Wading Bird Colony Timing, Location, and Size at Lake Okeechobee, 2005–2007

FINAL REPORT

to

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EXECUTIVE SUMMARY

The trophic hypothesis proposes that higher trophic level populations of organisms are limited by changes in hydrogeochemical properties of the environment that regulate lower trophic level resources. With reference to wading birds, this hypothesis states that if hydrology better mimics historic conditions then prey populations will proliferate during the wet season and wading birds will experience increased access to those prey during the breeding season. If wading birds experience enhanced foraging opportunities with improved water management strategies, then monitoring efforts will reflect short-term improvements in wading bird reproductive success which should lead to population recoveries over the long-term.

Under monitoring and Assessment Pan (MAP) Activity Numbers 3.1.3.13 and 3.1.3.14 of the Greater Everglades Wetlands (GEW) module, breeding wading bird populations are identified as key performance measures that will gauge ecosystem recovery and guide water management decisions. With information on the location, timing, size, and success of wading bird colonies, stakeholders will be able to (1) evaluate predictions from trophic hypotheses in coordination with multi-disciplinary monitoring efforts, and (2) hone management recommendations as the Comprehensive Everglades Restoration Plan (CERP) continues to be implemented. Because wading birds are a guild of highly vagile species with widespread dispersal potential, monitoring populations throughout the entire GEW is necessary. This report focuses specifically on FAU's 2005–2007 colony surveys at Lake Okeechobee.

The 2006 nesting season was a banner year in the Okeechobee region with nest effort and productivity reaching toward historical highs. We suspect complete inundation of littoral zone marshes increased the carrying capacity of the lake by increasing the dispersion and productivity of prey communities and by increasing the spatial extent of highly suitable foraging habitat in the landscape. The extended recession acted to increase prey availability and to continually replenish the landscape with available foraging patches throughout the nesting season. This study supports the inference that wading birds can experience comparatively high reproductive success when extensive flooding of littoral zone marshes is followed by an extended recession. Analysis of the historical record showed that nonextreme January lake stages followed by at least three months recession during the breeding season tended to maximize nest effort.

In January 2007, much of the littoral zone was waterless and remained dry throughout the nesting season, which negatively affected wading bird foraging habitat. In contrast, recession rates suggested that foraging conditions were good to fair throughout the breeding season, but drought conditions also reduced the spatial extent of suitable habitat for foraging and nesting wading birds. The poor nest effort and reproductive success during 2007 suggested that hydrological conditions associated with droughts produce poor quality foraging habitat. Again referring to the historical record, analysis demonstrated that when extreme low lake stages prevail to start the year, we can expect poor nest effort from wading birds in the Okeechobee region. Data also demonstrated that if recessions continue throughout the dry season following extremely low January lake stages, that wading bird nest effort will be lowest overall.

In 2007, we also detected of a small Wood Stork colony in cypress trees on private land about 4km north of Harney Pond. During aerial reconnaissance in mid-April, we detected 12 nesting pairs with 22 young. We observed chicks weekly via aerial survey thereafter. During our last visit on June 26, we observed only 9 chicks left at the colony and expect that all nestlings eventually fledged following the postflight period of attachment to nest sites.

Low nest effort has also been linked to prolonged high lake stages. In 1984, the only other year with extreme low wading bird nest effort (< 1,000 nests), lake stages had remained high since August 1982, and breeding season hydrology was characterized by periodic reversals and increasing lake levels. Thus, extended periods of extreme lake stage, whether high or low, appear to have negative impacts on wading bird populations. Additional research into the effects of different hydrological scenarios on habitat availability and wading bird reproduction is on-going.

From this study to-date, we can offer coarse-grained recommendations for Lake Okeechobee management strategies designed to benefit wading birds. Wading birds apparently respond positively to moderate lake levels at the beginning of the year that fall within the long term interquartile range of lake stages for January (4.14–4.73 m NGVD29). These conditions promote productivity of their prey base and maximize the spatial extent of potential foraging habitat during extended recessions. Seasonal dry downs provide the mechanism that concentrates prey and enhances their availability during the breeding season when wading bird energetic demands are high. Thus, we also suggest that dry season recessions following inundation of the littoral zone are a necessary aspect of lake management to promote and sustain wading birds that nest at Lake Okeechobee.

The importance of Lake Okeechobee to south Florida wading bird populations should not be underestimated. In 2006, if wading bird nest effort at Lake Okeechobee is included in system-wide estimates of nest effort, then Okeechobee colonies accounted for 17% of all nests in the GEW. Whether as a population source for wading birds that breed throughout the GEW, or as an important post-breeding dispersal stopover site for species of special management concern such as Roseate Spoonbills and Wood Storks, Lake Okeechobee continues to serve as a critical ecosystem component for wading birds that breed in the GEW.

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ACRONYMS AND ABBREVIATIONS

ARDsp – Ardeid species, reserved for characterization of Snowy Egret, Little Blue and Tricolored Heron reproductive indices because their nests and eggs are difficult to distinguish before chicks hatch

C&SFP – Central and Southern Florida Project for Flood Control

CAEG – Cattle Egret

CERP – Comprehensive Everglades Restoration Plan

DBHYDRO – the South Florida Water Management District's corporate environmental database which stores hydrologic, meteorologic, hydrogeologic and water quality data

DOQQ – Digital Orthophotoquarterquadrangles

DSR –Daily Survival Rate

FAA – Federal Aviation Administration

FAU – Florida Atlantic University

GBHE – Great Blue Heron

GEW – Greater Everglades Wetlands ecosystem, which includes the Kissimmee River, Lake Okeechobee, the Everglades, and Florida Bay

GLIB – Glossy Ibis

GREG – Great Egret

HSI – Habitat Suitability Index

LBHE – Little Blue Heron

LOPP – Lake Okeechobee Protection Plan

m NGVD29 – meters National Geodetic Vertical Datum 1929

MAP – Monitoring and Assessment Plan

NCDC – National Climatic Data Center

RECOVER – Restoration, Coordination and Verification program

SFWMD – South Florida Water Management District

SNEG – Snowy Egret

TRHE – Tricolored Heron

USACE – United States Army Corps of Engineers

WHIB – White Ibis

WOST – Wood Stork

WRDA 2000 – Water Resources Development Act of 2000

WSE – Water Supply and Environment

INTRODUCTION

Historical Wading Bird Nest Effort at Lake Okeechobee

Wildlife biologists recognized as early as the 1930's that Lake Okeechobee was an important nesting ground for many of South Florida's wading birds (David 1994a). An historically expansive freshwater marsh that was hydrologically connected to the lake provided quality nesting and foraging habitat for colonially breeding wading birds during dry season recessions. Wading bird reproduction coincided with the timing of these dry-downs, because when water levels receded, the expansive freshwater marshes supplied high concentrations of vulnerable prey in shallow pools that lingered within topographic depressions (Kushlan 1976a, Kushlan 1986, Frederick and Collopy 1989a, Loftus and Eklund 1994, Gawlik 2002). Today, Okeechobee's littoral zone harbors the last remnants of freshwater marsh still hydrologically connected to the lake basin.

In 1978, water managers proposed increasing the regulation schedule from 3.96–4.72 to 4.72–5.33 m National Geodetic Vertical Datum 1929 (NGVD29). At the time, regulation schedules represented a management envelope whereby the minimum water level represented a desired lake stage at the beginning of the wet season to allow for flood protection and water storage, while the maximum water level represented a desirable lake stage at the beginning of the dry season for water supply releases. From 1978–2000, managers operated under this elevated regulation schedule, which increased water storage capacity but also tended to increase the frequency of years with prolonged high water levels in littoral zone marshes (Zaffke 1984, David 1994a).

Similar to the Everglades, declines in the use of Okeechobee by foraging and nesting wading birds reflected management impacts that disrupted the natural hydrology of the lake (Zaffke 1984, David 1994b, Smith and Collopy 1995). To discern effects of the proposed increase in lake levels, the SFWMD began monthly aerial surveys of breeding wading birds (Zaffke 1984, David 1994b, Smith and Collopy 1995). These surveys were conducted throughout the breeding season from 1978–1992. The historical record provided results of surveys that were conducted from 1957–60, in 1971–72, in 1974–75, and in 1977 for comparison of pre- and post-management changes following the increased regulation schedule.

When compared to the historical record, David (1994a) showed that mean wading bird nest effort at Lake Okeechobee declined by 60% in the ten years following the 1978 changes in the regulation schedule (Fig. 1, Appendix B). In general, researchers concluded that disruptions to the timing, duration, and depth of wetland inundation reduced the availability of littoral zone wetland habitats for wading birds and caused declines in the nest effort and abundance among wading birds that depend on the lake (Zaffke 1984, David 1994a, b, Smith and Collopy 1995, Havens and Gawlik 2005). Prolonged high lake stages increased water depths in the littoral zone during the breeding season, which likely reduced foraging habitat suitability and limited prey availability (David 1994b). Moreover, these hydrological changes negatively impacted the extent of willow (*Salix caroliniana*), which is the preferred nest substrate of wading birds (Frederick and Collopy 1989b, David 1994b).

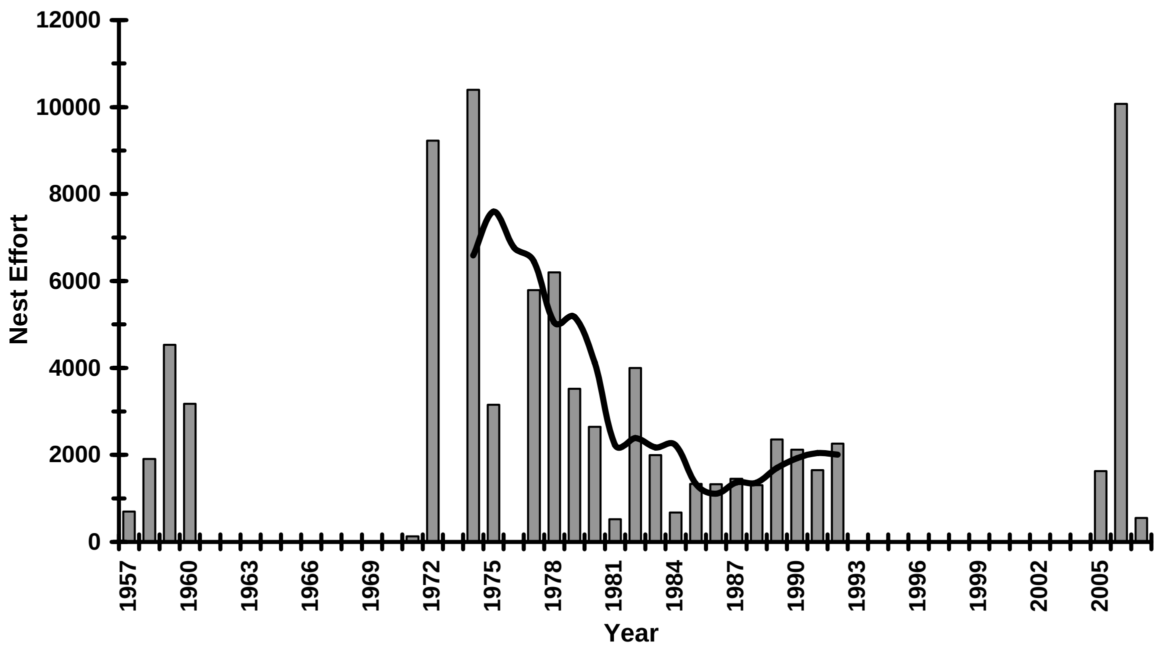

Figure 1. Historical record of wading bird nest effort from 1957–2007 for Lake Okeechobee, FL. Data were collated from David 1994a, Smith and Collopy 1995, and the current Florida Atlantic University monitoring effort. Trend line based on 3-yr moving averages from 1971–1992, which were the most reliable and continuous survey results on record. Missing columns indicate no survey data for the given year.

