# Wading Bird Colony Location, Size, and Timing in Lake Okeechobee 2023 Annual Report

**To**

**U.S. Army Engineer Research and Development Center**
**ERDC Contracting Office**
**3909 Halls Ferry Road**
**Vicksburg, Mississippi 39180-6199**

**Task Order No. W912HZ-19-2-0040**

**30 December 2023**


**Principal Investigator: Michelle Petersen**
**Research Assistant: Jennalie Lutes**
**Florida Atlantic University**

**Co-Principal Investigator: Dale E. Gawlik**
**Harte Research Institute for Gulf of Mexico Studies**

**Table of Contents**

**EXECUTIVE SUMMARY**

This document describes project activities 1 October 2022 to 30 September 2023 and summarizes data from the 2023 Lake Okeechobee wading bird breeding season. The project objectives are to document and monitor wading bird colony locations, size, and timing for 3 focal species, Snowy Egrets (SNEG, *Egretta thula*), Great Egrets (GREG, *Ardea alba*), and White Ibis (WHIB, *Eudocimus albus*), and monitor nesting success of Wood Stork (WOST, *Mycteria americana*) and Roseate Spoonbill (ROSP, *Platalea ajaja*).

We conducted monthly aerial surveys from 24 February to 7 June and detected 9 on-lake and 3 off-lake colonies. Peak nest abundance for focal species (GREG, SNEG, and WHIB) was 1,745 nests, which is 43.6% lower than average since 2008. GREG nest abundance was estimated to be roughly the same (<1% higher), while SNEG and WHIB nest abundance were 51% and 63% lower than the average since 2008.

We monitored the timing and survival of nests along paired transects at two spoil island nesting colonies (Little Bear Beach and Clewiston Spit) and one marsh colony (Moore Haven NW). Median estimated clutch initiation date was 24 March, 25 March, 18 March, 24 March for GREG, SNEG, TRHE, and WHIB, respectively. The median estimated clutch initiation date for GREG was the same as the average since 2009, 3 days later for SNEG, 12 days earlier for TRHE, and 21 days earlier for WHIB. Overall nest survival of GREG (1.0), small herons (0.36), and WHIB (0.37) were 33% higher, 45% lower, and 43% lower than the average since 2013, respectively.

Fifty-six WOST nests and 10 ROSP nests were detected at an off-lake colony (Gator Farm), 5 ROSP nests were detected at a spoil island colony (Clewiston Spit), and 2 ROSP nests were detected at a marsh colony (Moore Haven NW). This is the third year since 2015 that ROSP have been observed nesting in on-lake colonies. Six ROSP fledglings were observed at Gator Farm and 5 fledglings were observed Clewiston Spit during the 12 May flight. During the 7 June flight, we observed 4 ROSP fledglings at the Moore Haven NW colony. ROSP have nested at the Gator Farm in low numbers (4-20 nests) from 2016 to 2023 and successfully fledged chicks each year since 2018. We detected 14 WOST fledglings at Gator Farm in photos taken during the aerial survey on 7 June. WOST have nested and successfully fledged chicks at the Gator Farm in 12 of the last 15 years (2007-2010 and 2016-2023). Though nest abundance remains small, these species appear to be a regular part of the bird community at Lake Okeechobee.

Nesting occurred at twelve colonies in 2023. Eagle Bay ($n$ = 470), a marsh colony, and Little Bear Beach ($n$ = 434), a spoil island, supported the largest number of GREG, SNEG, and WHIB nests. Spoil island colonies supported the majority of nests in 2023 (42.7%), which is atypical of a wet year (average lake stage >14.1 ft), as the natural willow colonies are located in the marsh and surrounded by water,

decreasing predation risk and distance to suitable foraging habitat. This is likely due to the lake stage reversal event following heavy rains in mid-April.

## PROJECT MANAGEMENT OVERVIEW

***Progress accomplished during this period***

All field work for the 2023 breeding season was accomplished as stated in the work plan. We flew 5 aerial surveys (24 February, 24 March, 20 April, 12 May, and 7 June). Transects were established at 2 spoil island colonies (Little Bear Beach & Clewiston Spit) and one marsh colony (Moonshine Bay 4) which were monitored one to two times per week. We monitored the nests of 42 TRHE, 69 SNEG, 97 small herons (failed before eggs hatched), 4 GREG, 59 GLIB, 52 WHIB, 7 LBHE, 14 GLIB, and 8 ROSP.

***Anticipated needs or issues***

There are currently no unaddressed needs or issues.

***Funding status***

Cooperative Agreement executed November 11, 2020 extending funding through September 30, 2024.

***Employees working on this project for part of the year***

Dale Gawlik, Michelle Petersen, Jennalie Lutes, Katherine Christie, Rostam Mirzadi.

***Presentations***

Essian, D. A. and D. E. Gawlik. 2023. Summarizing prey use and selectivity by wading birds in four major wetland types in the Everglades. Greater Everglades Ecosystem Restoration Conference. April 2023.

***Publications in review or print***

Evans, J. D. and D. E. Gawlik. 2023. Productivity and nestling mortality for three species of herons at natural and anthropogenic islands. Waterbirds: 45, 371-382.

Larson, R.C. and D.E. Gawlik. 2023. Call rate as an index of nest count in wading bird colonies. IBIS: 165, 504-516.

## BACKGROUND

*Wading Birds as Performance Measures*

Large numbers of colonial wading birds were once a distinctive feature of south Florida wetlands. Anthropogenic changes to the natural hydrologic regime over the last hundred years have been extensive, altering suitable wading bird habitat at a landscape scale and resulting in nesting declines system-wide (Frederick et al., 2009). Restoring breeding wading bird populations to pre-drainage conditions is a primary objective of the Comprehensive Everglades Restoration Plan (CERP). The status of system-wide wading bird populations is assessed by examining four variables: numbers of nesting birds, locations of nesting colonies, timing of nesting, and frequency of supra-normal events. Wading birds are considered indicators of the overall health of the Greater Everglades ecosystem and provide performance measures by which to evaluate the CERP (RECOVER, 2006).

