MONITORING COLONIAL NESTING BIRDS IN ESTERO BAY AQUATIC PRESERVE

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Abstract: *Estero Bay Aquatic Preserve is a shallow-water estuary which contains a diverse array of natural communities that make it an attractive environment for wading and diving birds to forage and nest. Nest surveys conducted in Estero Bay for the last four decades detect trends in wading and diving bird populations while engaging and educating the public through volunteerism. Brown pelican (*Pelecanus occidentalis*) nest counts conducted in May show a significant decrease in nesting pairs in Estero Bay; a loss of approximately 5 nesting pairs per year across the record of study. Comparisons of historic April nest counts to modern nest counts for great blue heron (*Ardea herodias*) show an increase of 158 percent, which represents a gain of 32 nesting pairs between the two time periods. Other species showing increasing trends in nest counts are yellow-crowned night heron (*Nyctanassa violacea*) and double-crested cormorant (*Phalacrocorax auritus*), while anhinga (*Anhinga anhinga*) showed a decreasing trend. Species-level analyses of more recent standardized monitoring provide a more detailed view of population trends in the bay including shifts in species composition and peak nesting times. Future analyses should include nesting data collected by other agencies to assess nesting success on a larger geographical scale.*

Key Words: Estero Bay Aquatic Preserve, colonial nesting birds, wading birds, diving birds, volunteerism

Estero Bay was designated as Florida's first aquatic preserve in 1966 and is managed under the Florida Department of Environmental Protection's Office of Coastal and Aquatic Managed Areas. The Estero Bay Aquatic Preserve consists of approximately 11,000 acres of sovereign submerged lands and is located in southwest Florida, extending from Fort Myers Beach to Bonita Springs (Fig. 1). The shallow estuary is designated as an Outstanding Florida Waterbody by the Florida Department of Environmental Protection (FDEP, 1997a) and is fed by five freshwater tributaries and four passes connecting to the Gulf of Mexico. Estero Bay contains mangrove islands, nineteen of which have been documented as breeding colonies for a variety of bird species, including 10 species of wading birds and three species of diving birds. Long-term monitoring data of wading and diving bird populations is an important resource for aquatic preserve managers who are tasked with preserving the bay in its "*essentially natural or existing condition so that its aesthetic, biological and scientific values may endure for the enjoyment of future generations*" (FDEP, 1997b).