Lake experts currently recognize the need to operate under a regulation schedule that minimizes the frequency and duration of high water levels and reintroduces natural hydrological variability to restore lake health and the vitality of its wetland communities

(Steinman et al. 2002, USACE 2004, Havens and Gawlik 2005). The Water Supply and Environment (WSE) regulation schedule was organized under an adaptive framework that allows for periodic managed recessions of lake levels during dry season (Steinman et al. 2002), which is significant for wading birds because management coincides with the onset of the wading bird colony formation. Recessions are deemed necessary to maintain the diverse aquatic vegetation, invertebrate, and fish communities which inhabit the lake, but may also sustain regional wading bird populations (SFWMD 2004, Havens and Gawlik 2005). Following from the trophic level hypothesis for Everglades wading birds, the new regulation schedule authorized under the Lake Okeechobee Protection Plan (LOPP) should benefit wading birds, and continued documentation of wading bird breeding effort in coordination with other monitoring programs should help lake experts evaluate the effectiveness of water management procedures.

Restoration and the Trophic Hypothesis

In response to concern about the integrity of South Florida ecosystems, the United States Congress mandated the Water Resources Development Act of 2000 (WRDA 2000). Legislation authorized the Comprehensive Everglades Restoration Plan (CERP), which serves as a framework for developing modifications and operational changes to the Central and Southern Florida Project for Flood Control (C&SFP) that will attempt to balance restoration goals with other ecosystem services (USACE 2000). Provisions within WRDA 2000 also authorized creation of an adaptive Monitoring and Assessment Program (MAP). The MAP outlines performance measures that are representative of healthy South Florida ecosystems that will be used to evaluate the success of CERP. Under MAP Activity Numbers 3.1.3.13 and 3.1.3.14 of the Greater Everglades Wetlands module, breeding wading bird populations are identified as key performance measures that should be monitored to gauge ecosystem recovery and guide water management decisions (Jacobs 2005).

Wading birds are top predators in the GEW ecosystem, and healthy populations are emblematic of a robust South Florida wetland complex. Thus, healthy wading bird populations are central to evaluating the trophic hypothesis upon which restoration is centered. With information on the location, timing, size, and success of wading bird colonies, stakeholders will be able to (1) evaluate predictions from trophic hypotheses in coordination with multi-disciplinary monitoring efforts, and (2) hone management recommendations as CERP continues to be implemented.

The trophic hypothesis proposes that higher trophic level populations of organisms are limited by changes in the hydrogeochemical properties of the environment that regulate lower trophic level resources (DeAngelis et al. 1998, Curnutt et al. 2000). With reference to wading birds, this hypothesis states that if hydrology better mimics historic conditions then (1) increases in fish and macroinvertebrate populations will result, and (2) wading bird access to those prey will be enhanced during the breeding season (Fleming et al. 1994). More generally, if wading birds experience enhanced foraging opportunities with improved water management strategies, then monitoring efforts will reflect short-term improvements in wading bird reproductive success which will lead to population recoveries over the long-term.

Because wading birds are a guild of highly vagile species with widespread dispersal potential, monitoring populations throughout the entire GEW is necessary. Multiple components of the MAP wading bird monitoring are being conducted concurrently in Florida Bay by National Audubon Society, in the southern Everglades by National Park Service staff, in the central and northern Everglades by University of Florida, and at Lake Okeechobee by Florida Atlantic University. This report focuses specifically on breeding wading bird populations in the Lake Okeechobee region. Results will expand upon the historical wading bird dataset that has already served as an early warning of ecological degradation throughout the GEW (Kushlan 1993, David 1994a, Ogden 1994, Weller 1995, Crozier and Gawlik 2003, Frederick and Ogden 2003).

Current Monitoring Effort

In May of 2005, Florida Atlantic University received funding to document the timing, size and location of wading bird colonies at Lake Okeechobee as part of CERP monitoring for the GEW. On June 3, 2005, we conducted a single aerial survey just as the rainy season was beginning and lake levels were rising. Then from 2006–2007, Florida Atlantic University (FAU) conducted monthly aerial surveys of breeding wading birds. To our knowledge, these efforts represent the first systematic aerial surveys at Okeechobee since 1992.

Herein, we report results from the 2005–2007 colony surveys. Because of the late project start in 2005, it is possible that some colonies had already abandoned their nests, as they had done in the Everglades. While locations may be representative, we could make no comparison of 2005 colony timing or size with 2006–2007 data. Thus, we focused discussion of results on comparison of 2006–2007 nest data with ambient environmental conditions during those years. Contrasting environmental conditions respectively produced one of the best and one of the worst nesting years on record for the Lake Okeechobee region.

METHODS

Colony Surveys

In June 2005, and monthly from January through June 2006–2007, observers surveyed wading bird nests along systematic aerial transects (Fig. 2). Given the inherent risk in low altitude aerial surveys, we maintained minimum safe altitude guidelines outlined in Section 91.119 of Federal Aviation Administration (FAA) Regulations. We flew transects in a Cessna 172 at an altitude of 244 m and a speed of 185 km/hr. One transect paralleled the eastern rim of the lake from Eagle Bay Island to the Clewiston Lock. Remaining transects were oriented East-West, spaced at an interval of 3 km, and traversed the littoral zone. Two observers searched for colonies, one from each side of the plane.

When a colony was located, the colony was circled several times while we documented species composition and counted nests. To maintain consistency with past wading bird reports for Lake Okeechobee (e.g. Zaffke 1984, David 1994a, Smith and Collopy 1995), we counted all birds sighted and categorized them as “nesting” if nests were visible or known assemblages of nests existed for a species. At the largest, most diverse, and accessible colonies, we followed aerial surveys with ground monitoring to improve count accuracy (Frederick et al. 1996). Even so, despite combined ground surveys and photographs, small dark-colored wading birds are difficult to census, which diminishes our confidence in their observed nest numbers.

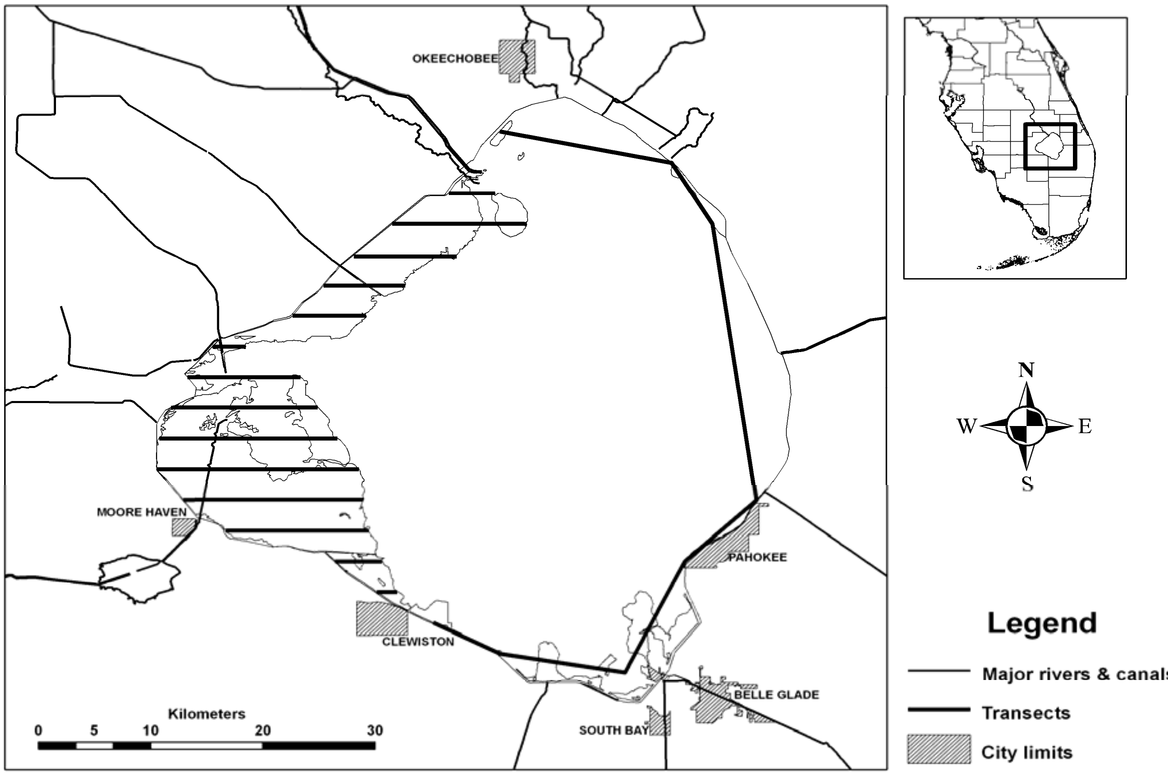

Figure 2. Map of systematic aerial surveys flown monthly between January and June from 2005–2007 at Lake Okeechobee, FL. Transects covered the entire vegetated zone of the lake.

We also recorded photographs and geographic coordinates with each visit and then mapped colonies to specific stands of vegetation or islands onto 1-m resolution digital orthophotoquarterquadrangles (DOQQ). Colonies were defined post-hoc as any assemblage of ≥ 2 nests that were separated by ≥ 200 m (Erwin et al. 1981, Smith and Collopy 1995). We calculated intercolony distances using ArcGIS.

Colony locations were documented on maps, and their coordinates were listed in tables of peak nest effort. We compared colony locations to published maps of past wading bird colony survey results from David (1994a) and Smith and Collopy (1995) to determine whether a colony site was undocumented or previously occupied. We also documented the timing of nest initiation and peak effort for each colony and species. We defined "peak nest effort" as the peak seasonal nest count from monthly surveys to maintain consistency with the historical record. Total nest effort summed the size of all wading bird colonies each month, including Tricolored Herons (*Egretta tricolor*), Little Blue Herons (*Egretta caerulea*), and Glossy Ibis (*Plegadis falcinellus*). We also documented Cattle egrets (*Bubulcus ibis*) because of traditional mention in Lake Okeechobee survey reportss, but they are not considered to be wading birds because they are not wetland dependent foragers.