*Aerial Surveys at Lake Okeechobee*

The first aerial surveys conducted on wading bird colonies on Lake Okeechobee began in 1957 and proceeded inconsistently until 1976. Nest counts recorded during these annual surveys ranged from 130 nests in 1971 to 10,400 nests in 1974. These aerial surveys may have underestimated clutch initiations since they were only performed once during the nesting season which typically occurs from February to June. In 1977, aerial surveys shifted to systematic monthly-surveys to better assess the effects of water management on wading bird populations (David, 1994; Smith and Collopy, 1995). The four wading bird species historically surveyed were WHIB, GREG, Great Blue Heron (*Ardea herodias*), and SNEG. These species were surveyed annually to detect wading bird responses to water level changes on the Lake.

*Current Monitoring*

In May of 2005, Florida Atlantic University (FAU) began monitoring the timing, size, and location of wading bird colonies at Lake Okeechobee as part of the CERP Monitoring and Assessment Plan (MAP). On June 3, 2005, an aerial survey was conducted at the onset of the wet season as the Lake level began to rise. From 2006 to 2022, FAU conducted monthly aerial surveys of breeding wading birds to assess the performance measures outlined in MAP using standard MAP wading bird survey protocols. In addition to monthly aerial surveys, FAU monitored nest survival by visiting a subset of colonies weekly. On-the-ground surveys validated data collected during aerial surveys and determined nest survival. Aerial and ground surveys provided a measure of the ecological condition of the Lake for routine water management purposes.

## RESULTS AND DISCUSSION

*Hydrology*

Rainfall and lake stage data were obtained from the South Florida Water Management District (SFMWD) DBHYDRO database. The lake stage is calculated as the mean of four gauges in the pelagic zone of Lake Okeechobee (L001, L005, L006, and LZ40). All elevation data are presented in National Geodetic Vertical Datum 1929 (NGVD 1929) and locations are in North American Datum 1983 (NAD 1983). Stage data from 2008 represents the lake levels under the current Lake Okeechobee Regulation Schedule.

Water levels during the 2023 nesting season, 01 January to 30 June, were similar to the 2016 nesting season (mean lake stage was 14.99 ft in 2016 and 14.9 ft in 2023, respectively). Water conditions in 2023 were characterized by high lake stage, a moderate recession rate, and six reversals (0.03-in rise in stage per day from 05 February to 06 February, 0.03-in rise per day from 13 April to 17 April, 0.01-in rise per day from 24 April to 29 April, 0.03-in rise from 23 May to 28 May, 0.02-in rise from 01 June to 14 June, and 0.04-in rise from 17 June to 30 June) preceding the onset of the wet season beginning 23 May. (**Figure 1**). On 01 January, lake stage was at 16.38 ft. The lake receded at a mean rate of 0.01 in/wk from 01 January to 04 February before unseasonal rainfall caused the lake stage to increase from 15.93 ft on 04 February to of 15.98 ft on 06 February. The lake receded at a mean rate of 0.03 in/wk from 07 February to 12 April when rainfall caused the lake stage to increase from 14.20 ft on 12 April to 14.35 ft on 17 April. The lake receded at a rate of 0.01 in/wk from 18 April to 23 April, when rainfall caused the lake stage to increase from 14.27 ft on 23 April to 14.32 ft on 29 April. The lake receded at a rate of 0.03 in/wk from 30 April to 22 May, when rainfall caused the lake stage to increase from the seasonal low lake stage of 13.72 ft on 22 May to 13.90 ft on 28 May. After this, a few days of recession were followed by continuous increase in lake stage from 01 June to 30 June, indicating the arrival of the wet season.