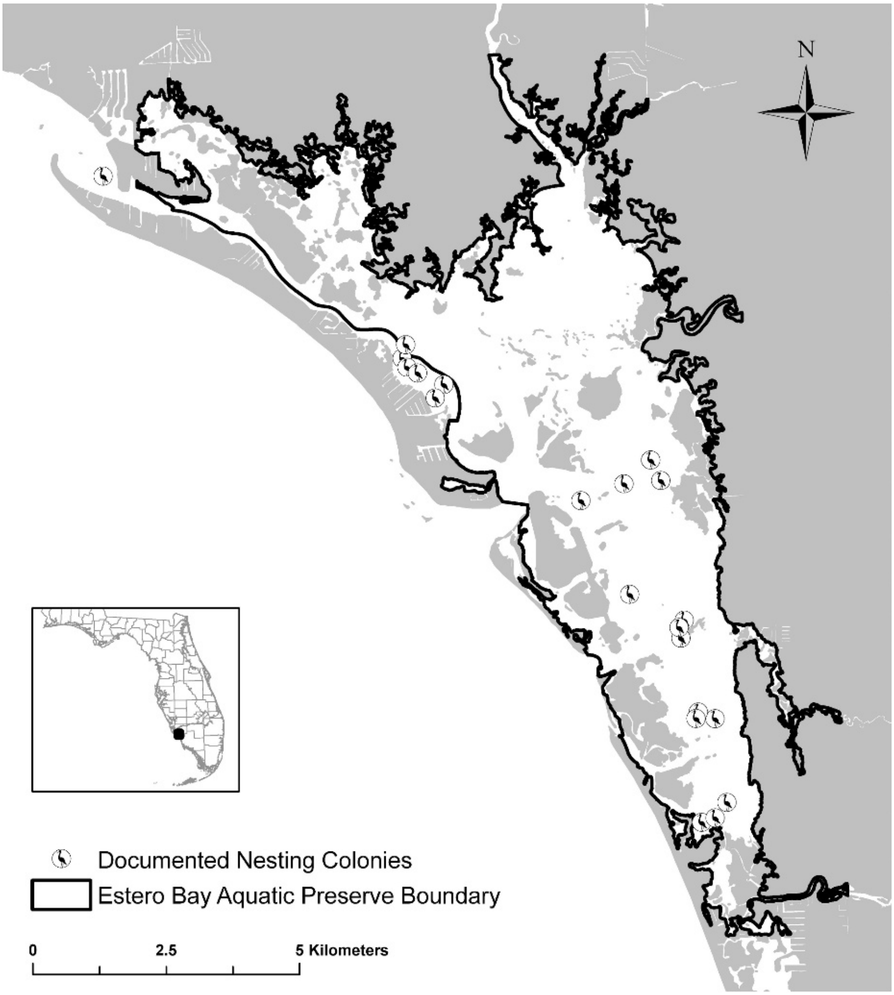

FIG. 1. Extending from Fort Myers Beach to Bonita Springs, Estero Bay Aquatic Preserve consists of approximately 11,000 acres of sovereign submerged lands located in southwest Florida. Nineteen nesting islands have been documented in Estero Bay since the induction on surveys in 1977; 13 of these islands are located within the aquatic preserve boundary and all consist primarily of mangroves.

In the late nineteenth century, after 40 years of plume hunting, wading birds became a focal point for conservation. In the 1970s, extensive colonial nesting bird surveys were initiated along the North American Atlantic and Gulf coasts (Kushlan, 1997). Governmental and non-governmental agencies began collecting data on wading bird populations and decades of data set the standard for their use as an indicator species (Kushlan, 1993). Wading birds maintain a high aesthetic and recreational value to humans and their reproductive performance is a crucial aspect of their population dynamics

(Kushlan, 1993). During the nesting season, breeding adults are using a limited portion of their environment and populations are concentrated (Kushlan, 1997; Urfi et al., 2005), making them an ideal subject for volunteer-based management studies. Nesting surveys in Estero Bay began in 1977 and the program implemented a variety of survey techniques throughout its history. Since 2008, Estero Bay Aquatic Preserve staff and volunteers have conducted monthly nest counts throughout the nesting season. This program provides peak estimates of nesting effort for each species of colonial nesting bird, monitors population trends, maintains a current atlas of historic and active colonies, documents human disturbance, documents the number of entanglements and fatalities due to fishing-line and trash, and increases community involvement through volunteerism and by engaging and educating the public.

Colonial nesting wading birds are particularly susceptible to local human disturbances (Parnell et al., 1988). This is a concern in Estero Bay since boats bring tour groups to select colonies several times a day, and other recreational activities such as photography, camping, kayaking, paddle boarding and personal watercraft use frequently take place within the 100 meter buffer suggested for nesting wading birds (Erwin, 1989; Rodgers and Smith, 1995; Burger, 1998; Carney and Sydeman, 1999). Disturbances in early nest building and incubation periods can cause nest desertion (Steinkamp et al., 2003) and frequent disturbance may cause a reduction in clutch size and hatching success (Schreiber and Risebrough, 1972). Predation of eggs by fish crows (*Corvus ossifragus*) when adult birds are flushed from the nest due to disturbance was noted by Schreiber and Risebrough (1972) as the leading cause of egg loss.