Additionally, when historical comparisons of nest effort were made, we found that only four "core" species were common among all reports and all years— Great Blue Heron (*Ardea herodias*), Great Egret (*Ardea albus*), Snowy Egret (*Egretta thula*), and White Ibis (*Eudocimus albus*). Herein, we distinguished core counts from the total nest effort recorded in 2005–2007 for clarity. Treating core counts separately strengthened comparisons of environmental variability with long-term nesting trends.

Hydrology and Nest Effort

Regional rainfall and hydrology data were obtained from the South Florida Water Management District's DBHYDRO database and the National Climatic Data Center (NCDC). Lake stages and recession rates reported herein were based on average stage readings from four principal gauges located in the pelagic zone at Lake Okeechobee (L001, L005, L006, and LZ40). Lake stages were reported as m NGVD29. We used the recession rate index from Sklar (2002) to assess the suitability of wading bird foraging conditions. The index was based on weekly changes in lake stage. We limited hydrology narratives to the 2006 and 2007 breeding seasons, because we conducted only one survey during 2005.

We sought improved understanding about the hydrological conditions that produced increasing nest effort among wading birds breeding at Lake Okeechobee. To do so, we collated historical information on lake stage and calculated weekly recession rates from February through May for each year that nest effort was recorded. We then tested whether (1) the average January lake stage at the start of the breeding season, and (2) the continuity of recession during the breeding season influenced nest effort. Historical lake stage data ranged back to 1932. Extreme high and low stages were outside the long term (1932–2007) interquartile range (4.14 < > 4.73 m NGVD29) for mean January lake stage. Weekly recession rates were calculated as the change in water level across seven day intervals beginning on January 1 of each year for which we have nest counts.

In statistical models, nest effort was the dependent variable. We collated peak annual nest counts from the historical record using David 1994a, Smith and Collopy 1995, and FAU's 2005–2007 results. Collation yielded 27 yrs with nest counts from 1957–2007. Only records of four species were common to all investigators among all years. Those species were Great Blue Heron, Great Egret, Snowy Egret, an White Ibis. Thus, only nest counts for these species were used in our analyses.

We expected that moderate lake stages at the beginning of the season, and continuous recessions would interact to produce large nesting events. We transformed nest effort using the natural log transformation to meet assumptions of normality. To test our hypothesis, we conducted a fixed factor analysis of variance (ANOVA) using general linear model in SAS 9.1.3. We described central tendencies and variability within groups by reporting back transformed means and Bonferroni adjusted 90% confidence intervals (CI). We used a Type I error rate of 0.10 was used to improve power given the low number of years for which we have nesting records relative to the number of years since the first documented nest count.

RESULTS

Hydrology 2006–2007

The 2005 wet season was the wettest since 1995, and subsequently the 2006 lakes stages began the year at 4.79 m NGVD29 with deeper waters in the marsh (Figs. 3, C-1). High rainfall was associated with an active storm season that brought four hurricanes to Florida. January lake stage was above the long term average, but not outside its normal range because lake levels had receded steadily since Hurricane Wilma in November. Water levels continued to recede steadily throughout the breeding season, except for a brief reversal in early February due to unseasonably heavy rains. Falling lake stages indicated that recession rates were good to fair from March 11 until June 30 when lake levels began to increase again following initiation of the rainy season.

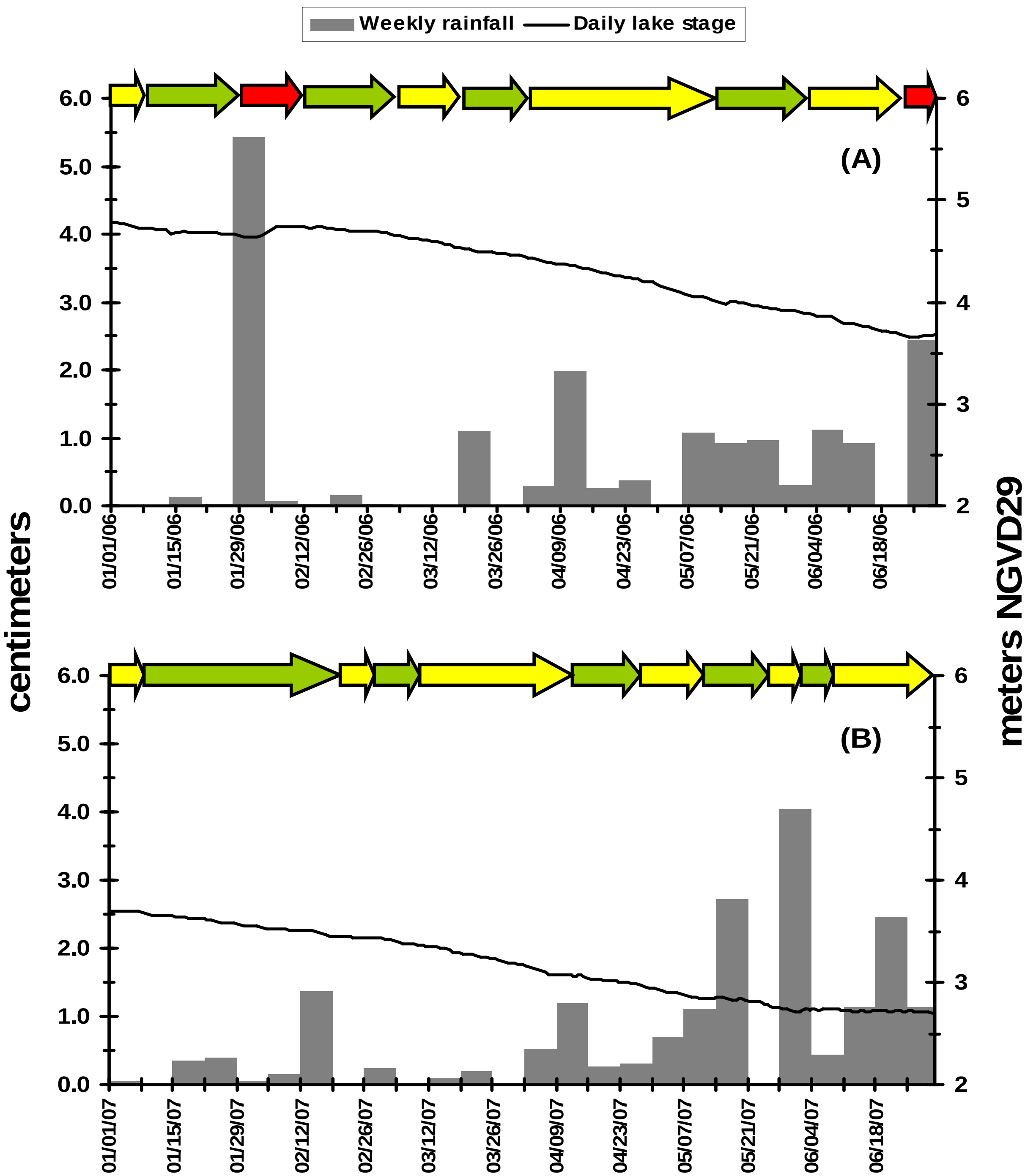

Figure 3. Weekly precipitation totals (cm) and average daily lake stage (m NGVD29) for Lake Okeechobee, FL during the 2006 (A) and 2007 (B) wading bird breeding seasons. Suitability of wading bird foraging recession rates were depicted in colored arrows. Good foraging conditions (green) existed when average lake stage decreased ≥ 1.5 and < 4.9 cm per week, fair foraging conditions (yellow) when stage decreased ≥ 4.9 and < 18.3 cm or decreased only < 1.5 cm per week, and poor foraging conditions (red) when stage levels increased or if decreases were ≥ 18.3 cm per week.

In 2007, hydrological conditions for the Lake Okeechobee region contrasted with those of 2006 (Fig. 3). From June to December 2006, the Lake Okeechobee region received its lowest wet-season rainfall accumulation over the last twelve years. The SFWMD reported the drought was the third most severe on record. Lake levels began the 2007 season 1.05 m lower than in 2006, extremely low for that time of year and because lake levels never recovered from the previous dry season, the littoral zone had remained waterless since May 2006. Average lake stage began at 3.74 m on January 1, 2007, and steadily receded throughout the breeding season, eventually reaching a record low of 2.70 m on June 30, 2007. With little rainfall throughout the breeding season, recession rates remained beneficial to foraging wading birds from January–June.

Colony Locations, Timing, and Size

Locations: 2005–2007

We located 8 colonies with nesting wading birds in June 2005 (Fig. 4), and 27 colonies in 2006. All detected colonies were on-lake during these years. We located 6 colonies in the Okeechobee region during 2007—four on-lake and two off-lake. Across years, colony sites included both traditional sites recorded in the recent literature and two novel sites (David 1994a and Smith and Collopy 1995). The most prominent traditional sites included Clewiston Spit, Liberty Point, Moore Haven East 4, Indian Prairie North 1, and Eagle Bay Island North (Appendix A). Only Indian Prairie South and Torry Island in 2006 and Little Bear Beach and two off-lake colonies in 2007 were previously undocumented sites.

In contrast to historical nesting reports, we did not observe any on-lake nesting activity at either King's Bar, Okeetantie, Harney Pond/Twin Palms, or Observation Island. We also observed no activity at either Lake Hicpochee or in Cowpen Marsh, two former colony sites outside of the lake levee (Smith and Collopy 1995). The five largest colonies during 2006 were Moore Haven West 1, Moore Haven East 4, Indian Prairie South 1, Eagle Bay Island North, and Liberty Point, respectively (Appendix A). We grouped Moore Haven Marsh colonies into East and West because the marsh is split by a canal that runs north-south. Moore Haven West 1 was a traditional colony site whose location was similar to unnamed colonies previously reported. Moore Haven East 4 was likely the same as the “Moore Haven B” colony in David (1994a), but was left unnamed by Smith and Collopy (1995). We grouped Indian Prairie colonies into North and South because the landmass is split by Indian Prairie Canal. No previous record existed for the Indian Prairie South colonies. Liberty Point was likely the oldest and most perennial site of all the active colonies located during 2006. Nests attempts were initiated here during 80% of the breeding seasons from 1977–1992. Eagle Bay Island is not mentioned by David (1994a), but was active during 1989–1992 (Smith and Collopy1995).