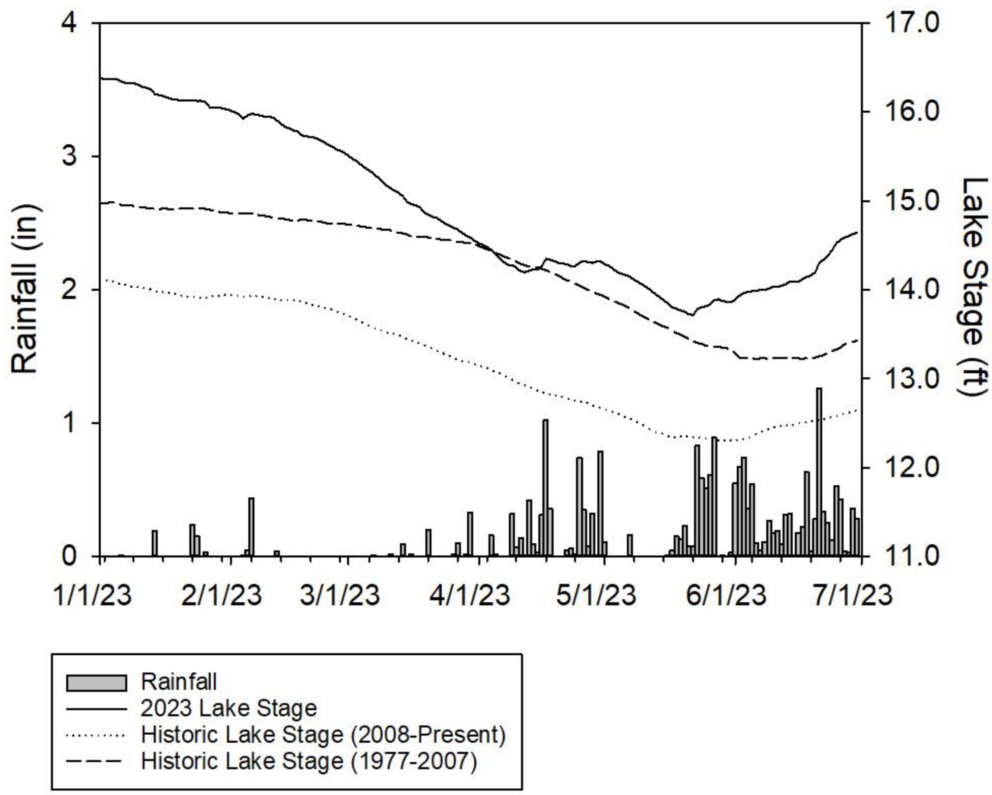


**Figure 1**. Hydrologic patterns on Lake Okeechobee from January to July 2023 and mean lake stage from 1977-2007 and Average Lake Stage since the implementation of the 2008 Lake Okeechobee Regulation Schedule (LORS08).

*Nesting and foraging conditions*

High lake stages at the beginning of 2023 were a result of above average rainfall during the 2022 wet season and, resulted in moderate habitat availability in January, February, and March, when the littoral zone was partially flooded. Habitat availability peaked on 07 April and decreased from 08 April to the start of the wet season on 22 May. Habitat availability on the lake peaks at a moderately high lake stage (14.3 ft), and sharply declines at higher and lower lake stages (**Figure A2**). Available habitat was estimated to be about 197 $km^2$. The proportion of the littoral zone available as foraging habitat on the Lake during the breeding season was about average (2023= 0.52; 2013-2023 S= 0.55; SE = 0.14).

*Colony locations*

Twelve colonies (**Figure 2**) supporting 1,745 GREG, SNEG, and WHIB nests were detected, which is 43.6% lower than the average from 2008-2023 (3,096 ± 1,901 SD). Colonies were detected at three created spoil islands (Little Bear Beach, Clewiston Spit, and Pahokee Airport), seven natural willow colony in the marsh (Eagle Bay Island, Clewiston Marsh, Moore Haven East 1, Moore Haven West 1 Moonshine Bay 1, Moonshine Bay 3, and Moonshine Bay 4), and three off-lake, created islands (Lakeport Marina, Gator Farm, Gun Range). Eagle Bay was the largest colony, supporting 470 GREG, SNEG, and WHIB nests (**Table 1**).

During wet years, like 2023, wading birds nest in short-hydroperiod colonies more frequently than dry years, because colonies are surrounded by water, making them inaccessible to mammalian predators and decreasing the travel-distance to suitable foraging habitat in the marsh. Willow ridge colonies that are surrounded by long-hydroperiod marsh, such as Eagle Bay, are an exception because they remain inundated and are closer to suitable foraging habitat at the western edge of the littoral zone during dry years.

Colonies built on created spoil islands and off-lake colonies are typically active every year, likely because high water levels are rarely sustained long enough to destroy nest substrate. Spoil island colonies have supported 27% of on-lake nests in dry years (mean lake stage <12.9 ft), 29% in moderate years (13.0 –14.0 ft), and 22% in wet years (>14.1 ft) since 2008. Variation in nest abundance in 2023 is slightly higher in spoil island colonies (coefficient of variation at spoil island colonies = 79%) than marsh colonies (2008-2023) mean coefficient of variation at natural colonies = 78%), which is abnormal because the small size of created colonies limits total nest numbers, usually resulting in lower annual productivity in spoil island colonies (Chastant et al. 2017). Nevertheless, spoil island colonies continue to be an important contributor to the Lake's wading bird numbers, providing the only suitable nesting substrate during some years.