MATERIALS AND METHODS—*Historic surveys*—Annual nesting surveys conducted between 1977 and 1982 were performed in May (TABLE 1); file notes indicate that perimeter counts were employed and only brown pelican (*Pelecanus occidentalis*) nests were recorded. Counts were conducted once annually in late May 1983 through 1987 using ground survey methods; colonies were entered on foot to document active wading and diving bird nests. May 1989 counts were conducted using a perimeter count method to survey all active nests. No written protocols have been documented for May surveys conducted between 1977 and 1989; all method descriptions are based on field notes and written communications. Surveys conducted on 03 April 1989 and 06 March 1998 did not include all active nesting islands in the area, or data were lost, so results are not included in these analyses. Surveys conducted on 29 April 1998, 24 April 2001 and 18 April 2007 employed a direct count method as described in the National Audubon Society's Project Colony Watch, later published as Audubon of Florida (2004): "*Colonies on coastal islands can be circled repeatedly by boat until counts are complete…ask multiple observers to compare counts, and use cooperation to arrive at reasonable estimates.*" Surveys conducted in 2002 on 05 June, 01 July, 04 July and 14 July were conducted by canoe using a perimeter count method; however, surveys were only conducted in the southern portion of the bay, so results were not used in these analyses. No nesting surveys were conducted in 1988, 1990 through 1997, 1999 through 2000, or 2003 through 2006.

Modern surveys—Surveys between 2008 and 2011 were conducted once mid-month throughout the nesting season. Each year, surveys were initiated when birds were observed carrying nesting materials and concluded when all chicks had fledged. Surveys were conducted using a direct count method as described by Audubon of Florida (2004). A 17-foot boat with an outboard and trolling motor was used to circle each island at a distance of 30 to 45 meters. Two

TABLE 1. Colonial nesting bird surveys conducted in Estero Bay and used for analysis in this paper; including survey methods employed as described by Steinkamp and co-workers (2003) and species counted. Surveys were conducted once per month at each known active nesting colony for years and months listed. (BRPE=brown pelican, DCCO=double-crested cormorant, ANHI= anhinga, GBHE=great blue heron, GREG=great egret, SNEG=snowy egret, LBHE= little blue heron, TRHE=tri-colored heron, REEG=reddish egret, CAEG=cattle egret, YCNH=yellow-crowned night-heron, BCNH=black-crowned night-heron, GRHE=green heron).

Year	Month(s)	Method Employed	Species Counted	Comments
1977	May	Perimeter	BRPE	No protocol available
1978	May	Perimeter	BRPE	No protocol available
1979	May	Perimeter	BRPE	No protocol available
1980	May	Perimeter	BRPE	No protocol available
1981	May	Perimeter	BRPE	No protocol available
1982	May	Perimeter	BRPE	No protocol available
1983	Late-May	Ground	BRPE, DCCO, ANHI, GBHE, GREG, SNEG, LBHE,TRHE, REEG, CAEG	No protocol available; written corres-pondence indicates "walked through the islands"
1984	Late-May	Ground	BRPE, DCCO, ANHI, GBHE, GREG, SNEG, LBHE,TRHE, REEG, CAEG	No protocol available; written correspondence indicates "I walked through the islands"
1985	Late-May	Ground	BRPE, DCCO, ANHI, GBHE, GREG, SNEG, LBHE,TRHE, REEG, CAEG	No protocol available; written correspondence indicates "I walked through the islands"
1986	Late-May	Ground	BRPE, DCCO, ANHI, GBHE, GREG, SNEG, LBHE,TRHE, REEG, CAEG	No protocol available; written correspondence indicates "I walked through the islands"
1987	Late-May	Ground	BRPE, DCCO, ANHI, GBHE, GREG, SNEG, LBHE,TRHE, REEG, CAEG	No protocol available; written correspondence indicates "I walked through the islands"
1989	May	Perimeter	BRPE, DCCO, ANHI, GBHE, GREG, SNEG, LBHE,TRHE, REEG, CAEG	No protocol available; only BRPE were included in analyses
1997	May	Perimeter	BRPE	No protocol available
1998	29, April	Perimeter	BRPE, DCCO, ANHI, GBHE, GREG, SNEG, LBHE,TRHE, REEG, CAEG, YCNH, BCNH, GRHE	Direct Count Method
1998	May	Perimeter	BRPE	No protocol available
2001	24, April	Perimeter	BRPE, DCCO, ANHI, GBHE, GREG, SNEG	Direct Count method LBHE,TRHE, REEG - species were present but nest counts were not conducted

TABLE 1. Continued.