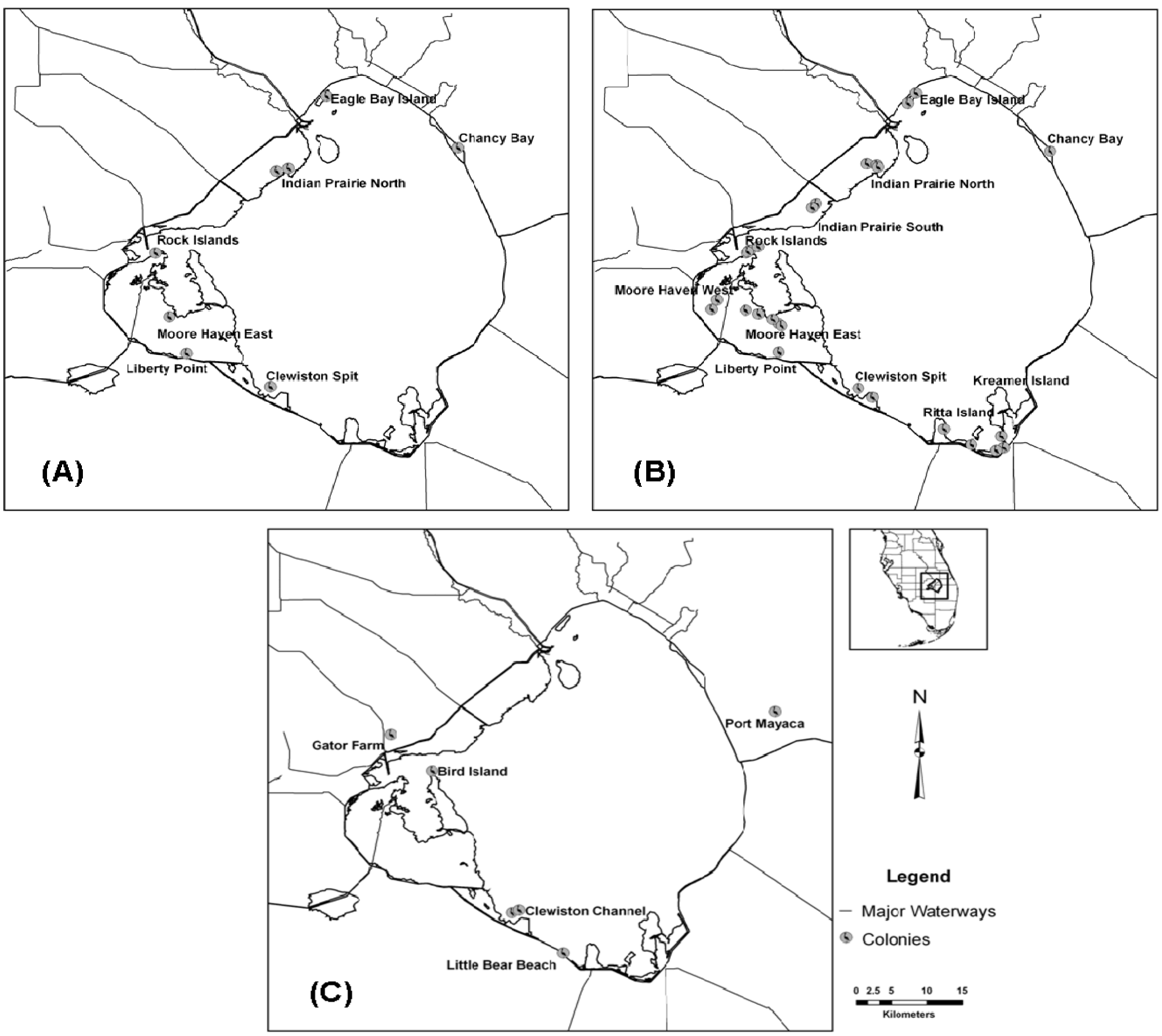

Figure 4. Maps of wading bird colonies at Lake Okeechobee, FL during the 2005 (A), 2006 (B), and 2007 (C) breeding seasons.

In 2007, the largest colony was Clewiston Spit. This colony was also consistently mentioned in the historic literature and is the only site perennially occupied during the study (Appendix A). Bird Island was the second colony site with significant nest effort in 2007. Smith and Collopy (1995) reported that Bird Island was occupied from 1989–1992, but we did not detect a colony there until this year. Additionally, we located another small colony on another spoil island along Clewiston Channel, ca. 800 m ENE from Clewiston Spit; and another along the rim canal levee near Little Bear Beach. We also detected two colonies off-lake during foraging wading bird reconnaissance—one on an alligator farm near Lakeport and another at the Martin County Florida Power and Light Reservoir near Port Mayaca. The last four mentioned colonies were previously undocumented.

Table 1. Comparison of 2005–2007 core nest counts with long term (1957–1960, 1971–1972, 1974–1975, 1977–1990) mean nest effort, standard error (SE), and interquartile (IQ) range.

Year	Great Blue Heron	Great Egret	Snowy Egret	White Ibis	Total
2005	0	1,590	0	0	1,590
2006	55	1,782	2,393	5,800	10,030
2007	0	7	543	0	550
Mean	126	1,184	526	1,639	3,140
SE	38	163	108	440	557
IQ Range	8–192	200–1,240	145–664	200–2,100	1,326–4,000

Nest effort: 2005

In 2005, the total number of nesting wading birds was below average (Table 1). Recorded nest numbers were likely below the seasonal peak, because the count was conducted at the end of the breeding season. It is possible that nest effort would have been low anyway due to abandonment that is often linked with water reversals associated with unseasonable rainfall (Frederick and Collopy 1989a). Stage hydrographs reflected that average water depth steadily increased 26 cm from February 25–March 28, more than a month of rising water levels. Nest failures were observed in other colonies throughout the Everglades and were also presumed to be associated with heavy spring rains and protracted water reversals (Cook and Call 2005). Even with corroboration from the southern Everglades, however, few inferences can be drawn from the 2005 nest count data until we better understand the relationship between nesting wading birds at Okeechobee and nesting wading birds throughout the rest of the GEW.

Timing and peak nest effort: 2006

Nest monitoring data suggested that Great Blue Herons and Great Egrets began nesting in early December 2005 before the 2006 aerial surveys began. Small ardeids began nesting during the third week of March, and ibises began nesting the first week of April. Several colonies remained active until the last week of June when the last surveys were conducted. Timing of peak nest effort for each colony is listed in Appendix A.

In 2006, we observed a peak count of 10,881 wading bird nests during our April surveys (Table 2). However, to put this number into its proper historical context, we also summed the core nest effort for the four species that appeared continuously throughout the historical record. That core count was 10,030 nests (Table 1), which made 2006 the largest nesting year on record since 1974 when effort peaked at 10,400 nests. However, these early surveys (1957–1975) were sporadic between years and typically occurred only once during the breeding season, making it possible that peak nest effort was underestimated and some good years were missed.

The largest colonies during 2006 were Moore Haven West 1, Moore Haven East 4, Indian Prairie South 1, Eagle Bay Island North, and Liberty Point, respectively (Appendix A). These five colonies accounted for 86% of the overall peak nest effort among wading birds. Moore Haven West 1 was the largest colony in 2006, harboring 45% of the total nests with all principal wading bird species breeding there at some point during the season. All five colonies maintained diverse species compositions and were still active in June during the final surveys, but lake levels had receded to a point that ground access was problematic.

Table 2. Comparison of total nest effort by wading birds at Lake Okeechobee, FL during the 2006 and 2007 breeding seasons.

	2006										2007									
Month	**GBHE**	**GREG**	**SNEG**	**TRHE**	**LBHE**	**CAEG**	**WHIB**	**GLIB**	**WOST**	**Monthly Totals** [1]	**GBHE**	**GREG**	**SNEG**	**TRHE**	**LBHE**	**CAEG**	**WHIB**	**GLIB**	**WOST**	**Monthl Totals**
January	34	50	[2] 0	0	0	0	0	0	0	84	0	0	0	0	0	0	0	0	0	
February [3]	*98*	480	0	0	0	0	0	0	0	578	0	0	0	0	0	0	0	0	0	
March	72	*1,796*	203	63	25	0	400	80	0	2,639	0	0	0	0	0	0	0	0	0	
April	55	1,782	2,393	*234*	*182*	650	*5,800*	435	0	10,881	0	*7*	*543*	*157*	0	15	*0*	*41*	*12*	76
May	22	1,067	*2,580*	137	158	1,530	2,980	*620*	0	7,564	0	7	137	107	*14*	886	0	5	11	1,15
June	15	655	1,764	83	82	1,215	170	305	0	3,074	*3*	0	0	0	4	*1,260*	0	0	11	1,26

[1] Monthly totals excluded Cattle Egrets

[2] Species undetected during the survey

[3] Italics denoted annual peak nest effort for each wading bird species

Timing and peak nest effort: 2007

No wading bird nesting was detected via aerial surveys until April 2007 when we detected colonies at Clewiston Spit and Bird Island. We suspect these colonies initiated nesting earlier than aerial surveys would suggest because we observed Snowy Egrets and Tricolored Herons carrying nest material into phragmites beds (*Phragmites australis*) on April 3 via ground surveys. Initial nest monitoring efforts suggested that courtship and nest building began during the third week of March, which was similar to the timing of small ardeid nest initiation in 2006. Clewiston Spit and Bird Island grew into the largest wading bird colonies for 2007. By mid-April wading bird nests peaked at 635 and 96 wading bird nests, respectively. However, the Clewiston Spit colony was abandoned in May.

Two upstart colonies and one previously undetected colony were detected in May. The upstart colonies were at Little Bear Beach and in Port Mayaca. The effort at Little Bear Beach was short-lived and birds abandoned the colony by June surveys. The Port Mayaca colony was located in the middle of the Martin County Florida Power and Light Reservoir and was still active in June, but due its proximity to the power plant we were unable to survey the area effectively. The previously undetected Gator Farm colony contained 11 Wood Stork (*Mycteria americana*) nests along with 73 other wading bird nests when it was detected in May (Appendix A). We monitored the Wood Stork nests from the air (see below), but we were unable to monitor other wading bird nests because the colony was on private land.

In 2007, season-wide nest effort for all wading birds breeding in the Okeechobee region peaked in April at 760 nests (Table 2). By comparison, a partial count of nest effort was 553 nests, far below average and ranking the third lowest on record (Table 1). Only counts from 1971 and 1981 ranked lower. In 2007, we observed no on-lake nesting among Great Blue Herons, Great Egrets, Little Blue Herons, or White Ibis. Similar to 1971, no Great Egrets and no Great Blue Herons were detected, and in 1981, some Great Egrets nested but not Great Blue Herons or Glossy Ibis (David 1994a).

Wood Stork Reproductive Success

In 2007, we detected of a small Wood Stork colony in cypress trees on an alligator farm about 4 km north of Harney Pond along Highway 721. During aerial reconnaissance, we detected 12 Wood Stork pairs nesting on April 19. Maturity of Wood Stork chicks at the time suggested that storks began nesting between the first and second weeks of March.

Despite getting a late start, the colony fledged 22 young at the end of June. On June 14, plumage condition and movement away from the nest to adjacent branches suggested that chicks were 55-60 days old (Coulter et al. 1999). During our last visit on June 26, we observed only 9 chicks left at the colony and expect that all nestlings eventually fledged following the postflight period of attachment to nest sites (Kahl 1964, Coulter et al. 1999).

