Wading Bird Colony Location, Size, and Timing in Lake Okeechobee

2021 Annual Report

To

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Principal Investigator: Michelle Petersen
Florida Atlantic University

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

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EXECUTIVE SUMMARY

This document describes project activities 1 October 2020 to 30 September 2021 and summarizes data from the 2021 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 18 February to 17 June and detected 5 on-lake and 2 off-lake colonies. Peak nest abundance for focal species (GREG, SNEG, and WHIB) was 3,024 nests, which is 9% lower than average since 2008. GREG and SNEG nest abundance were 12% and 11% lower than the average since 2008, whereas WHIB were 4% higher, respectively.

We monitored the timing and survival of nests along paired transects at four nesting colonies (Little Bear Beach, Clewiston Spit, Eagle Bay Island, and Moonshine Bay). Median estimated clutch initiation date was 7 March, 28 March, 29 March, 8 May for GREG, SNEG, TRHE, and WHIB, respectively. The median estimated clutch initiation date for GREG was 7 days earlier than the average since 2009, 1 day earlier for SNEG, 10 days earlier for TRHE, and 9 days earlier of WHIB. Overall nest survival of GREG (0.86), small herons (0.76), and WHIB (0.76) were 16%, 1%, and 14% higher than the average since 2011, respectively.

Forty WOST nests and 21 ROSP nests were detected at an off-lake colony (Gator Farm), 3 ROSP nests were detected at a spoil island colony (Clewiston Spit), and 1 ROSP nest was detected at a marsh colony (Moonshine Bay). This is the first time since 2015 that ROSP have been observed nesting on on-lake colonies. We detected 41 WOST fledglings in photos taken during the aerial survey on 17 May, and 24 ROSP fledglings in photos taken during the aerial survey on 17 June. WOST have nested and successfully fledged chicks at the Gator Farm in 9 of the last 14 years (2007-2010 and 2016-2021). ROSP have nested at the Gator Farm in low numbers (4-20 nests) from 2016 to 2021 and successfully fledged chicks each year since 2018. Though nest abundance remains small, these species appear to be a regular part of the bird community at Lake Okeechobee.

Nesting occurred at ten colonies in 2021. Moonshine Bay (n = 1,114), a Marsh colony, and Pahokee Airport (n = 425), a spoil island, supported the largest number of GREG, SNEG, and WHIB nests. Marsh colonies supported the majority of nests in 2021 (61%), which is typical of a wet year (average lake stage >14.1 ft), because the majority of the natural willow colonies are located in the marsh and surrounded by water, decreasing predation risk and distance to suitable foraging habitat.

PROJECT MANAGEMENT OVERVIEW

Progress accomplished during this period

All field work for the 2021 breeding season was accomplished as stated in the work plan. We flew 5 aerial surveys (20 February, 20 March, 17 April, 17 May, and 17 June). Transects were established at 4 breeding colonies (Little Bear Beach, Clewiston Spit, Eagle Bay Island, and Moonshine Bay) which we monitored twice per week. We monitored the nests of 52 TRHE, 227 SNEG, 139 small herons (failed before eggs hatched), 66 GREG, 59 GLIB, 32 WHIB, 1 Great Blue Heron, and 30 CAEG.

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, Rostam Mirzadi, and Lars Nelson.

Presentations

Essian, D. A. and D. E. Gawlik. 2021. Greater Everglades Ecosystem Restoration Conference. Virtual. April 2021.

Larson R. C. and D. E. Gawlik. 2021. Call rates are as an index of nest abundances and provisioning rates in wading bird colonies. North American Ornithological Conference. August 2021.

Mirzadi, R. E. and D. E. Gawlik. 2020. Evaluation of small unmanned aerial systems for monitoring wading bird colonies. Northeast Natural History Conference. April 2021.

Publications in review or print

Essian, D.A, R. Paudel, and D.E. Gawlik. 2022. Predicting effects of water management on breeding abundance of three wading bird species. Journal of Wildlife Management. 86:e22155.

Larson, R.C. and D.E. Gawlik. In review. Using passive acoustic sampling to estimate wading bird provisioning rates. Journal of Field Ornithology.

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 2021, 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 2021 nesting season, 01 January to 14 July, were similar to the 2015 nesting season (mean lake stage was 14.21 ft in 2015 and 14.36 ft in 2021, respectively). Water conditions in 2021 were characterized by high lake stage, a moderate recession rate, and four reversals (0.01-in rise in stage per day from 06 February to 18 February, 0.05-in rise per day from 11 April to 13 April, 0.05-in rise per day from 19 April to 21 April, and 0.04-in rise on 31 May) preceding the onset of the wet season beginning 14 June (**Figure 1**). On 01 January, lake stage was at 15.81 ft. The lake receded at a mean rate of .08 in/wk from 01 January to 06 February before unseasonal rainfall caused the lake stage to increase from 15.36 ft on 06 February to a seasonal high of 15.92 ft on 18 February. The lake receded at a mean rate of 1.45 in/wk from 18 February to 11 April when unseasonal rainfall caused the lake stage to increase from 14.14 ft on 11 April to 14.23 ft on 13 April. The lake receded at a rate of 1.85 in/wk from 14 April to 14 June, except for one minor reversal in late May. During that reversal, lake stage increased .04 in before receding to the lowest depth of the season, 12.41 ft, on 14 June.