Year	Month(s)	Method Employed	Species Counted	Comments
2007	18, April	Perimeter	BRPE, DCCO, ANHI, GBHE, GREG, SNEG, LBHE,TRHE, REEG, CAEG, YCNH, BCNH, GRHE	Direct Count method as described by Audubon of Florida (2004)
2008	March–August	Perimeter	BRPE, DCCO, ANHI, GBHE, GREG, SNEG, LBHE,TRHE, REEG, CAEG, YCNH, BCNH, GRHE	Direct Count method as described by Audubon of Florida (2004)
2009	February–August	Perimeter	BRPE, DCCO, ANHI, GBHE, GREG, SNEG, LBHE,TRHE, REEG, CAEG, YCNH, BCNH, GRHE	Direct Count method as described by Audubon of Florida (2004)
2010	February–September	Perimeter	BRPE, DCCO, ANHI, GBHE, GREG, SNEG, LBHE,TRHE, REEG, CAEG, YCNH, BCNH, GRHE	Direct Count method as described by Audubon of Florida (2004)
2011	January–September	Perimeter	BRPE, DCCO, ANHI, GBHE, GREG, SNEG, LBHE,TRHE, REEG, CAEG, YCNH, BCNH, GRHE	Direct Count method as described by Audubon of Florida (2004)

observers counted the number of nesting pairs, or nests, by species and nesting stage. The primary observer, an aquatic preserve staff member, was consistent throughout the study period, and trained volunteers conducted secondary observer counts. The average of the two observers' counts was reported; empty nests were not included in calculations. Monthly counts from 2008 through 2011 are compared only with corresponding monthly counts from historic datasets.

Data analysis—Statistics were calculated using IBM SPSS 19.0 and the USGS's KTRLine 1.0. Analyses were run for all individual species, canopy nesters, and interior nesters, as described by Burger (1978), McCrimmon (1978) and Spendelow et al. (1989), and total counts. Canopy nesters include great blue heron (*Ardea herodias*), great egret (*Ardea alba*), brown pelican, double-crested cormorant (*Phalacrocorax auritus*) and anhinga (*Anhinga anhinga*). Spendelow et al. (1989) separated great egrets from other canopy nesting species and McCrimmon (1978) found that their nesting patterns were significantly different from interior nesting species. However, Burger (1978) grouped great egrets with great blue herons as a canopy nesting species, and based on personal observations of nesting in Estero Bay great egret are classified as a canopy nesting species for these analyses. Interior nesters include snowy egret (*Egretta thula*), little blue heron (*Egretta caerulea*), tricolored heron (*Egretta tricolor*), reddish egret (*Egretta rufescens*), cattle egret (*Bubulcus ibis*), yellow-crowned night-heron (*Nyctanassa violacea*), black-crowned night-heron (*Nycticorax nycticorax*), and green heron (*Butorides virescens*).

Assumptions of normality were tested using the Jarque & Bera LM test. The assumption of homoscedasticity was tested using the Breusch-Pagan test. In addition, assumptions of linearity were examined using plots of observed versus predicted values and residuals versus predicted values. Assumptions of independence were assessed using the Durbin-Watson d test. An analysis comparing historic surveys to modern surveys used independent samples t-tests if assumptions were met, and Mann-Whitney U with Hodges-Lehmann estimator (for the confidence interval, CI) if assumptions were violated. In addition, analyses comparing "decades" (i.e., 1977–1979=1970s; 1980–1982=1980s; 1989–1998=1990s; and 2008–2011=2000s) for the month of May (brown pelican only) were conducted using ANOVA along with Gabriel's *post hoc* test if assumptions were met, and Kruskal-Wallis H with Mann-Whitney U and Hodges-Lehmann if assumptions were violated. If the transformed data did not satisfy all assumptions, robust nonparametric regressions (Theil-Kendall regression; KTRL) were used for detection of trends. However, if assumptions were met, ordinary least squares (OLS) regression was used. The data were further screened using ANOVA (on transformed data) in order to determine if there were statistically significant differences between: historic ground surveys (1983–1987) and historic perimeter surveys (1977–1982); historic brown pelican data for the month of May (1977–2001) and modern surveys (2008–2011); and historic data for all species for the month of April (1998 and 2001) and modern data (2007–2011). ANOVA by year was used on the modern data (2008–2011) to detect significant differences due to the different sampling periods, and to assess shifts in peak nesting by month, both 2-way factorial ANOVA and repeated measures mixed ANOVA were used.