Historical Wading Bird Nest Effort and Hydrology

Favorable conditions, such as average to above average lake stages at the start of the nesting season followed by a protracted hydrologic recession, were observed at Lake Okeechobee during 2006. Given research from the Everglades, which indicated (1) the importance of prolonged hydroperiods for increasing fish and invertebrate populations and (2) the benefit of dry season recessions that concentrate those prey to wading bird foraging strategies (Kushlan 1976a,b, 1979, 1980,1986; Powell 1987, Frederick and Collopy 1989a, Loftus and Eklund 1994, Gawlik 2002), we expect similarly favorable hydrological conditions at Lake Okeechobee contributed to the high reproductive effort observed during 2006. Additionally, data suggested that conditions were qualitatively similar in 1972 and 1974, years with similarly high nest counts, when lake stage began the year within the long term interquartile range and then experienced an extended recession throughout the breeding season (Fig. 5). In 1972, however, spring rains slowed recession rates and the rainy season began a few weeks earlier than the other comparable seasons.

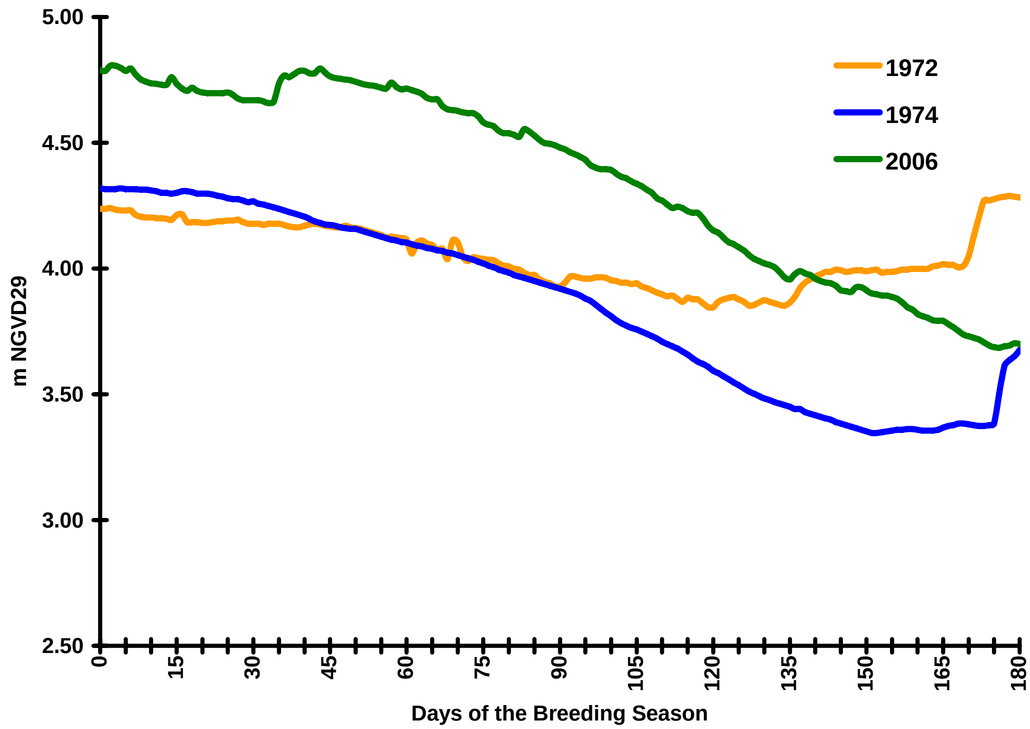

Figure 5. Comparison of lake stages during the 1972, 1974, and 2006 wading bird breeding seasons at Lake Okeechobee, FL. These years produced the three highest nest efforts on record. Stage is reported as meters National Geodetic Vertical Datum 1929 (m NGVD29). Day zero equals January 1.

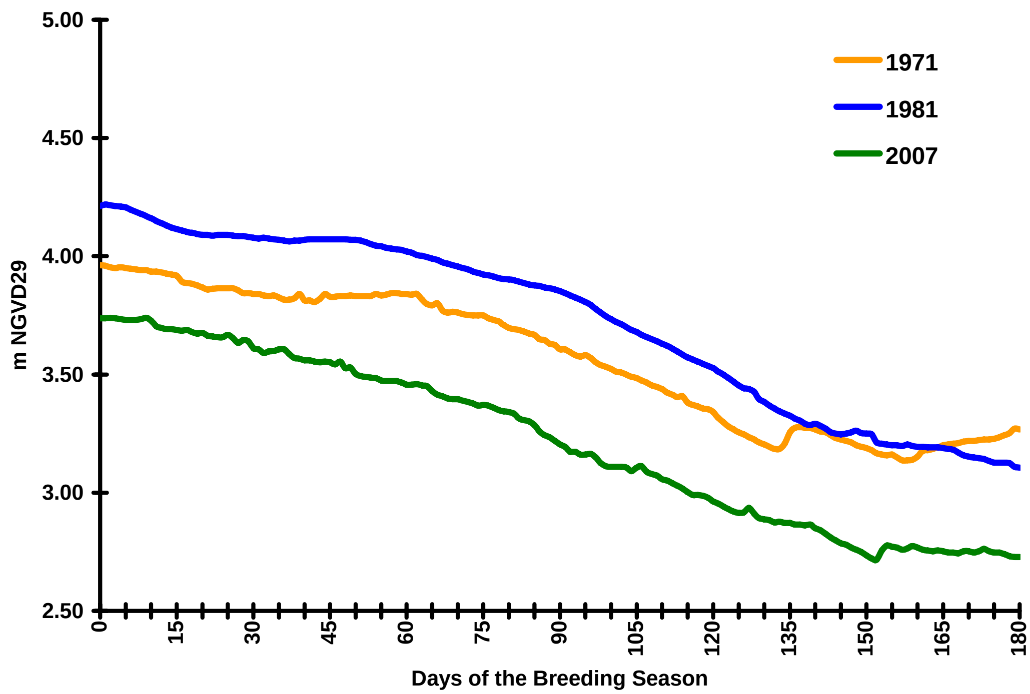

Figure 6. Comparison of lake stages across the 1971, 1981, and 2007 wading bird breeding seasons at Lake Okeechobee, FL. These years produced the three lowest nest efforts on record. Stage is reported as meters National Geodetic Vertical Datum 1929 (m NGVD29). Day zero equals January 1.

In contrast, 2007 was one of the worst nesting years on record. Again, similar counts in 1971 and 1981 had qualitatively similar hydrology. The three seasons were characterized by low lake stages to start the breeding season and below average rainfall during the preceding wet season (Fig. 6). Data suggested that extreme low lake stages followed by a steady recession may limit wading bird nest effort at Lake Okeechobee and that these conditions likely contributed to the poor reproductive performance of wading birds at Okeechobee despite a favorable recession throughout the breeding season.

To better understand the dynamic interaction between lake stage and recessions, we sought to quantitatively characterize the relationship between hydrological conditions and nest effort. Mean January lake stage and recession type produced significant effects on wading bird nest effort (Table 3). Extremely low or high initial lake stages tended to reduce peak nest effort (Fig. 7). Recession per se was not significant, but the interaction of recession type with initial lake stage was. Normal initial lake stages in January followed by a continuous recession produced the highest nest effort among wading birds that breed at Lake Okeechobee (Fig. 7). Data also showed that nest effort is lowest when extreme low initial lake stages are followed by steady recessions.

Table 3. ANOVA results (adj.-R^2 = 0.45) for the effects of average January lake stage and recession continuity across the breeding season on wading bird nest effort at Lake Okeechobee, FL.

Source	Type III Sum of Squares	d.f.	M.S.E.	*F*	*P*
Corrected Model	14.4	5	2.9	5.2	0.003
Intercept	948.4	1	948.4	1712.2	> 0.001
Stage	8.7	2	4.4	7.9	0.003
Recession	0.3	1	0.3	0.5	0.498
Stage * Recession	4.8	2	2.4	4.3	0.027
Error	11.6	21	0.6		
Corrected Total	26.0	26			

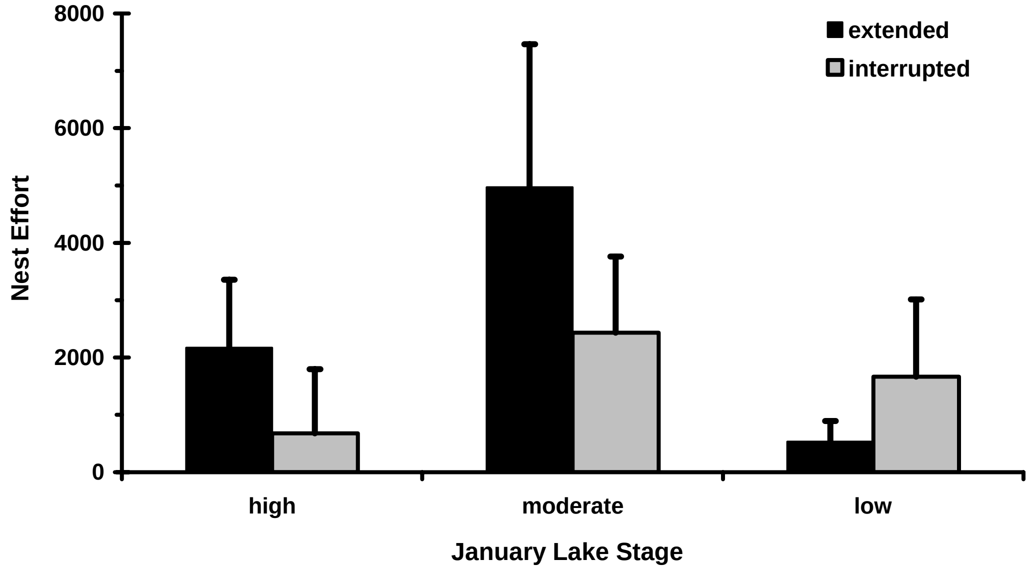

Figure 7. Contrasts of mean historical nest effort (1957–2007) among different hydrological conditions at Lake Okeechobee, FL. We compared years with extended and interrupted recessions among high, normal, and low January lake stages at the beginning of each nesting season. Means and 90%CIs were back transformed from analyses that used natural log transformed data to stabilize and homogenize variances. Extended recessions were continuous drops in water levels for at least 3 months from February to May. Interrupted recessions were breeding seasons characterized by recession reversals due to unseasonal rainfall when continuous recession never exceeded 2 months. Extreme high and low stages were outside the long term (1932–2007) interquartile range (4.14 < > 4.73 m NGVD29) for mean January lake stage.

