at least the shorter-term weather cycles. Because of the uniformity of sampling design, MAP data provide a better baseline for assessments of CERP effects than existing historical data, which was collected under various other designs. Early-CERP assessments, based on short time series of MAP data collected before substantive CERP changes are made, should be used to develop robust assessment methods and should be viewed as examples of what could be achieved later with firmer data

The historical data may not be the appropriate basis for establishing thresholds or goals based on quartiles. Natural conditions no longer existed in these estuaries at the time the historical data were collected. Future improvements in the assessment method may include pink shrimp targets developed considering natural conditions but independent of historical data.

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Figure 1. Pink shrimp indicator assessment regions (yellow circles) and the 19 FIAN sampling grid locations (green patches).

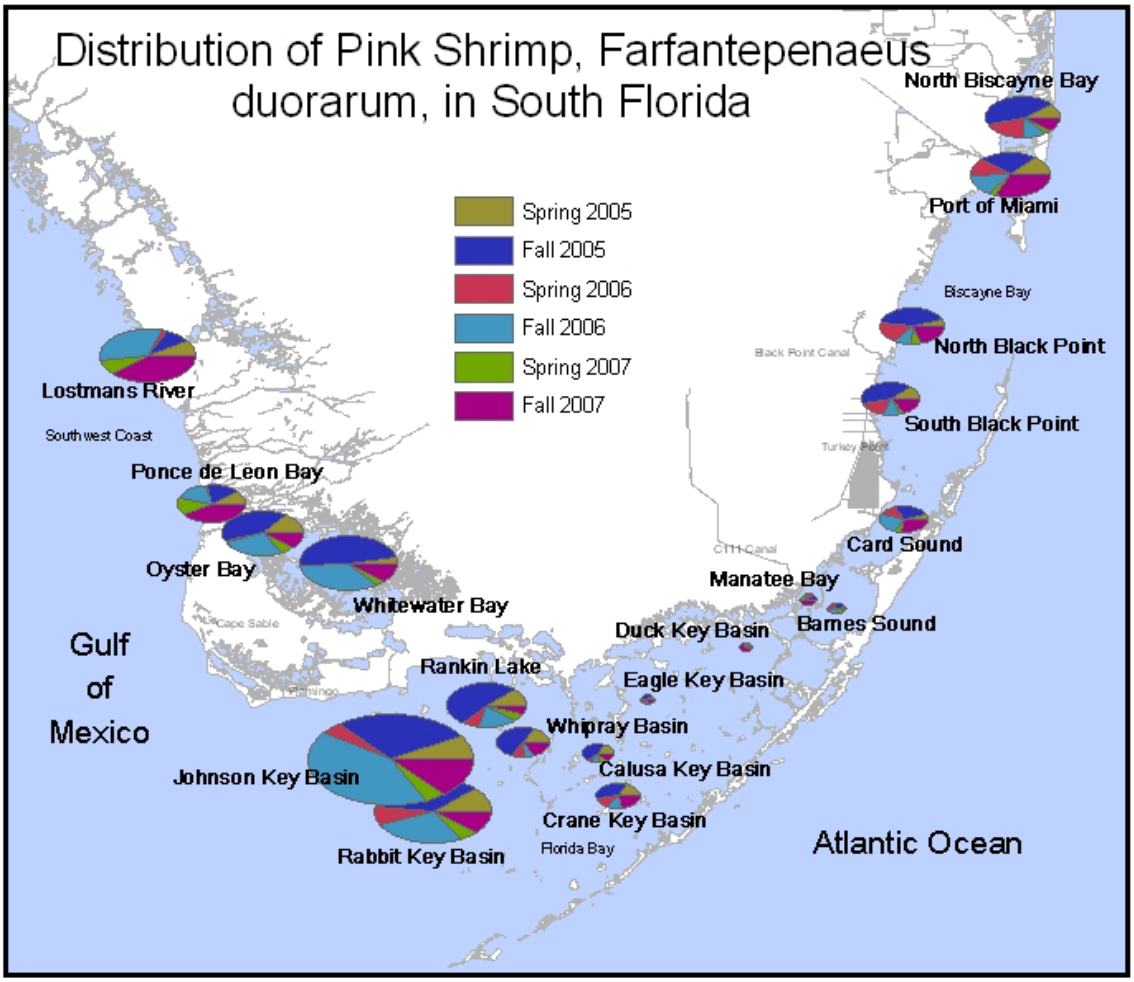

Figure 2. Distribution of the pink shrimp, *Farfantepenaeus duorarum*, distributed among FIAN monitoring locations, Spring 2005 – Fall 2007. The size of the pie represents the sum of pink shrimp for all collections at the monitoring location. The sizes of the slices within each pie represent relative abundance among collections (i.e., season-year).