RESULTS—All of the raw data were found to be non-normal, and most were heteroscedastic. However, assumptions of independence and linearity were rarely violated. Therefore, the data were transformed, and analyses were run on the transformed data. The historic ground survey data were significantly different from the historic perimeter surveys ($p<0.01$) and were removed from further analyses.

Comparison of historic and modern data—Historic brown pelican data for the month of May were significantly different from modern data ($p<0.01$). However, it is unclear if this is due to sampling technique or if this is because of a declining trend. Therefore, these data were included for analyses. The transformed brown pelican data for the month of May, from 1977–2011, did not violate assumptions, and were regressed using OLS. Comparisons of historic surveys to modern surveys for brown pelicans during the month of May show a mean decrease of 56.9 percent (SE=16.6, $p<0.01$, 95% CI=57.27–130.51), representing a significant decrease in nesting pairs of brown pelicans in Estero Bay for this time period (FIG. 2). Robust KTRL regression of the raw data showed this trend to be a loss of approximately five nesting pairs per year. In addition, when comparing decades, there was a 62.1 percent mean decrease between the 1970s and the 2000s (SE=21.4, $p<0.01$, 95% CI=61.29–171.38), a 54.3 percent mean decrease between the 1980s and the 2000s (SE=11.9, $p=0.01$, 95% CI=50.61–118.06), and a 53.3 percent mean decrease between the 1990s and the 2000s (SE=20.5, $p=0.02$, 95% CI=28.32–133.68). There were no statistically significant differences between the 1970s, 1980s, and the 1990s.

Analysis of April surveys show that nest counts for some species differed substantially between historic and modern periods (TABLE 2). Nest counts of double-crested cormorant ($p=0.05$), great blue heron ($p=0.05$), and yellow-crowned night heron ($p=0.04$) increased between 110 and 204 percent.

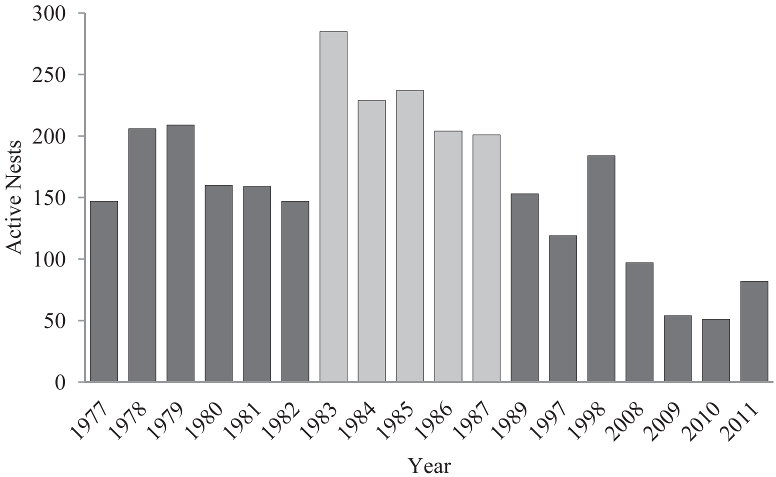

FIG. 2. May brown pelican (BRPE) surveys were conducted using perimeter surveys (black bars) and ground surveys (grey bars). Ground surveys conducted between 1983 and 1987 were significantly different from the historical perimeter surveys ($p<0.01$) and were removed from analyses. Comparison of historic perimeter surveys (1977–2001) and modern perimeter surveys (2008–2011) show a loss of 94 nesting pairs.

Modern data analysis—April nest counts were used to analyze annual trends in nesting success by species. All transformed data for the month of April, from 2007 to 2011, were non-normal; therefore, KTRL regression of the raw data was used. Regressions showed that black-crowned night-heron, little blue heron, and tricolored heron were increasing; there was no trend for cattle egret, green heron, or reddish egret; and brown pelican, double-crested cormorant, anhinga, great blue heron, great egret, snowy egret and yellow-crowned night-heron were declining. However, none of the KTRL regressions were significant.