DISCUSSION

2006 Nesting Season

As the result of an active 2005 storm season that included Hurricane Wilma in October, lake stages began the dry period extremely high. But a managed recession of Lake Okeechobee immediately following the storm season dropped lake levels from extremely high levels (5.22 m) in November back to normal levels (< 4.73 m) by January 2006. During heavy wet seasons, high lake levels will flood the littoral zone as water piles up against the Hoover Dike. Early in the season then, extensive inundation can engender low quality foraging habitat for wading birds due to deeper waters (> 30 cm) in freshwater marshes. Despite reduced foraging opportunities, the flooding process enhances marsh colonization and productivity among prey fishes and aquatic macroinvertebrates (Kushlan 1976b, Chick and McIvor 1994, Loftus and Eklund 1994, Smith et al. 1995, Johnson et al. 2007), which in turn increases the energetic potential of foraging patches that become exposed during the dry season recession (Smith 1995a, Smith and Collopy 1995, Smith et al. 1995).

Observations suggested that wading birds began concentrating foraging efforts on-lake once the average lake stage dropped below 4.7 m in March and water depths in the marsh became suitable (Marx and Gawlik 2006). Thereafter, a steady protracted recession with no major reversals in the receding water pattern provided good to fair foraging conditions for several months during the breeding season. The recession likely exposed new foraging patches regularly throughout the season and gave wading birds time to complete their nest cycle (Frederick and Collopy 1989a, Smith and Collopy 1995). Moreover, as water levels continued to fall, abundant prey communities that proliferated during the wet season were likely concentrated among isolated pools that lingered in longer hydroperiod areas of the littoral zone, similar to slough habitats in the Everglades (Kushlan 1976b, Smith et al. 1995).

We expect the favorable hydrological conditions increased Okeechobee's carrying capacity for wading birds, which led to high reproductive effort and success. The 2006 nesting season was a banner year in the Okeechobee region with nest effort and productivity reaching toward historical highs. We expect complete inundation of the littoral zone marshes increased the carrying capacity of the lake (1) by increasing the dispersion and productivity of prey communities, and (2) by increasing the available pool of potential of highly suitable foraging habitat (Fig. C-1). The extended recession acted to increase prey availability and to continually replenish the landscape with available foraging patches throughout the nesting season (Frederick and Collopy 1989a, Smith et al. 1995, Gawlik et al. 2004).

Powell and Powell (1986) suggested that reproductive success of wading birds and foraging habitat quality are positively correlated. Given the similarity of hydrological conditions among years with similarly high wading bird nest effort, data provided some guidance for the hydrologic conditions that might increase the quality of wading bird foraging habitats on-lake. This study supports the inference that wading birds can experience comparatively high reproductive success when extensive flooding of littoral zone marshes is followed by an extended recession, which in turn suggests these conditions provide quality foraging habitat (Powell 1987, Frederick and Collopy 1989a, Smith 1995a, Smith et al. 1995). Thus, we suggest that on-lake habitat quality for breeding wading birds at Okeechobee is optimized when extensive inundation of the littoral zone during the wet season is followed by an extended recession during the spring dry down. Analysis of the historical record corroborated our conclusion when data showed that nonextreme January lake stages followed by at least three months recession during the breeding season tended to maximize nest effort.

2007 Nesting Season

In January 2007, much of the littoral zone was waterless and remained dry throughout the nesting season, which negatively affected wading bird foraging habitat. In contrast, recession rates suggested that foraging conditions were good to fair throughout the breeding season (Fig. 3). Still, by the start of the year, only the edges of the littoral zone remained inundated, and habitats with suitable water depths were still connected to the pelagic zone where fish could disperse into lower densities (Chick and McIvor 1994). Lake Okeechobee is a shallow lake—shallow enough that plenty of suitable foraging habitat existed in 2007 if water levels and recession rates were considered in isolation. However, the interaction of hydrology with local floristic and microtopographic pattern is a fundamental mechanism for enhancing prey availability, and observations suggested that extensive hydrologic connectivity among available foraging patches and the lake's basin prevented recession mechanisms from concentrating prey into shallow isolated pools, possibly making prey less vulnerable to capture (Kushlan 1976a, Frederick and Collopy 1989a, Smith 1995a, Smith et al. 1995).

In complement, drought conditions also reduced the spatial extent of suitable habitats for foraging and nesting wading birds (Smith and Collopy 1995). On-lake foraging observations indicated that wading birds were limited to feeding in grass (e.g. *Panicum hemitomon* and *P. repens*) and bulrush (*Scirpus californicus*) beds along the margin of the littoral and nearshore zones to start the season. These beds completely dried down by May, leaving wading birds to forage in shallow, wide-open-water, nearshore and pelagic zones (Figs. 8, C-2). Additionally, nesting wading birds prefer woody islands, especially willow heads, surrounded by water for colony sites (Frederick and Collopy 1989b, Smith and Collopy 1995). By January 2007, however, lake levels were low enough that traditional colony sites in the littoral zone were waterless. Birds were left to nest in phragmites stands on spoils islands. Then, early in May as the drought continued, the lake bed surrounding the Clewiston Spit colony became completely exposed, which might have been one of the factors that contributed to abandonment.

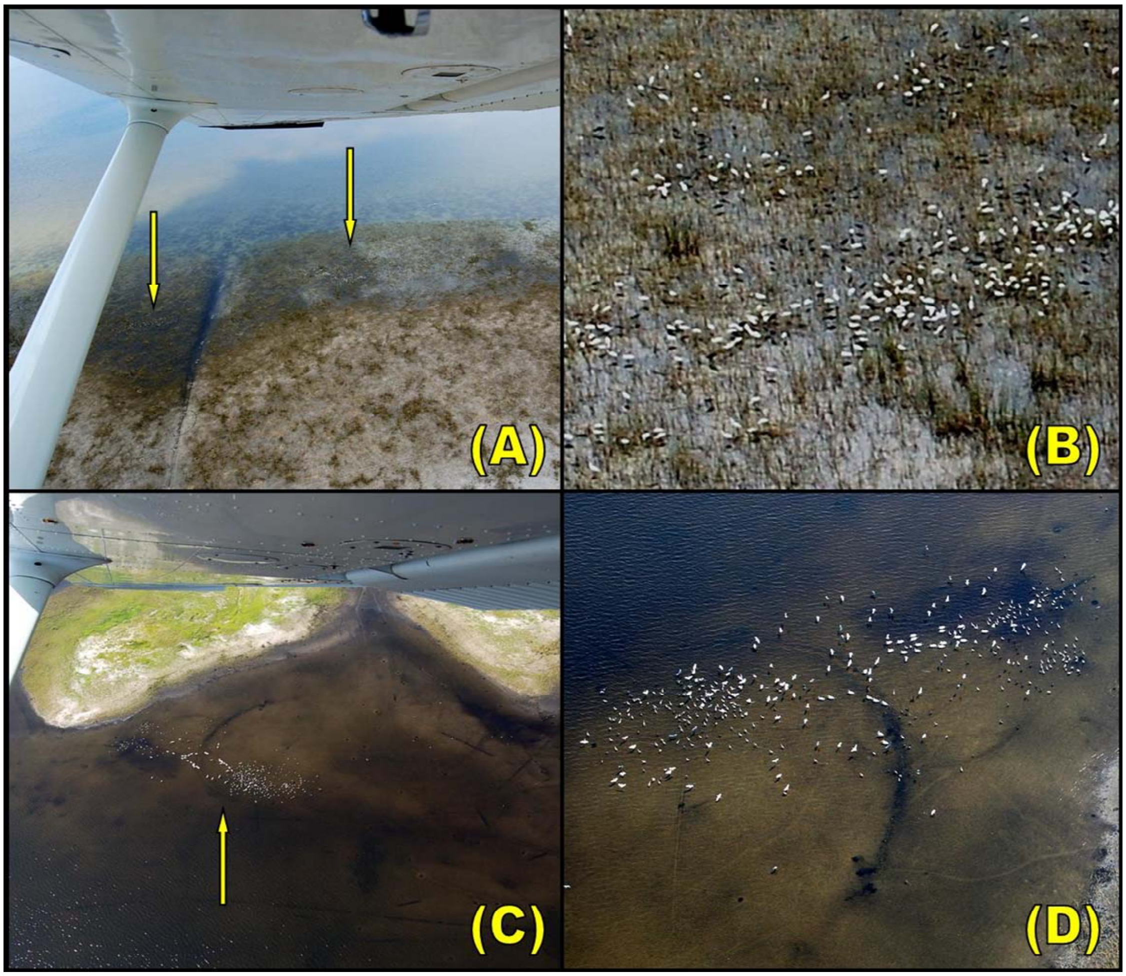

Figure 8. Landscape and zoomed views of foraging wading birds at Lake Okeechobee, FL during the 2007 nesting season. Figs. 4A & 4B depict wading birds foraging in grass beds along littoral zone fringes in February. Figs. 4C & 4D depict wading birds foraging in shallow, wide-open, nearshore areas in May. Notice both foraging areas were still hydrologically connected to the pelagic zone. Yellow arrows mark foraging flock locations in landscape views.

Hydrological conditions between 2007 and other correspondingly weak nesting years exhibited a similar pattern. For each of these years, drought precluded inundation of the littoral zone during preceding wet season months, low lake stages (≤ 4.14 m) prevailed to begin the year, and a steady recession brought lake stages below 3.35 m.

We observed a 93% reduction in nest effort from the 2006 to the 2007 breeding seasons and suspect that this year's poor reproductive effort was associated with drought conditions that persisted throughout the breeding season. Low lake stages associated with prolonged drought likely limited littoral zone prey production and foraging habitat availability for wading birds (Fig. C-2), which would combine to diminish the carrying capacity of Lake Okeechobee for colonially breeding wading birds (Smith et al. 1995). Poor reproductive success suggests that the hydrological conditions associated with droughts produce poor quality foraging habitat. Analysis of the historical nest record showed that when extreme low lake stages prevail to start the year, we can expect poor nest effort from wading birds in the Okeechobee region. Data also demonstrated that if recessions continue throughout the dry season with low starting stages, then wading bird nest effort will be lowest overall.

We should also note that low nest effort has also been linked to prolonged high lake stages. David (1994) reported that prolonged high water levels during the late 1970s and early 1980s coincided with declines in wading bird nest effort. And in 1984, the only other year with extreme low wading bird nest effort (< 1,000 nests), lake stages had remained high since August 1982, and breeding season hydrology was characterized by periodic reversals and increasing lake levels. Thus, extended periods of extreme lake stage, whether high or low, appear to have similarly negative impacts on wading bird populations (David 1994a, Smith et al. 1995, Frederick and Ogden 2001). Additional research into the effects of different hydrological scenarios on habitat availability and wading bird reproduction is on-going.

Management Implications

The importance of Lake Okeechobee to south Florida wading bird populations should not be underestimated. In 2006, if wading bird nest effort at Lake Okeechobee is included in system-wide estimates of nest effort, then Okeechobee colonies accounted for 17% of all nests in the GEW. Whether as a population source for wading birds that breed throughout the GEW, or as an important post-breeding dispersal stopover site for species of special management concern such as Roseate Spoonbills and Wood Storks, Lake Okeechobee continues to serve as a critical ecosystem component for wading birds that breed in the GEW (Zaffke 1984, David 1994a, Smith and Collopy 1995, Havens and Gawlik 2005).