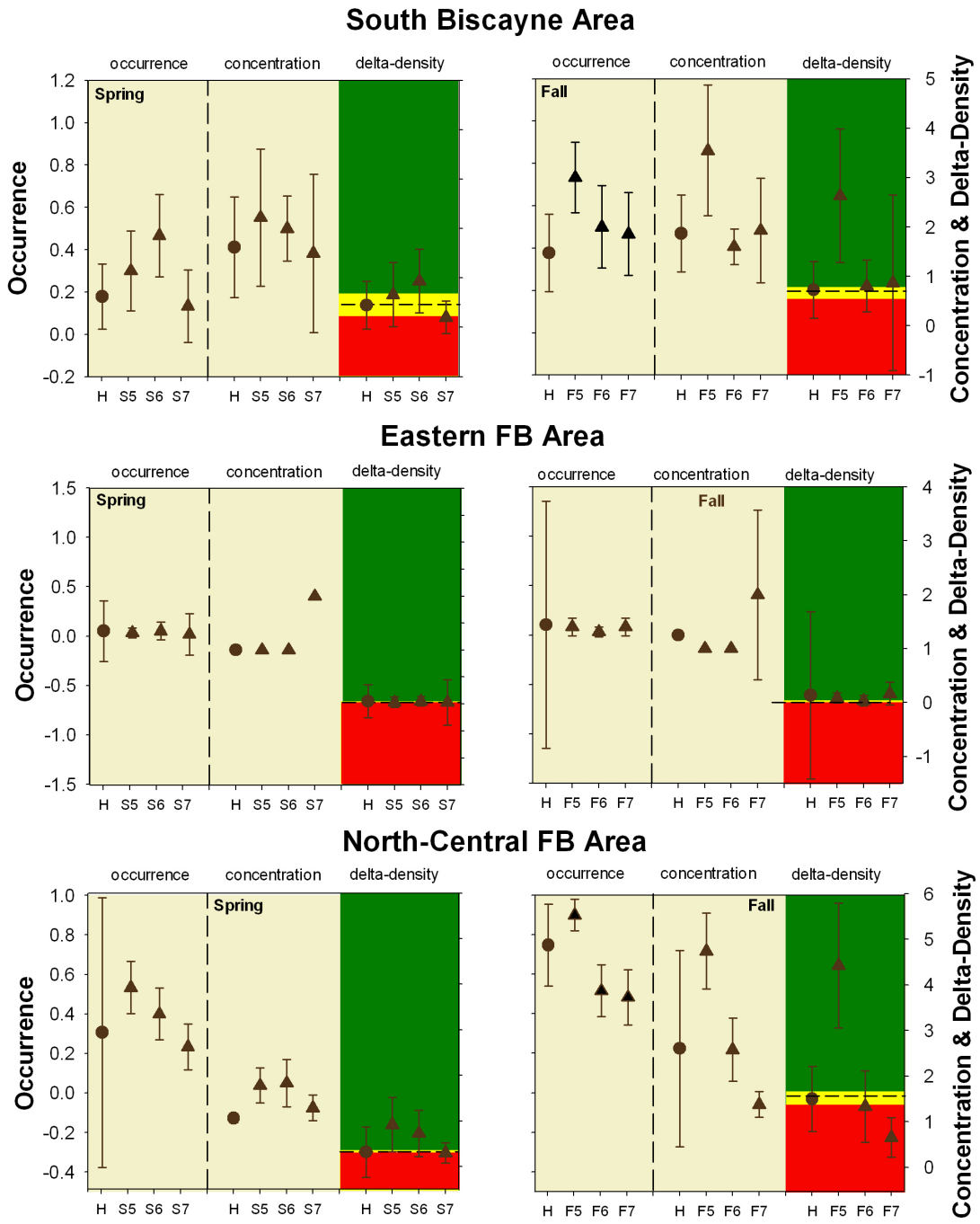

Figure 3. Pink shrimp regional indicator abundance metrics for South Biscayne Bay, Eastern Florida Bay, and North-Central Florida Bay in relation to historical data (H) and indicator targets; Spring 2005-2007 (S5, S6, S7) and Fall 2005-2007 (F5, F6, F7); occurrence (proportion of positive samples), concentration (mean density of positive samples), and delta-density (back-transform of log transformed [ln] concentration x occurrence); indicator targets based on historical data: green > 3rd quartile, yellow >1^{std} and < 3rd quartile, and red < 1st quartile. Solid black symbols indicate means, and vertical bars are 95% confidence intervals.