In addition to testing for annual trends in nest counts by using April surveys only, an analysis of all monthly nest counts available in the modern surveys was conducted to detect any long-term trends. There were no significant differences between monitoring season length (i.e., nesting season) between years during the modern surveys, with the exception of great egret and brown pelican ($p=0.02$ and $p=0.02$, respectively); therefore, the entire dataset was analyzed. Transformed data of the modern surveys were non-normal; therefore, KTRL regression of the raw data was used. In the March 2008 through September 2011 modern survey record, there were declining trends in brown pelican, double-crested cormorant, great egret, canopy nesters, and total counts. However, these were not significant. There were no other significant trends for this time period.

Combining peak nest counts of all species during each year of the modern surveys revealed a 38 percent reduction in overall nesting activity: March through July 2008 (N=534), February through August 2009 (N=428), February through August 2010 (N=424), and January through August 2011

TABLE 2. Mean nest count, standard error, and percent mean difference, by species, for April historic surveys (1998 and 2001) and modern surveys (2007–2011). For the historic period, standard error that is null indicates that nest counts for that species only occurred in one of the two years, and SE that is equivalent to its respective mean results from a species that had a positive nest count in one year and a count of zero in the other. See Table 1 for abbreviations.

	Historic Surveys		Modern Surveys		Percent Difference
	Mean	Std. Error	Mean	Std. Error	
BRPE	158.0	32.0	83.2	28.6	−47.3
GBHE	23.5	11.5	60.6	6.7	157.9
TRHE	95	–	2.8	1.5	−97.1
LBHE	6	–	3.2	1.3	−46.7
SNEG	46.0	39.0	6.8	3.1	−85.2
GREG	35.0	20.1	39.8	8.7	13.7
REEG	9	–	2.2	1.2	−75.6
CAEG	50.0	50.0	1.4	1.0	−97.2
YCNH	2.5	2.5	7.6	1.0	204.0
BCNH	6.5	6.5	3.0	1.0	−53.9
GRHE	0.0	0.0	0.6	0.4	–
DCCO	27.0	4.0	56.8	9.7	110.4
ANHI	4.5	0.5	0.4	0.4	−91.1

(N=351). A shift in peak nesting time (FIG. 3) from March (2008) to April (2009) to June (2010), then back to April (2011), was observed in Estero Bay; this shift, however, was not statistically significant.

Shifts in species composition among canopy nesters, specifically brown pelican and great blue heron, were observed between 2008 and 2011 (FIG. 4). Brown pelican and great blue heron combined represent 43 to 51 percent of documented nests annually. The decline in brown pelican nesting success between 2008 and 2010 coincided with an increase in great blue heron nesting. Peak nest counts indicate that brown pelican were the dominant nesting species in 2008, 2009 and 2011. In 2010, great blue heron was the dominant nesting species.

DISCUSSION—*Methodology and scale*—Variation in survey methods, lack of written protocols, and gaps in data collection throughout the monitoring program in Estero Bay made interpretation of historic data difficult. Perimeter surveys have been the dominant survey technique implemented in Estero Bay over the past four decades. There are several limiting factors to using perimeter counts including detection probability and double counting (Nichols et al., 2000; Steinkamp et al., 2003). However, the reliability of nest counts using this method to assess populations is reasonably high (Urfi et al., 2005). May brown pelican surveys 1977–1982, 1989 and 1997 were conducted using a boat to circle islands and at least one experienced birder to count nesting pairs. However, detailed protocols and raw data are not available for these surveys. Multiple observer perimeter counts have been employed in Estero Bay since April 1998 when members of National Audubon Society began conducting and