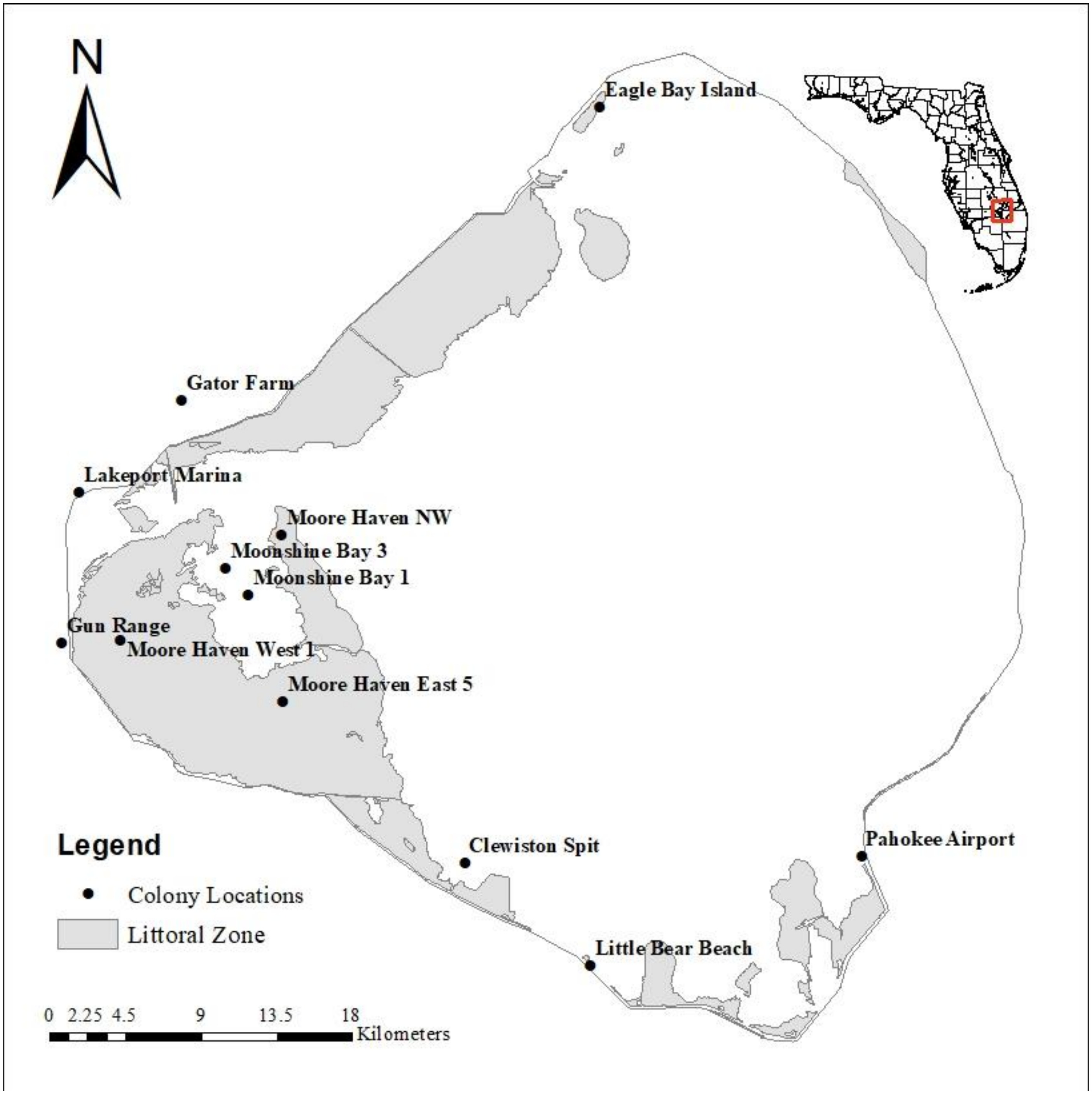


**Figure 2.** Map of wading bird colonies detected on Lake Okeechobee from February through June 2023.

**Table 1.** Geographic coordinates (NAD 83) and species-specific peak nest abundances in detected colonies during the 2023 breeding season at Lake Okeechobee.

| **Colony** | **Peak Month**[1,2] | **Latitude** | **Longitude** | **GREG** | **WHIB** | **SNEG** | **WOST** | **ROSP** | **GBHE** | **LBHE** | **TRHE** | **GLIB** | **CAEG** | **ANHI** | **Total**[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clewiston Spit | FEB | 26.77573 | -80.90938 | 178 | 13 | 105 | -- | 5 | 3 | 8 | 99 | 26 | 2 | -- | **437** |
| Eagle Bay Island | MAR | 27.179183 | -80.837133 | 25 | 204 | 241 | -- | -- | 1 | 48 | 144 | 102 | 228 | 10 | **765** |
| Gator Farm | FEB | 27.022778 | -81.060833 | 109 | 26 | 37 | 58 | 10 | 1 | 10 | 8 | 15 | 292 | 12 | **274** |
| Gun Range | MAR | 26.893252 | -81.124557 | 23 | -- | -- | -- | -- | 1 | -- | -- | -- | 129 | 29 | **24** |
| Lakeport Marina | MAR | 26.97336 | -81.11562 | 134 | -- | 78 | -- | -- | -- | -- | 13 | -- | 410 | 8 | **225** |
| Little Bear Beach | APR | 26.721389 | -80.842222 | 99 | 178 | 157 | -- | -- | 1 | 18 | 64 | 41 | 13 | -- | **558** |
| Moonshine Bay 1 | APR | 26.91327 | -81.02416 | 2 | -- | -- | -- | -- | 5 | -- | -- | -- | -- | -- | **7** |
| Moonshine Bay 3 | APR | 26.92755 | -81.03479 | 2 | -- | -- | -- | -- | 2 | -- | -- | -- | -- | -- | **4** |
| Moore Haven NW | MAR | 26.9511 | -81.00739 | 130 | 2 | 111 | -- | 2 | 7 | 25 | 99 | 2 | 24 | 8 | **378** |
| Moore Haven West 1 | APR | 26.898056 | -81.088333 | 22 | -- | 18 | -- | -- | -- | -- | -- | -- | -- | -- | **40** |
| Moore Haven East 5 | MAR | 26.86221 | -81.006862 | 109 | -- | 12 | -- | -- | 2 | -- | -- | -- | -- | 5 | **123** |
| Pahokee Airport | MAR | 26.77908 | -80.6976 | 18 | 74 | 136 | -- | -- | -- | 58 | 116 | 12 | 111 | 2 | **414** |

[1]**CAEG and ANHI were excluded from totals since they are not wetland wading birds.**

[2]**Peak month refers to the month during which combined nest effort peaked and does not refer to species-specific peak nest efforts.**

*Nest abundance*

To avoid double counting birds as a result of colony turnover, we used peak monthly nest abundance to estimate the total number of nests in 2023. Peak nest abundance was 703, 637, and 405 for GREG, SNEG, and WHIB respectively (1,745 nests; **Table 2**). This was 43.6% lower than the average since 2008, when the current lake schedule went into effect (3,096 ± 1,902; all averages use SD). GREG nest abundance was 0.86% higher, while SNEG and WHIB nest abundance were 52% and 65% lower than the average since 2008, respectively (697 ± 460 GREG; 1,336 ± 1,041 SNEG; 1,153 ± 849 WHIB).