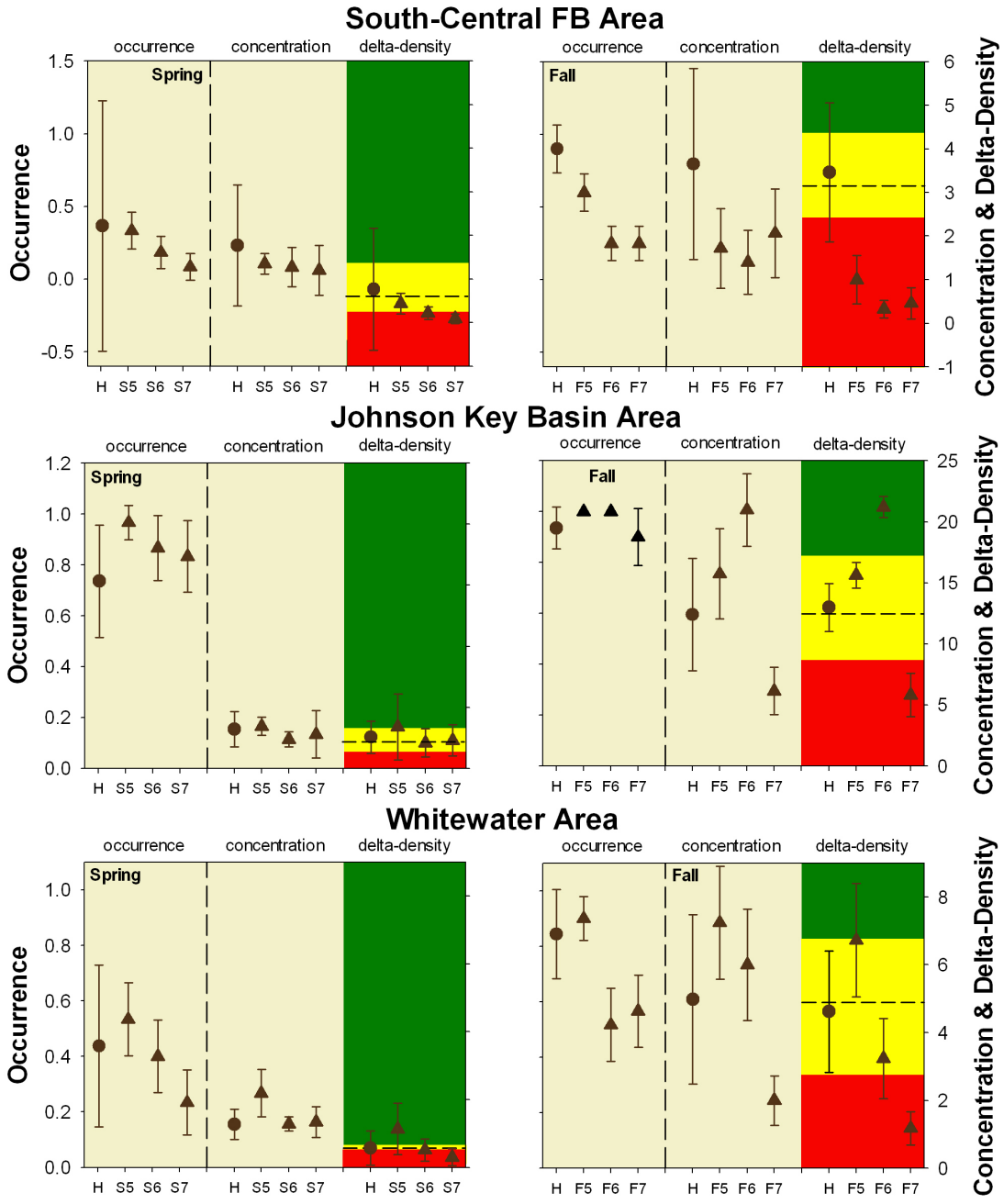

Figure 4. Pink shrimp regional indicator abundance metrics for South-Central Florida Bay, Johnson Key Basin, and the Whitewater Area in relation to historical data (H) and indicator targets; Spring 2005-2007 (S5, S6, S7) and Fall 2005-2007 (F5, F6, F7); occurrence (proportion of positive samples), concentration (mean density of positive samples), and delta-density (back-transform of log transformed [ln] concentration x occurrence); indicator targets based on historical data: green > 3rd quartile, yellow >1^{std} and < 3rd quartile, and red < 1st quartile. Solid black symbols indicate means, and vertical bars are 95% confidence intervals.