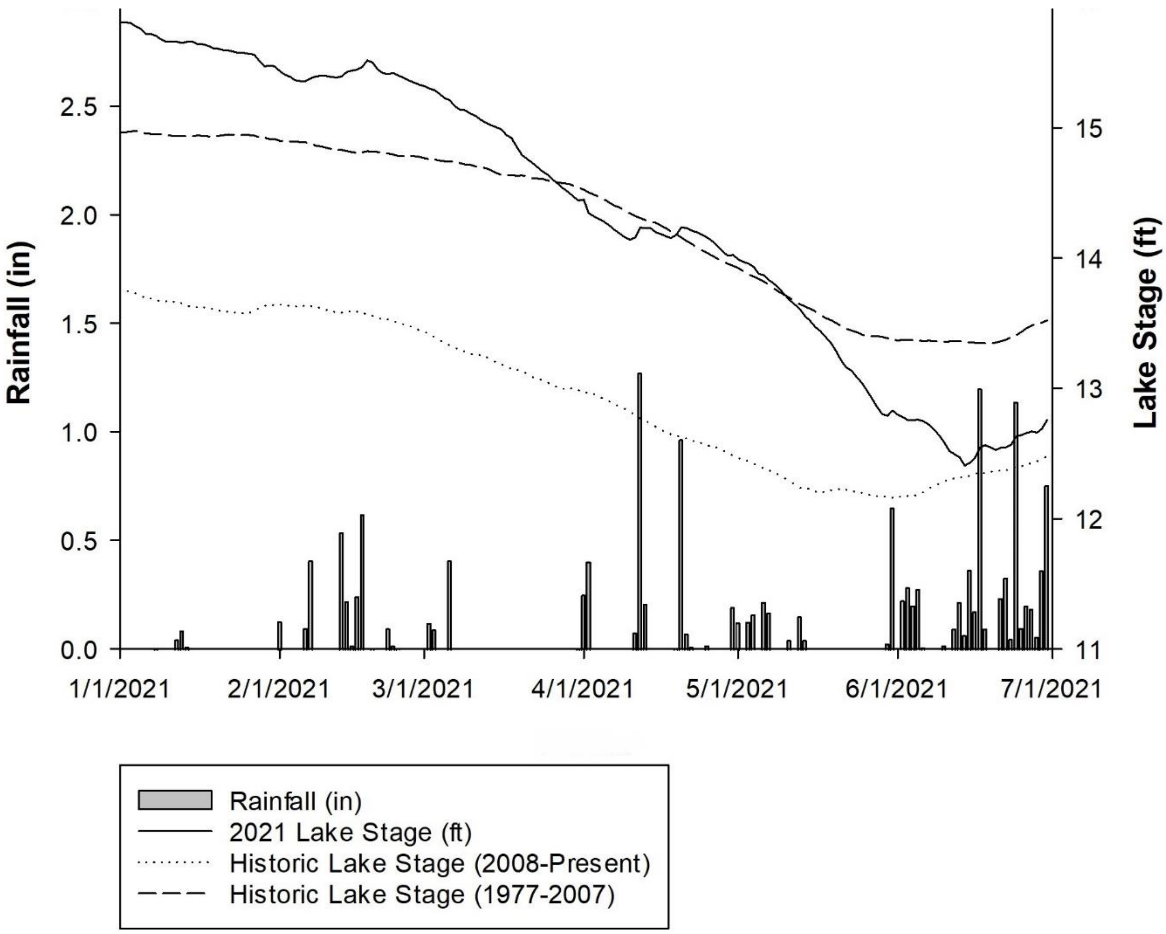

Figure 1. Hydrologic patterns on Lake Okeechobee from January to July 2021 and mean lake stage from 1977-2007 and from 2008-Present, since the 2008 Lake Okeechobee Regulation Schedule (LORS2008) was implemented.

Nesting and foraging conditions

High lake stages at the beginning of 2021 were a result of above average rainfall during the 2021 wet season and, resulted in moderate habitat availability in January, February, and March, when the littoral zone was partially flooded. Habitat availability peaked on 04 April and decreased from 05 April to the start of the wet season on 14 June. 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 A1**). The proportion of the littoral zone available as foraging habitat on the Lake during the breeding season was about average (2021 = 0.50; 2011-2020 = 0.48; SE = 0.08).