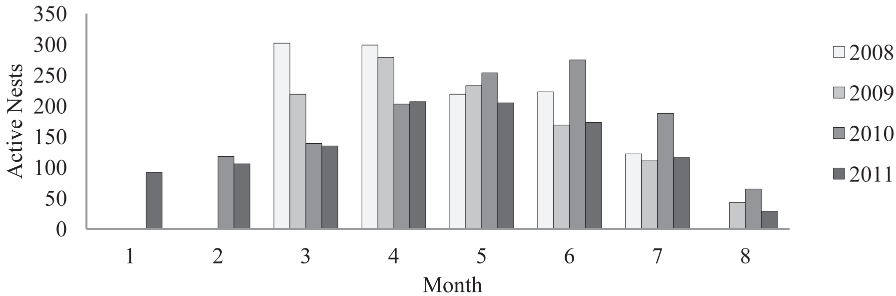

FIG. 3. Monthly nest counts of all species combined (March–August 2008, February–August 2009, February–August 2010 and January–August 2011). Peak nesting time shifted from March (2008) to April (2009) to June (2010), then back to April (2011); this shift however was not statistically significant.

assisting with surveys using the Project Colony Watch protocol. In 2008, the Project Colony Watch protocol was modified slightly when the program was expanded- instead of having multiple observers discuss nest counts and come to a conclusion, nest counts from two observers are recorded and averaged in an effort to reduce errors produced by one of the observers under counting or double counting nests, which were identified by Steinkamp et al. (2003) as problems with perimeter counts. Ground surveys were conducted between 1983 and 1987 by walking through the colonies to document nests. Surveys during this time period provided statistically higher nest counts (FIG. 2); however, it is unclear if this difference is due to survey method or increased nesting activity since a comparison of methods during that time period does not exist. Steinkamp et al. (2003) state that ground surveys provide the most accurate counts at nesting colonies and Urfi et al. (1997) recommend testing multiple census techniques to provide data for comparison of survey methods. Due to the level of disturbance and limitations associated with ground surveys,

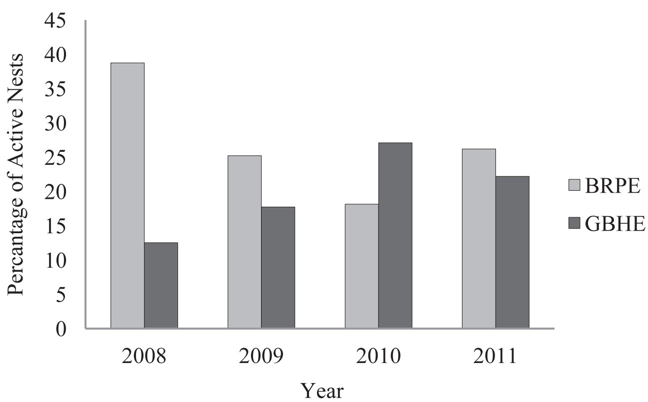

FIG. 4. Percentage of active brown pelican (BRPE) and great blue heron (GBHE) nests, based on peak annual nest numbers for each species, within Estero Bay colonies.

perimeter counts will continue to be the primary survey methods employed by aquatic preserve staff. However, periodic ground surveys may be employed in the future so that more nesting data are available for future analyses. Detection probability for the primary observers, at minimum, should be calculated as outlined by Nichols et al. (2000) annually to allow for additional analysis of data.

Expanding the colonial bird monitoring dataset to include a wider geographical range would allow resource managers to conduct analyses of population trends on a region-wide basis. In the present study, there were few significant trends; this is most likely due to the small size of the dataset. Understanding of trends in these nesting colonies may be bolstered with a larger dataset using standardized methods. Most species of colonial waterbirds are long-lived and decades of data are needed to evaluate significant changes in populations (Steinkamp et al., 2003). Some species of colonial waterbirds have complex annual cycles and wide geographic ranges (Kushlan, 1993), so continuing the monthly monitoring in Estero Bay in conjunction with data collected by Charlotte Harbor Aquatic Preserves and J.N. "Ding" Darling National Wildlife Refuge, who currently use the same survey techniques, would enable managers to examine nesting success on a larger geographical scale and assess whether colonies are moving to other areas.