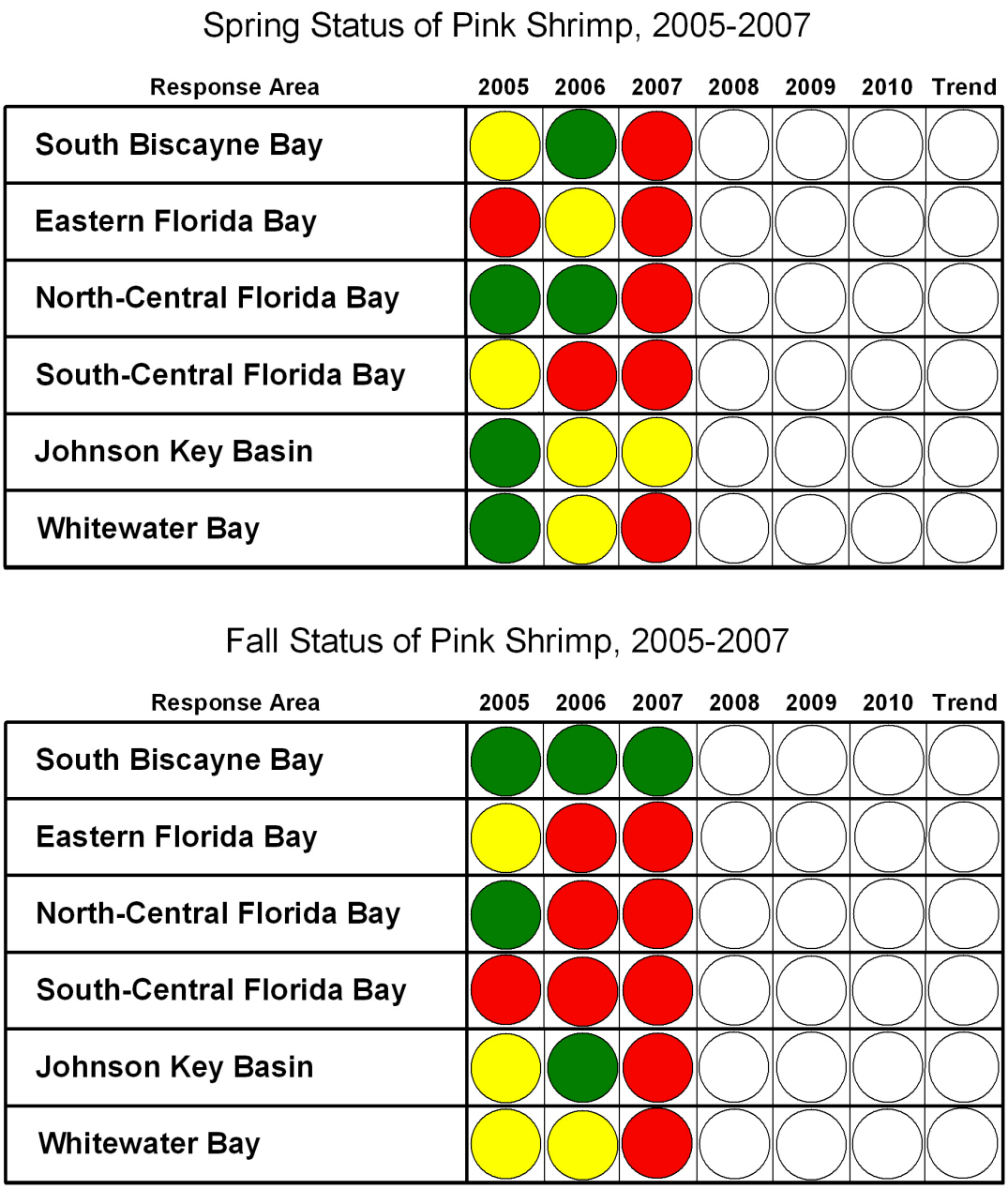

Figure 5. Responses of the pink shrimp indicator, by year and region, spring and fall, based on MAP data (Fish and Invertebrate Assessment Network).