From this study to-date, we can offer coarse-grained recommendations for Lake Okeechobee management strategies that will benefit wading birds. Analysis of the historical record supported Gawlik and Crozier's (2007) assertion that water levels may provide the cue that wading birds respond to when selecting foraging habitats while recession provides the mechanism driving prey availability and thereby quality of the foraging habitat once it has been selected by the individual. Wading birds apparently respond positively to moderate lake levels at the beginning of the year that fall within the long term interquartile range of lake stages for January (4.73 < > 4.14 m NGVD29). These conditions promote productivity of their prey base and maximize the spatial extent of potential foraging habitat during extended recessions (Smith et al. 1995). While seasonal dry downs concentrate prey communities and enhance their availability to wading birds during the breeding season when energetic demands are high. Thus, we also suggest that dry season recessions following inundation of the littoral zone are a necessary aspect of lake management to promote and sustain wading birds that breed at Lake Okeechobee.

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APPENDIX A

2005–2007 Colony Coordinates and Total Peak Nest Effort

Table A-1. Geographic coordinates (ddmmss, NAD83), species composition, and timing of peak nest effort for each colony detected during the 2005, 2006, and 2007 breeding seasons at Lake Okeechobee, FL.

Year	Colony name	Peak nesting month	Geographic Location		GBHE	GREG	SNEG	TRHE	LBHE	CAEG	WHIB	GLIB	WOST	Totals [1]
			Longitude	Latitude										
2005	Clewiston Spit [5]	n/a [2]	80° 54' 31"W	26° 46' 40"N	[3] 0	30	0	0	0	20	0	0	0	50
2005	Liberty Point [4]	n/a	81° 00' 53"W	26° 49' 25"N	0	85	0	5	0	20	0	0	0	110
2005	Moore Haven East 4 [4]	n/a	81° 02' 11"W	26° 52' 28"N	0	600	0	15	8	25	0	0	0	648
2005	Rock Islands [4]	n/a	81° 03' 15"W	26° 57' 45"N	0	655	0	2	0	300	0	0	0	957
2005	Indian Prairie North 1 [4]	n/a	80° 53' 06"W	27° 04' 46"N	0	90	0	0	0	740	0	0	0	830
2005	Indian Prairie North 2 [4]	n/a	80° 54' 04"W	27° 04' 32"N	0	20	0	6	1	0	0	0	0	27
2005	Eagle Bay Island North [5]	n/a	80° 50' 14"W	27° 10' 45"N	0	110	0	0	0	1200	0	0	0	1,310
2005	Chancy Bay [4]	n/a	80° 40' 15"W	27° 06' 29"N	0	0	0	0	0	700	0	0	0	700
2006	Chancy Bay [4]	MAY	80° 39' 58"W	27° 06' 14"N	3	0	0	0	2	220	0	0	0	225
2006	Clewiston [5]	FEB	80° 53' 29"W	26° 45' 48"N	5	0	0	0	0	0	0	0	0	5
2006	Clewiston Spit [5]	APR	80° 54' 33"W	26° 46' 33"N	2	220	0	1	0	0	0	0	0	223
2006	Eagle Bay Island North [5]	MAY	80° 50' 11"W	27° 11' 04"N	0	55	180	40	20	480	480	250	0	1,505
2006	Eagle Bay Island South [5]	MAR	80° 50' 47"W	27° 10' 14"N	12	80	0	0	0	0	0	0	0	92
2006	Indian Prairie North 1 [4]	FEB	80° 53' 53"W	27° 05' 11"N	6	0	0	0	0	0	0	0	0	6
2006	Indian Prairie North 2 [4]	MAR	80° 53' 10"W	27° 05' 05"N	1	95	0	0	0	0	0	0	0	96
2006	Indian Prairie North 3 [4]	MAR	80° 53' 04"W	27° 04' 55"N	3	68	0	0	0	0	0	0	0	71
2006	Indian Prairie South 1	APR	80° 57' 47"W	27° 01' 53"N	2	160	800	80	80	480	0	0	0	1,602
2006	Indian Prairie South 2	MAR	80° 58' 06"W	27° 01' 33"N	4	37	0	0	0	0	0	0	0	41
2006	Torry Island	FEB	80° 45' 58"W	26° 41' 51"N	7	0	0	0	0	0	0	0	0	7
2006	Ritta Island [5]	FEB	80° 48' 02"W	26° 43' 10"N	8	2	0	0	0	0	0	0	0	10
2006	Liberty Point [4]	MAY	81° 00' 38"W	26° 49' 32"N	0	260	550	2	12	0	150	100	0	1,074
2006	Moore Haven East 1 [4]	APR	81° 00' 25"W	26° 51' 44"N	4	170	0	0	0	0	0	0	0	174
2006	Moore Haven East 2 [4]	MAR	81° 00' 39"W	26° 51' 55"N	3	0	0	0	0	0	0	0	0	3

APPENDIX A

2005–2007 Colony Coordinates and Total Peak Nest Effort

Table A-1. Continued.

Year	Colony name	Peak nesting month	Geographic Location		GBHE	GREG	SNEG	TRHE	LBHE	CAEG	WHIB	GLIB	WOST	Totals [1]
			Longitude	Latitude										
2006	Moore Haven East 3 [4]	APR	81° 03' 08"W	26° 53' 02"N	0	300	200	2	20	0	150	5	0	677
2006	Moore Haven East 4 [4]	MAY	81° 02' 10"W	26° 52' 43"N	0	100	900	30	60	0	1,200	150	0	2,440
2006	Moore Haven East 5 [4]	MAR	81° 01' 06"W	26° 52' 17"N	2	46	0	0	0	0	0	0	0	48
2006	Moore Haven West 1 [4]	APR	81° 05' 18"W	26° 53' 53"N	4	300	850	30	18	20	5,000	40	0	6,262
2006	Moore Haven West 2 [4]	MAR	81° 05' 42"W	26° 53' 06"N	1	90	0	0	0	0	0	0	0	91
2006	Rock Islands 1 [4]	APR	81° 03' 04"W	26° 57' 48"N	1	70	130	2	1	50	0	0	0	254
2006	Rock Islands 2 [4]	APR	81° 02' 48"W	26° 58' 01"N	0	30	90	16	0	20	0	0	0	156
2006	Rock Islands 3 [4]	APR	81° 02' 57"W	26° 57' 54"N	0	0	0	0	0	35	0	0	0	35
2006	Rock Islands 4 [4]	MAY	81° 02' 12"W	26° 58' 20"N	0	0	0	0	0	140	0	0	0	140
2006	South Bay 1	MAR	80° 43' 30"W	26° 41' 37"N	2	0	0	0	0	0	0	0	0	2
2006	South Bay 2	MAY	80° 44' 05"W	26° 41' 23"N	1	26	0	0	1	0	0	0	0	28
2006	South Bay 3	MAY	80° 43' 41"W	26° 42' 33"N	0	8	0	0	0	40	0	0	0	48
2007	Clewiston Spit [5]	APR	80° 54' 27" W	26° 46' 36" N	0	0	485	115	0	0	0	35	0	635
2007	Bird Island [4]	JUN	81° 00' 31" W	26° 58' 20" N	0	0	0	0	0	350	0	0	0	350
2007	Gator Farm	MAY	81° 03' 39" W	27° 01' 22" N	0	7	25	37	14	340	0	0	12	435
2007	Clewiston Channel [5]	MAY	80° 53' 53" W	26° 46' 50" N	0	0	33	0	18	0	0	3	0	54
2007	Little Bear Beach	MAY	80° 50' 32" W	26° 43' 17" N	0	0	70	40	0	0	0	0	0	110
2007	Port Mayaca	JUN	80° 34' 28" W	27° 03' 17" N	3	0	m [6]	m	m	640	0	0	0	643

[1] Colony total included all species present.

[2] Not applicable, because only one survey was conducted during 2005 on June 3 at the end of the breeding season.

[3] Species undetected during survey effort.

[4] Reported in David 1994a and Smith and Collopy 1995.

[5] Reported in Smith and Collopy 1995.

[6] Missing data. Unable to finish counts due to proximity of colony to the Martin County Florida Power and Light power plant (m = missing value).

APPENDIX B

Species-specific Nest Histories

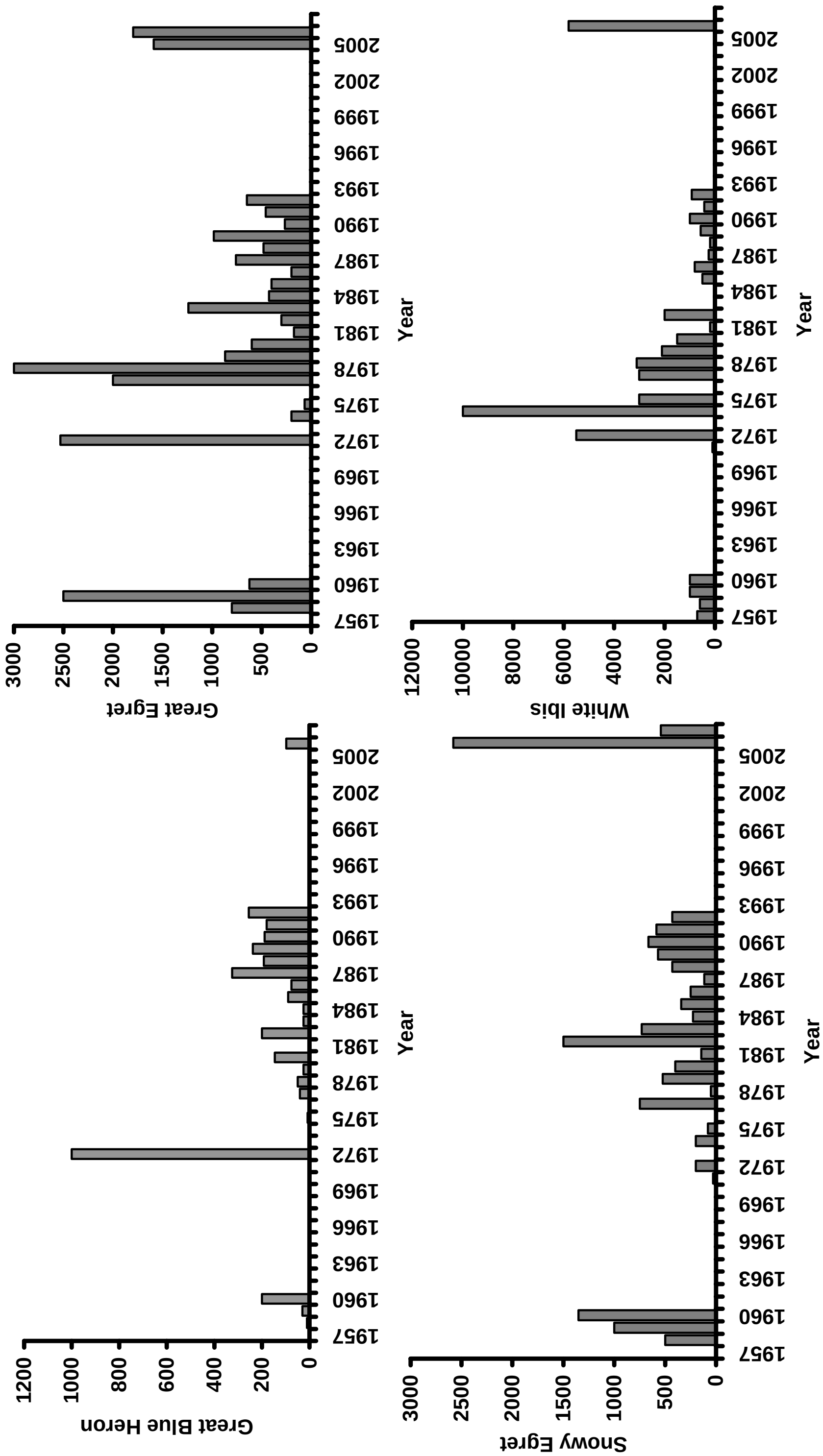

Figure B-1. Species-specific nest histories collated from David 1994a, Smith and Collopy 1995, and FAU's monitoring program. Only these 4 species were used because they were the only species common among all investigators during all years for which data existed. No data exists for 1961–1970, 1973, 1976, and 1993–2004.