Mean nest abundance of the three focal species on the Lake was higher from 2008-2023 (3,096 ± 1,902) than from 1977-1992 (2,704 ± 2,136; **Figure 3**). SNEG nest abundance increased since 2007, compared to 1977-1992 ($P < 0.002$), while GREG and WHIB nest abundances remained relatively unchanged ($P > 0.35$). A continuing trend identified in this study is the importance of Lake Okeechobee in supporting nesting SNEG, relative to the other nesting regions in South Florida. From 2009 – 2021, the Lake has supported approximately 48%% of SNEG nesting in the Greater Everglades, suggesting that Lake Okeechobee provides critical habitat for SNEG nesting in South Florida.

**Table 2.** Timing and nest numbers for species breeding in wading bird colonies at Lake Okeechobee in 2023.

| Month | GREG | WHIB | SNEG | WOST | ROSP | GBHE | LBHE | TRHE | GLIB | CAEG | AHNI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| February | 500 | 6 | 306 | **58** | 0 | 5 | 0 | 166 | 0 | 0 | **12** |
| March | **703** | 85 | 576 | 56 | 14 | **14** | **126** | **525** | 47 | 0 | 52 |
| April | 266 | 300 | **637** | 46 | **16** | 10 | 59 | 256 | **144** | 516 | 55 |
| May | 155 | 350 | 394 | 33 | 4 | 3 | 40 | 250 | 109 | 921 | 32 |
| June | 37 | **405** | 198 | 23 | 0 | 1 | 43 | 183 | 110 | **1433** | 10 |

Note: Bold Values denote peak nest effort for species.

*Timing*

The median clutch initiation date for GREG (15 March ± 4.24 days) was the same as the average since 2009 (15 March). Median clutch initiation date for SNEG (24 March ± 21.7 days) was three days later than the average since 2009 (21 March) and median clutch initiation for TRHE (13 March ± 19.1 days) was twelve days earlier (25 March) than the average since 2009. Median clutch initiation date for WHIB (27 April ± 24.2 days) was nineteen days later than the average since 2009 (6 April). Peak nest numbers were observed in March, April, March, and June for GREG, SNEG, TRHE and WHIB (**Table 2**).

Nest initiations for SNEG, TRHE, and WHIB peaked between 09 March and 07 April, which coincides with the first prolonged water recession (**Figure 1**). Due to the small sample size of GREG nests ( n = 4) each with varying estimated clutch initiation dates, a peak nest initiation could not be calculated. There has been no apparent relationship observed between the timing of nest initiations and overall nest survival of focal species, but the temporal pattern of nest initiation by species is consistent with previous years at the Lake and in other regions, with GREG initiating nests earlier than small herons (Ogden 1994, Smith and Collopy 1995, Klassen et al. 2016).

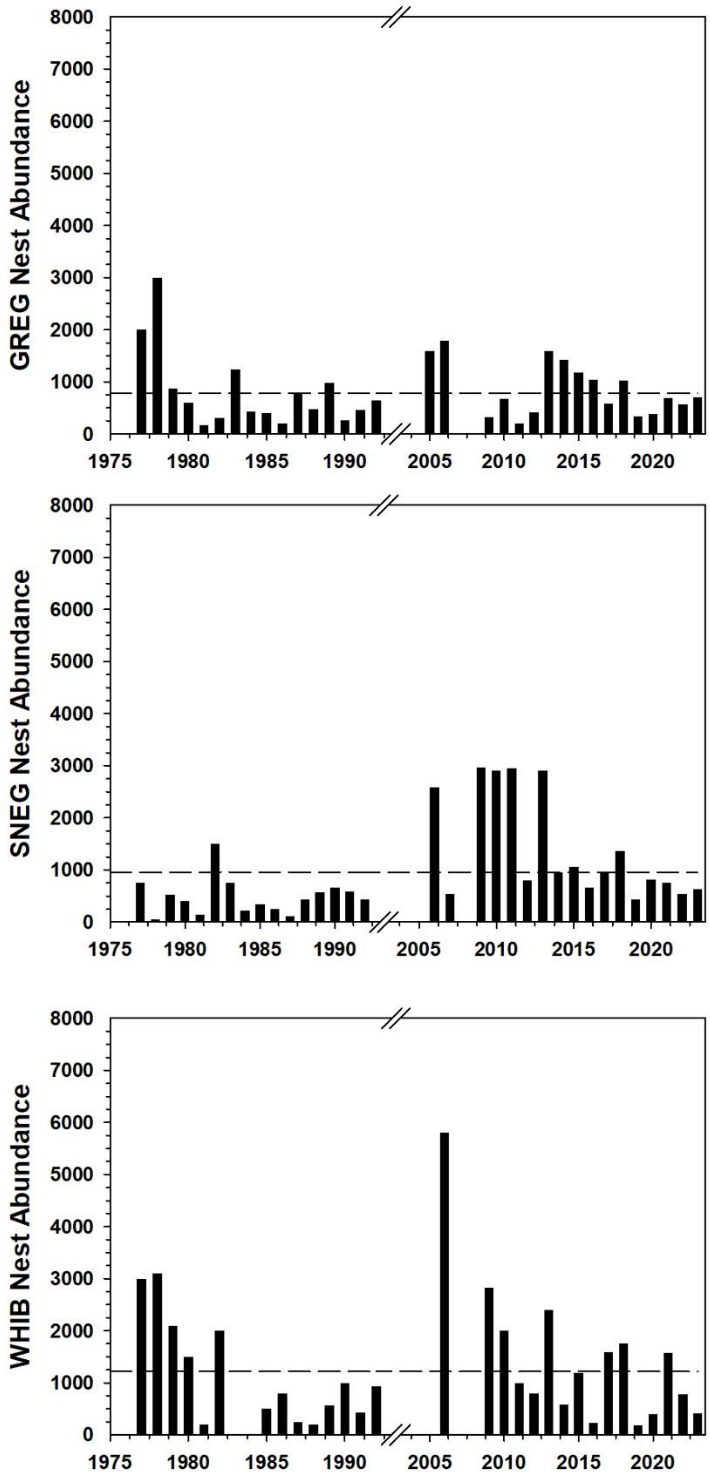


**Figure 3.** Estimates of nest abundance from Lake Okeechobee aerial surveys during the 1977-1992, 2006-2007, and 2009-2023 nesting seasons. Mean nest abundance is represented by the horizontal line.