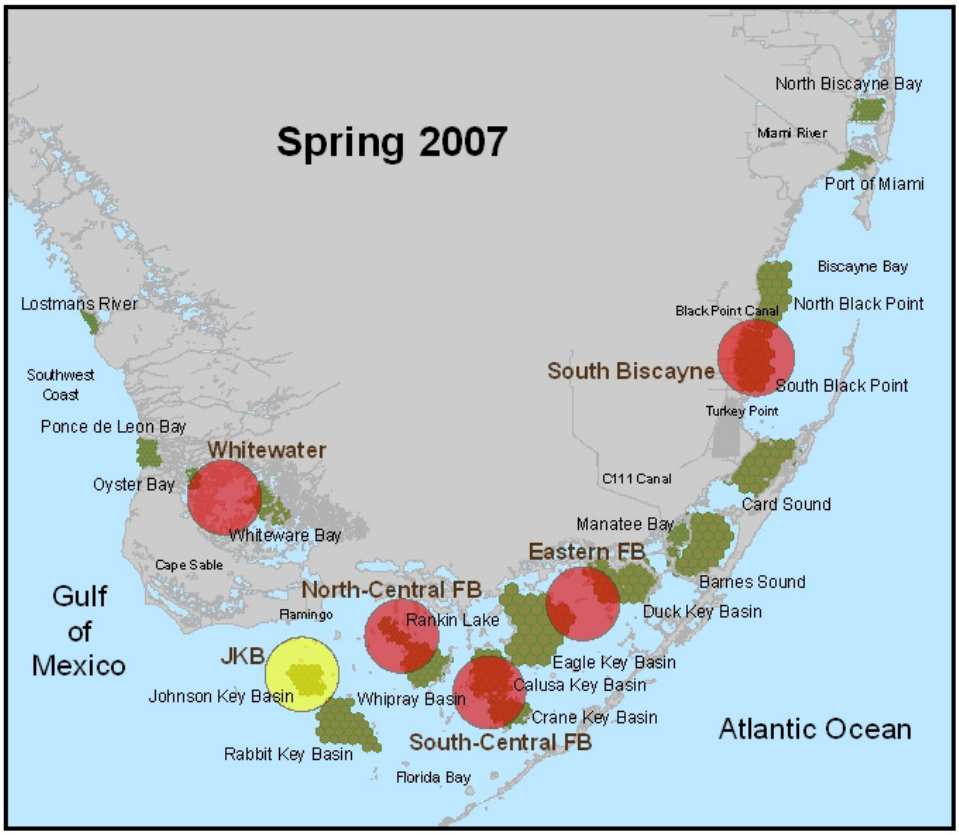

Figure 6. Map of spring 2007 responses of the pink shrimp indicator, by response region.