APPENDIX C
Available Wading Bird Foraging Habitat

Maps represent a coarse-grained analysis of foraging habitat availability at different times during the breeding season for 2006 and 2007 at Lake Okeechobee, FL. The habitat suitability index (HSI) was a function of water levels similar to Gawlik et al. (2004). We interpolated lake surface elevation from mean daily lake stage reports provided via DBHYDRO and then subtracted lake surface elevation from bathymetry data provided by the SFWMD. The minimum mapping unit was Water depths of < -10 cm were assumed to dry ground and > 40 cm were too deep. If water depths were 0–10 cm, then HSI = 1.0; if between -10–0 cm or between10–20 cm, then HSI = 0.75; if between 20–30 cm, then HSI = 0.5; and if between 30–40 cm, then HSI = 0.25. We used 40 cm for the upper margin of suitable water depths, because wading bird behavior is highly plastic, and at Lake Okeechobee, researchers have noted that wading birds will use vegetation to stabilize themselves while they forage over deeper waters (Smith 1995a, b, Smith et al. 1995). See Figures C-1 and C-2 below.

APPENDIX C
Available Wading Bird Foraging Habitat

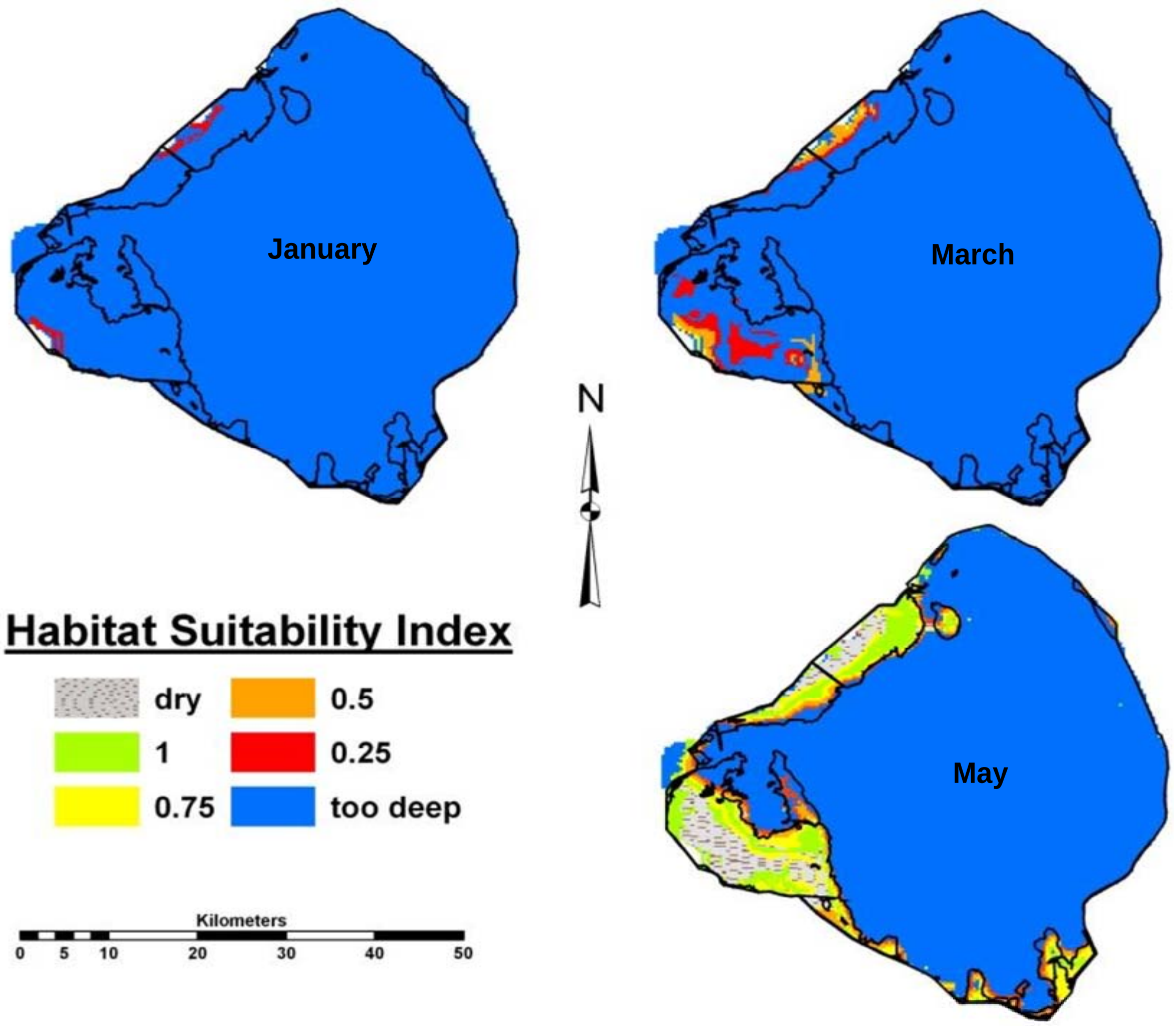

Figure C-1. Maps of available wading bird foraging habitat at Lake Okeechobee, FL during January, March, and May 2006. Suitability indices follow Gawlik et al. (2004) for water depth. Water depth was modeled from average lake stage and bathymetric data provided by the SFWMD.

APPENDIX C

Available Wading Bird Foraging Habitat

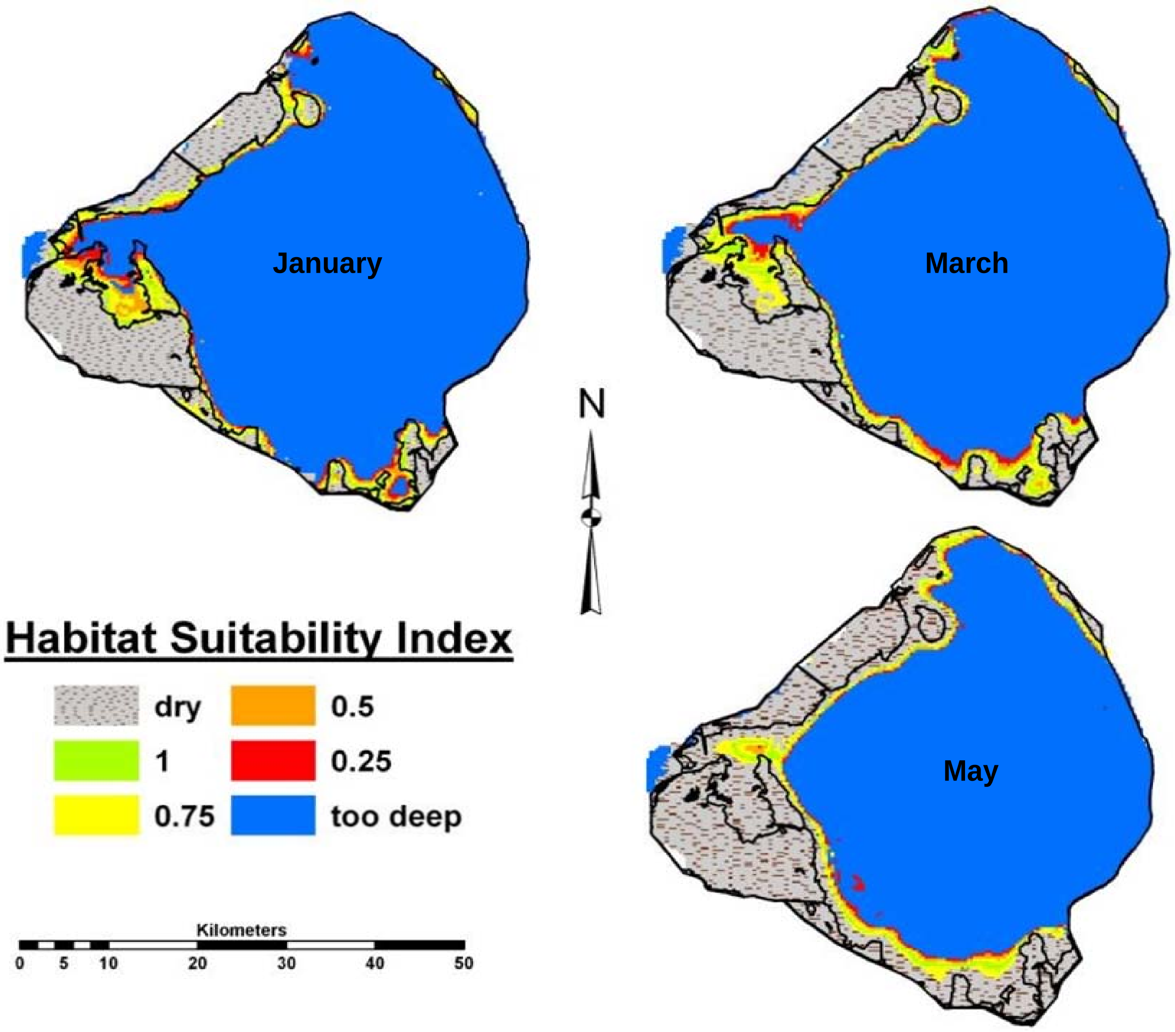

Figure C-2. Maps of available wading bird foraging habitat at Lake Okeechobee, FL during January, March, and May 2007. Suitability indices follow Gawlik et al. (2004) for water depth. Water depth was modeled from average lake stage and bathymetric data provided by the SFWMD.