*WOST and ROSP abundance*

Fifty-eight WOST nests and 10 ROSP nests were detected at Gator Farm, an off-lake colony located north of the Fisheating Bay area (**Figure 2**). Five ROSP nests were also detected at Clewiston Spit and 2 ROSP nests were detected at Moonshine Bay. This is the second time since 2015 that ROSP have been observed nesting in on-lake colonies, and nests at Clewiston Spit and Moonshine Bay were successful. From the detected nests, we counted 14 WOST fledglings in photos taken during the aerial survey on 7 June and 11 ROSP fledglings in photos taken during the aerial survey on 12 May. WOST have nested at the Gator Farm in 12 of the last 17 years (2007-2010 and 2016-2023) and have successfully fledged chicks every year nesting has occurred. ROSP have nested at natural and anthropogenic colonies since 2009 and every consecutive year since 2015 (Table 3).

The pattern of the presence and absence of WOST nesting on the Lake hints at a connection with the Everglades, as the year that WOST began nesting on the Lake (2007) and the year that they returned to nest after a five-year absence (2016) were both years of very low WOST nesting in the Everglades. WOST continued nesting at the Lake until 2010, when they experienced poor success due to a lack of seasonal water level recession, followed by suboptimal dry hydrologic conditions the subsequent year (Tsai et. al 2016). This pattern suggests that the Lake may provide alternate nesting habitat for some WOST when conditions are poor in the Everglades.

**Table 3.** Total abundance of ROSP nests detected in natural and anthropogenic colonies since 2009.

| Colony Type | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Natural | 3 | -- | -- | -- | 2 | -- | -- | -- | 5 | -- | -- | -- | 1 | 5 | 2 |
| Anthropogenic* | -- | -- | -- | 1 | -- | -- | 3 | 4 | 7 | 6 | 20 | 51 | 3 | 17 | 15 |

*Anthropogenic includes created spoil islands as well as off-lake colonies such as the Gator Farm.

*Nest survival*

We estimated nest survival (proportion of nests that fledge at least one nestling) using logistic exposure models to account for biases resulting from variation in the initial nest ages at monitored nests (Shaffer, 2004). Generalized linear models were fitted with a loglink distribution function. The model estimates daily survival rate (DSR), which can be converted to overall survival rate ($DSR^{interval\ length}$). We developed separate models for the incubation and nestling periods because there were clear differences in nest survival rates between the two. Interval lengths were 21 days during the incubation period for small herons and 26 days for GREG (Parsons and Master, 2000; McCrimmon et al., 2011) during the nestling period interval lengths were 14 days for all species. Nest survival for GREG in 2023 was 1.0 (*n* = 4), which is 33% higher than the overall survival since 2013 (0.65 ± 0.14; *n* = 566). Nest survival for small herons in 2023 was 0.36 (incubating small heron, *n* = 226; fledgling TRHE, *n* = 52; and fledgling SNEG, *n* = 73, which is 45% lower than the overall survival rate since 2013 (0.66 ± 0.13; *n* = 3,301). Nest survival for WHIB in 2023 was 0.37 (*n* = 52), which is 43% lower than the overall nest survival since 2013 (0.65 ± 0.16; *n* = 581).

Since 2013 GREG survival rates ranged between 0.10 in 2019 and 1.0 in 2023 (Essian et al. 2019). However, high apparent survival rates in 2023 may not be representative of survival rates at the lake because a very small number of GREG nests (n = 4) were monitored at two colonies (Clewiston Spit and Little Bear Beach). Nest models have predicted that GREG nest survival decreases at low lake stages (<13 ft) and increases at moderate to high lake stages (13.5-15 ft) (Essian et al. 2019). The increase in GREG nest survival at moderate to high lake stages may be partially responsible for the increased GREG survival during 2023. The incidental small sample size may also have an effect.

Since 2013, small heron nest survival rates ranged between 0.54 in 2015 and 0.83 in 2019. Small heron survival in 2023 (37%) has been the lowest recorded thus far, likely due to the moderate recession rates and high rate of unseasonal precipitation and reversals beginning in mid-April. Small heron nest survival has been correlated to the hydrological regime of the current year (Essian et al. 2019), with higher survival rates observed during years with high recession rates and available foraging habitat.

WHIB nest survival rates have varied over the last ten years. Since 2013, WHIB survival rates ranged from 0.37 (2023) to 0.76 (2021), with 2023 being the lowest recorded survival rate. Poor nest success in 2023 could be a result of low prey availability due to average and high-water levels in 2021 and 2022 (respectively) as drought tends to promote prey availability in the Everglades (Frederick and Ogden 2001); however, Essian et al. (2019) found a weak relationship between days dry in the previous two water years and prey densities within the foraging ranges of wading birds (F = 2.87, R2 = 0.03, p = 0.09). Low nest success in 2023 is likely related to the high precipitation event at the beginning of April (total precipitation between April 9-17 = 3.83 in). Wading birds in the Everglades are known to abandon nests following a rainfall event receiving at least 1 in of rain (Frederick and Callopy 1989).

## CONCLUSION

Above average lake stages in January preceded by a moderate drydown, resulted in relatively wet conditions in the littoral zone during the 2023 breeding season. GREG, SNEG, and WHIB initiated an estimated 1,745 nests, which is 43.6% lower than average since 2008. The recession rate of the lake during the 2023 breeding season was moderate throughout the breeding season, resulting in less available foraging habitat at the beginning of the breeding season, and a reduced capacity to concentrate prey later in the breeding season. However, nest abundances of the focal species have been higher under the current lake management schedule (2008–2023) compared to the previous period (1977–1992), supporting management of lake stages at moderate levels.