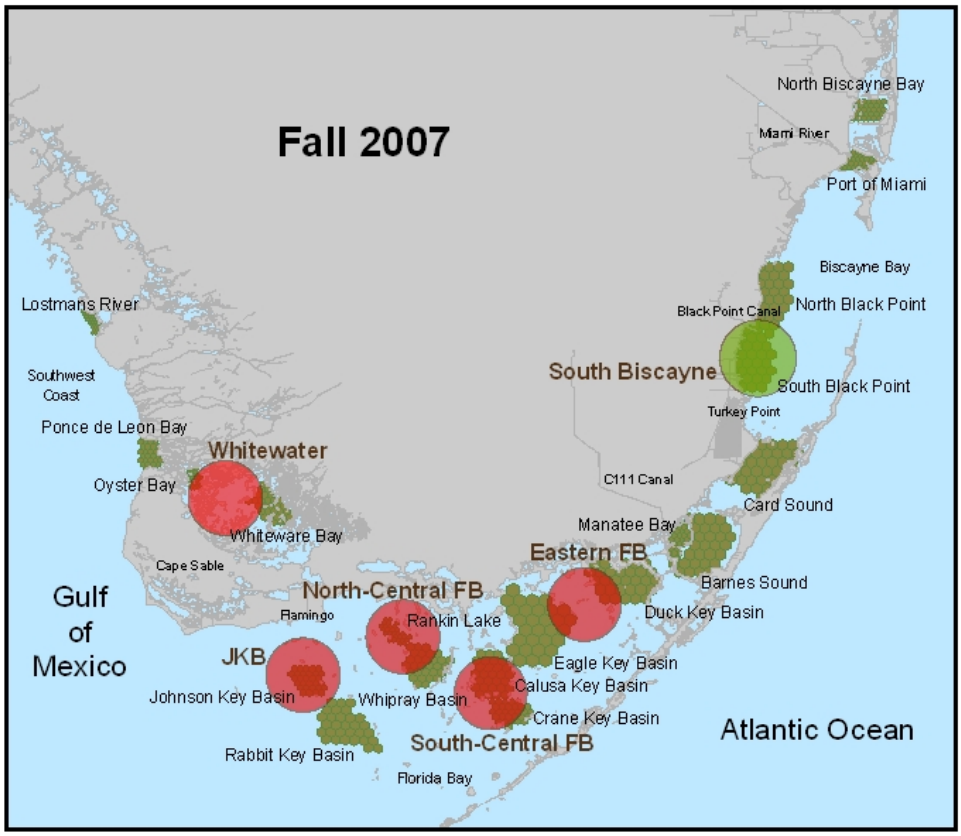

Figure 7. Map of fall 2007 responses of the pink shrimp indicator, by response region.