Comparison of historic and modern data—Data comparisons between time periods provided gross trends for species currently listed by the state as species of special concern which are now under consideration for changes in protection status. Five decades of data collected on the brown pelican in Estero Bay show a significant decreasing trend in nesting for the species while comparisons of historic and modern April surveys showed the decrease in nesting activity was not significant during the shorter time period. In 2011, the Florida Fish and Wildlife Conservation Commission (FWC) reviewed the status of the brown pelican statewide and are recommending its removal from the Florida imperiled species list (FWC, 2011). Several species nesting in Estero Bay are being recommended for state listing as threatened. These include little blue heron, reddish egret, snowy egret, and tricolored heron. Although not significant, these species showed a decrease in nesting activity of between 46 and 97 percent from the historic to modern periods.

Trends in the number of nesting pairs for each species can result in overall changes in the species composition at the colonies, which can influence colony dynamics. For example, night-heron populations have shown an increase from April historic surveys to current surveys, which may affect the nesting success of other species since they have been documented as preying upon avian nests (Kelly et al., 1993) including other wading birds (Hall and Kress, 2008). Hall and Kress (2008) found that 58% of boluses collected from black-crowned night-heron nestlings contained bird remains; however, this may be a specialized feeding behavior for a small subset of the population. Tern chicks were the most common bird prey species identified (Hall and Kress, 2008), which may also have implications for the tern colonies at Little Estero Island Critical Wildlife Area on Fort Myers Beach and at Lovers Key State Park.

Analysis of modern data—Although there were no significant changes in peak nest counts across the more recent sampling period, a declining trend over the past four years (61 nests per year) may reflect real losses of nesting pairs that warrants further monitoring or it may be an artifact caused by an extended nesting period. Peak nest counts are calculated by taking the highest nest count for each species at each of the colonies and adding them to obtain the total peak nest count for the season. Peak nest counts may exclude nests that are not occupied during the peak of the nesting season and therefore may exclude more nests when nesting seasons are spread out. This calculation does not take into account the duration the nest is occupied, which varies widely among species, from nest building to fledging. Using monthly surveys to calculate peak nest counts may provide a more accurate representation of the nesting population than annual surveys. Monthly surveys also provide the opportunity to better track peak nesting times which shifted annually over the four-year monthly survey period; peak nest counts were recorded once in March and June, and twice in April. Changes in nesting time could represent shifts in food availability (Keith, 1978; North American Bird Conservation Initiative, U.S. Committee, 2010), including feeding by humans at fish cleaning stations (Perrins, 1970), or shifts in age composition of the population since younger birds tend to nest later in the season (Perrins, 1970). Keith (1978), Perrins (1970) and Schreiber (1979) showed that brown pelicans and other species that nested earlier in the season were more successful at producing fledglings because young produced later in the season often starved.

Changes observed in species composition could result from changes in nesting time and species dominance. Body size, nest placement, and dominance during interactions influence species co-occurrence at colonies (Spendelow et al., 1989; Burger, 1978). Shifts in species dominance between the brown pelican and great blue heron, both large-bodied canopy nesting species, should be examined in conjunction with arrival time at nesting sites and initiation of nest building in future analyses.

Additional observations at the colonies—Disturbance on nesting islands has been documented through the history of Estero Bay monitoring. Repeated observations of commercial and recreational boat traffic prompted DEP biologists to post one active colony in 1998 with "closed" signs. In 2010, a local eco-tour operator began bringing boat tours to an active colony multiple times a day. Nest counts for this specific island have been documented during April surveys since 1998 and annual counts have averaged 55 nests with 77 active nests in April 2010. The boat tours were observed flushing birds from nests throughout the nesting season, and in 2011 the colony contained only three nests, including one great blue heron and two night-heron. Discarded fishing line also poses a threat to colonies within the bay. In 2009, 30 birds were documented entangled in fishing line; in 2010, 17 birds were documented; and in 2011, 9 birds were documented. Brown pelican accounted for 56–59 percent of fatalities. The decline in entanglement fatalities may be due in part to annual fishing line cleanups conducted by Estero Bay Aquatic Preserve staff and volunteers, as well as the efforts of other local agencies including Keep Lee County Beautiful.

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