**ACKNOWLEDGMENTS**

Funding for the nest monitoring was provided by the U.S. Army Engineer Research and Development Center and Florida Atlantic University. We appreciate the support from our technicians for their help with field work. We also benefited from discussions with Mike Baranski at the South Florida Water Management District.

**LITERATURE CITED**

Beerens, J.M., Noonburg, E.G., Gawlik, D.E., 2015. Linking Dynamic Habitat Selection with Wading Bird Foraging Distributions across Resource Gradients. PLOS ONE 10, e0128182.

Chastant, J.E., M.L. Petersen, and D.E. Gawlik. 2017. Nesting substrate and water-level fluctuations influence wading bird nesting patterns in a large shallow eutrophic lake. Hydrobiologia 788:371-383.

David, P.G., 1994. Wading Bird Nesting at Lake Okeechobee, Florida: An Historic Perspective. Colon. Waterbirds 17, 69.

Frederick, P., Gawlik, D.E., Ogden, J.C., Cook, M.I., Lusk, M., 2009. The White Ibis and Wood Stork as indicators for restoration of the everglades ecosystem. Ecol. Indic. 9, S83–S95.

Frederick, P. C. and M. W. Collopy. 1989a. Nesting success of five species of wading birds (Ciconiiformes) in relation to water conditions in the Florida Everglades. Auk 106: 625-63

Herring, G., Gawlik, D.E., Cook, M.I., Beerens, J.M., 2010. Sensitivity of Nesting Great Egrets (*Ardea alba* ) and White Ibises (*Eudocimus albus*) to Reduced Prey Availability. The Auk 127, 660–670.

Klassen, J.A., Gawlik, D.E., Frederick, P.C., 2016. Linking wading bird prey selection to number of nests. J. Wildl. Manag. 80, 1450–1460.

Loftus WF, Eklund AM. Long term dynamics of an Everglades small fish assemblage. In: Davis SM, Ogden JC, editors. Everglades The Ecosystem and its Restoration. St. Lucie Press; 1994. pp. 461–483.

Ogden, J.C. 1994. A comparison of wading bird nesting colony dynamics (1931–1946 and 1974–1989) as an indication of ecosystem conditions in the southern Everglades. Pages 533–570 in S. M. Davis and J. C. Ogden, editors. Everglades: the ecosystem and its restoration. St. Lucie Press, Delray Beach, Florida, USA

RECOVER. 2006. CERP Monitoring and Assessment Plan: Part 2 - Assessment Strategy for the MAP. Restoration Coordination and Verification Program, c/o United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

Smith, J.P., Collopy, M.W., 1995. Colony turnover, nest success and productivity, and causes of nest failure among wading birds (Ciconiiformes) at Lake Okeechobee, Florida (1989-1992). Arch. Batefur Hydrobiol. Adv. Limnol. 45, 287–316.

Smith, J.P., Richardson, J.R., and Collopy, M.W., 1995. Foraging habitat selection among wading birds (Ciconiiformes) at Lake Okeechobee, Florida, in relation to hydrology and vegetative cover.

Arch. Batefur Hydrobiol. Adv. Limnol. 45, 247-285.

Tsai, JS., Reichert, B.E., Frederick, P.C. et al. Breeding Site Longevity and Site Characteristics Have Intrinsic Value for Predicting Persistence of Colonies of an Endangered Bird. Wetlands 36, 639–647 (2016). https://doi.org/10.1007/s13157-016-0774-3

**APPENDIX I.**

**METHODS**

*Nest abundance estimates*

From February through June 2021, FAU personnel monitored the location, timing, and number of clutch initiations in wading bird nesting colonies on the Lake. Systematic aerial surveys were conducted in a fixed-wing aircraft flying at an altitude of 244 m and an average speed of 115 mph. 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 (**Figure A1**). A small alligator farm northwest of the Lake by County Road 721 was also included in the survey route since the site was known to have previously supported nesting WOST.

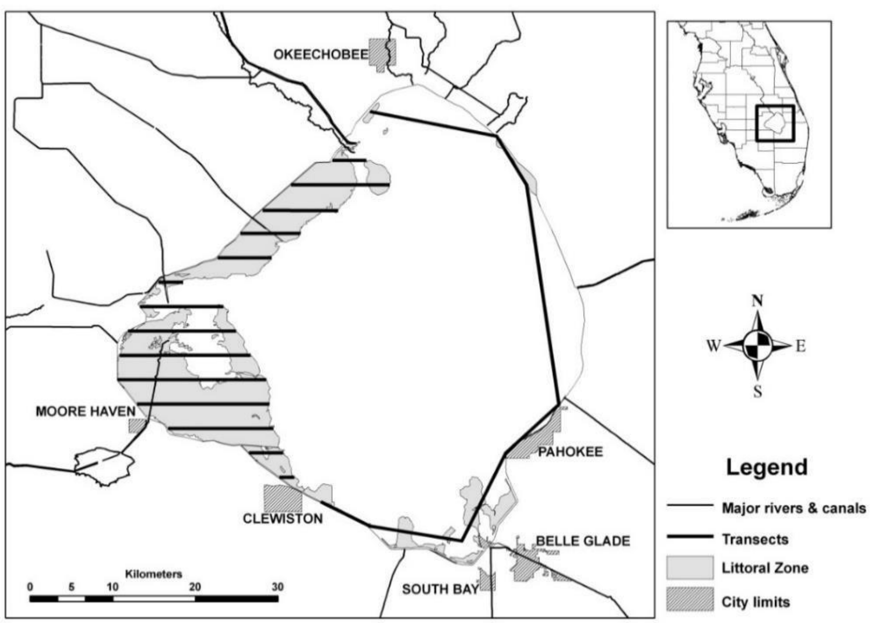


**Figure A1.** Map of systematic aerial transects flown over Lake Okeechobee during the 2021 wading bird breeding season.