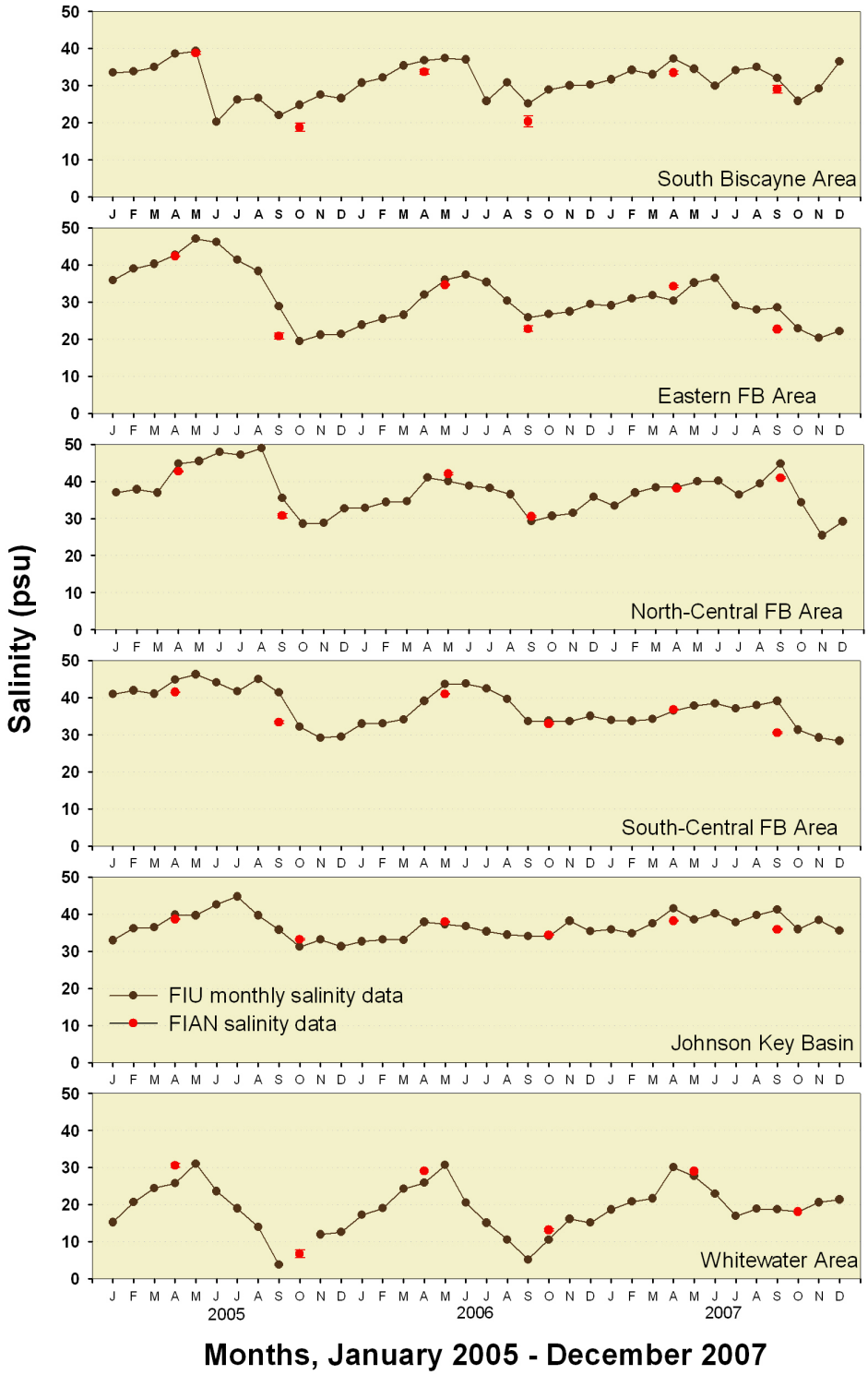

Figure 8. Surface salinity conditions in each pink shrimp response area, 2005 – 2007. Solid black circles are monthly surface salinity measurements from the FIU water quality monitoring network (Boyer and Briceño 2008). Solid red circles are mean and standard error of FIAN salinity measurements, in Practical Salinity Units (psu), from indicated site.

Table 1. South Florida Fish and Invertebrate Assessment Network (FIAN) monitoring locations used in current assessment and existing historical data (citations to existing data are footnoted).

Location	Existing Data
Biscayne Bay Region	
North Black Point	[1] 2002-2005
South Black Point	[1] 2002-2005
Card Sound	
Barnes Sound	
Manatee Bay	
Florida Bay Region	
Duck Key Basin	[3] 1998-2000
Eagle Key Basin	[5] 1986, [3] 1998-2000
Calusa Key Basin	
Crane Key Basin	
Rankin Lake	[3] 1998-2000
Whipray Basin	[5] 1986, [3] 1998-2000
Johnson Key Basin	[2] 1983-2005
Southwest Coast Region	
Ponce de Leon Bay	[4] 1995-1996
Oyster Bay	[4] 1995-1996
Whitewater Bay	[4] 1995-1996

[1] bi-monthly Oct 2002 – Oct 2005; Browder et al 2005
[2] six-week interval Jul 1983 – Jan 2005, with gaps in the POR; Robblee et al 1991; Robblee unpublished
[3] semi-annually Sept/Oct 1998 – Apr/May 2000; Robblee et al unpublished
[4] monthly Oct 1995 – Oct 1996; Rice 1997
[5] once in Jan/Feb 1986; Robblee et al 1991

Table 2. Criteria for assessing pink shrimp status.

Spring

Reference Areas	Historical Data						
	median	1st	3rd	mean	95 CL	POR	FIAN Sampling Locations
South Biscayne Bay	0.44	0.21	0.68	0.45	0.49	5 yr	South Black Point
Eastern Florida Bay	0.05	0.04	0.06	0.05	0.31	2 yr	Duck Key Basin, Eagle Key Basin
North-Central FB	0.30	0.30	0.40	0.32	0.55	2 yr	Rankin Lake, Whipray Basin
South-Central FB	0.61	0.23	1.38	0.77	1.40	2 yr	Calusa Key Basin, Crane Key Basin
Johnson Key Basin	2.28	1.45	3.32	2.55	1.31	18 yr	Johnson Key Basin
Whitewater Bay	0.56	0.50	0.63	0.56	0.50	1 yr	Oyster Bay, Whitewater Bay

Fall

Reference Areas	Historical Data						
	median	1st	3rd	mean	95 CL	POR	FIAN Sampling Locations
South Biscayne Bay	0.71	0.52	0.78	0.72	0.58	6 yr	South Black Point
Eastern Florida Bay	0.15	0.08	0.20	0.13	1.55	2 yr	Duck Key Basin, Eagle Key Basin
North-Central FB	1.50	1.42	1.60	1.50	0.71	2 yr	Rankin Lake, Whipray Basin
South-Central FB	3.15	2.43	4.38	3.46	1.59	2 yr	Calusa Key Basin, Crane Key Basin
Johnson Key Basin	12.47	8.62	17.23	12.98	1.95	20 yr	Johnson Key Basin
Whitewater Bay	4.86	2.73	6.75	4.62	1.79	2 yr	Oyster Bay, Whitewater Bay

Table 3. Pink shrimp indicator scores in the six FIAN response areas for Spring 2005 through Fall 2007 collections. Indicator scores: 1 = good, .5 = neutral and 0 = poor; green, yellow and red, respectively.

Pink Shrimp Indicator Scores

Reference Areas	Spring			Fall		
	2005	2006	2007	2005	2006	2007
South Biscayne Bay	0.5	1	0	1	1	1
Eastern Florida Bay	0	0.5	0	0.5	0	0
North-Central FB	1	1	0.5	1	0	0
South-Central FB	0.5	0	0	0	0	0
Johnson Key Basin	1	0.5	0.5	0.5	1	0
Whitewater Bay	1	0.5	0	0.5	0.5	0