Two dedicated observers surveyed for nests of focal species (SNEG, GREG, and WHIB) along aerial transects. As small, dark-colored wading birds are exceedingly difficult to detect from aircraft, aerial monitoring protocols target white wading birds. Colonies were defined as any assemblage of ≥ 2 nests that were separated by ≥200 m (Smith and Collopy 1995). Once a colony was detected, the aircraft circled down to an altitude of 400 ft to allow observers to estimate the number of nests for each species present in the colony. Total clutch initiations for focal species were recorded, as well as photographs and geographic coordinates of the colony. Ground surveys were performed by airboat to verify colony counts and species composition estimates. Distances between colonies were calculated using ArcGIS.

Ground surveys were performed by foot at three colonies to validate aerial survey counts, determine nest survival, and count small, dark-colored wading birds. At three colonies (Little Bear Beach, Clewiston Spit, and Bird Island) two 50-m transects were established so that they were situated 30-m apart and ran parallel to each other. Random transects were established by selecting a random bearing and distance (0-50 m) from a random entry point. Transects were established approximately parallel to each other so researchers could return to the entry point via the second transect and minimize colony disturbance. The three monitored colonies were spoil islands, which are generally narrow (<30 m wide) strips of land with patchily distributed nest substrate. Therefore, the position of randomly established transects were adjusted so they did not extend past the edges of islands or run entirely through unsuitable nesting habitat (unvegetated patches). At each colony, researchers walked transects and marked new nests within a 5-ft buffer along each transect with flagging tape and assigned an identification number. If sample size was small, we would mark nests outside of the 5-ft buffer and label it "off-transect". Species, clutch size, nest stage, and nest fate were recorded for each nest.

*Timing*

Timing of nesting by WOST is already a CERP indicator of restoration success in the Everglades (Frederick et al., 2009). Timing may also be important for other species of wading birds, since wading birds are generally sensitive to reversals (Beerens et al., 2015; Herring et al., 2010; Smith and Collopy, 1995), and reversals are stronger and occur more frequently in last half of the dry season. In historical reports, timing of clutch initiations was reported as the date of first nest detection for each species. Peak number of active nests were reported at a monthly scale, as seen in the South Florida Wading Bird Reports, or they were reported graphically at a biweekly scale (e.g. Smith and Collopy 1995). These methods of reporting the timing of wading bird nesting are coarse and difficult to interpret. Since 2011, nest monitoring has been conducted on the ground, which allows better estimates of individual clutch initiation dates.

The hatch date of each chick was directly observed (e.g. chicks pipping) or estimated based on the estimated age of the oldest chick in each clutch. Clutch initiation date was estimated by subtracting number of days in an average incubation period (26 days for GREGs, and 21 days for small herons) from the estimated hatch date. Median clutch initiation dates were calculated for each species

*Nesting and Foraging Conditions*

Proportion of ArcGIS raster cells (100 x 100ft) in the littoral zone available to foraging by wading birds (<1 ft depth, non-woody vegetation) is estimated using vegetation mapping, LIDAR depth estimates, and lake stage estimates from the South Florida Water Management District (SFMWD) DBHYDRO database.

We obtained spatial data of Lake Okeechobee littoral vegetation classes from the South Florida Water Management District, and excluded woody and dense herbaceous vegetation classes, which wading birds do not typically use as foraging habitat (Smith et al. 1995).

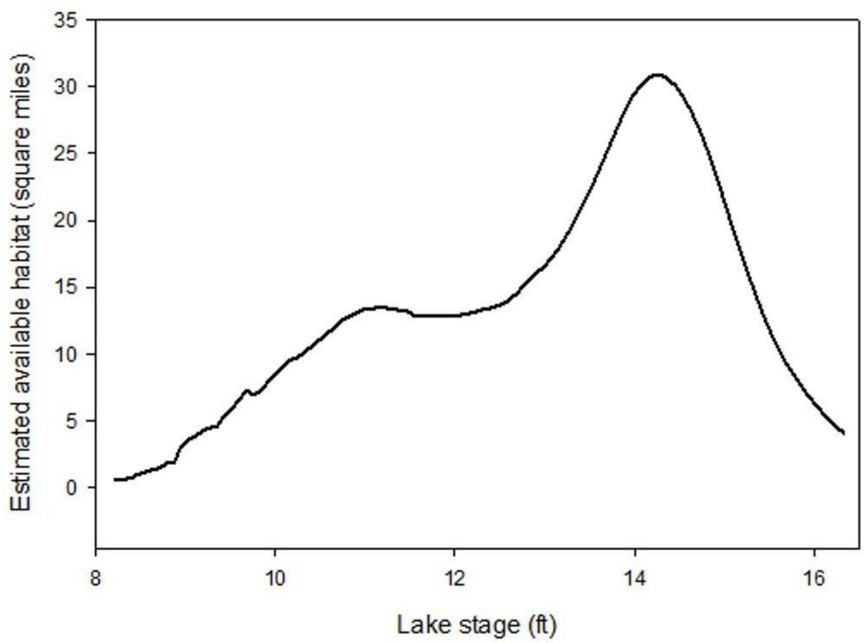


**Figure A2.** Habitat suitability curve for Lake Okeechobee. Habitat availability was estimated based on vegetation mapping last updated in 2012 and LIDAR depth estimates last updated in 2011.