Colony locations

Ten colonies (**Figure 2**) supporting 3,024 GREG, SNEG, and WHIB nests were detected, which is 9% lower than the average from 2008-2021 (3,309 ± 1,563 SD). Colonies were detected at three created spoil islands (Little Bear Beach, Clewiston Spit, and Pahokee Airport), four natural willow colony in the marsh (Eagle Bay Island, Clewiston Marsh, Moorehaven East 4, Moonshine Bay), and three off-lake, created islands (Lakeport Marina, Gator Farm, Gun Range). Moonshine Bay was the largest colony, supporting 1,114 GREG, SNEG, and WHIB nests (**Table 1**).

During wet years, like 2021, wading birds' nest in short-hydroperiod colonies more frequently than dry years, because most of the natural willow colonies located in the marsh are surrounded by water, making them inaccessible to mammalian predators and decreasing the 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 29% of on-lake nests in dry years (mean lake stage <12.9 ft), 16% in moderate years (13.0 –14.0 ft), and 16% in wet years (>14.1 ft) since 2006. Variation in nest abundance is lower in spoil island colonies (coefficient of variation at spoil island colonies = 47%) than marsh colonies (2008-2021 mean coefficient of variation at natural colonies = 72%) because the small size of created colonies limits total nest numbers, 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.

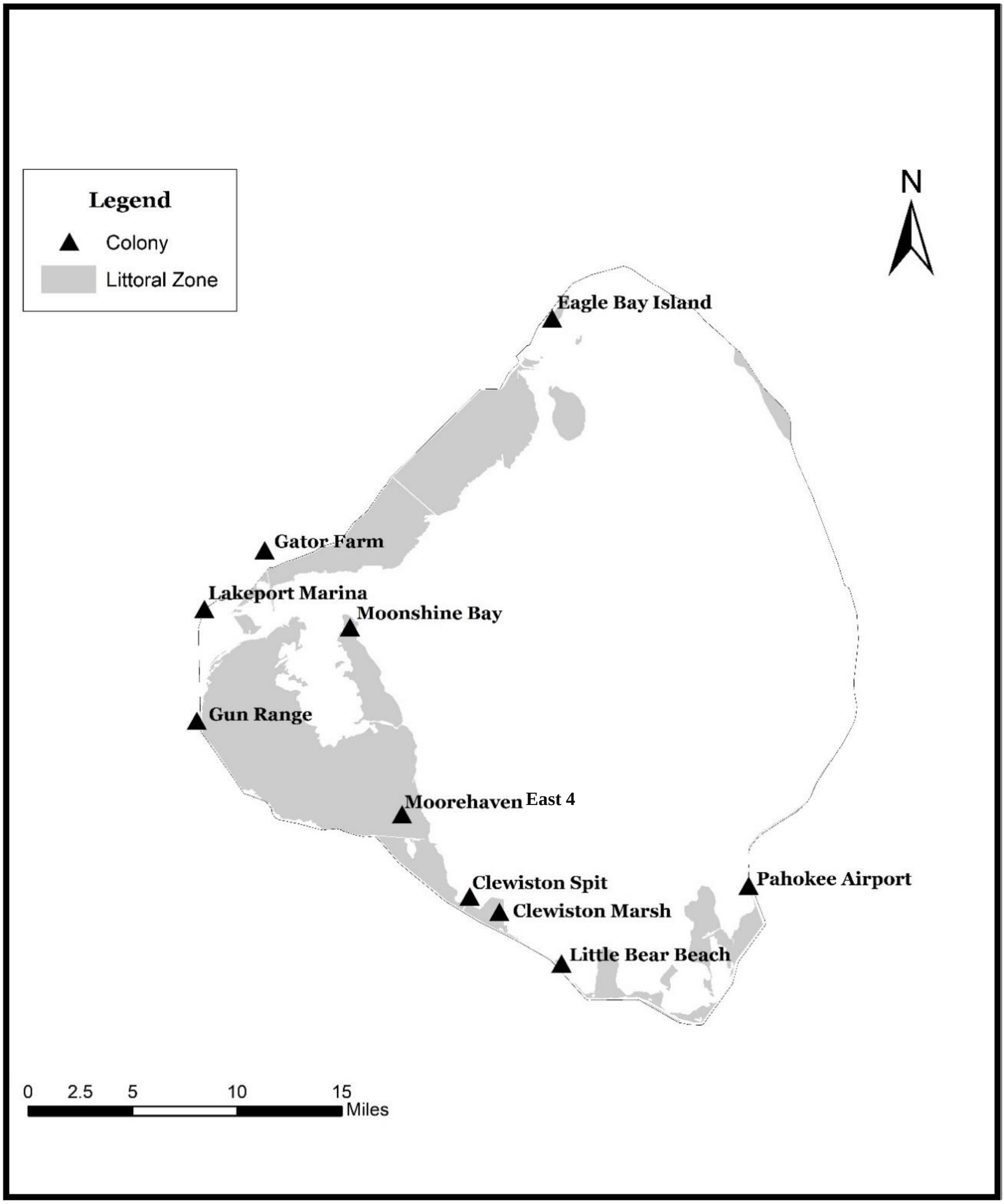

Figure 2. Map of wading bird colonies detected on Lake Okeechobee from February through June 2021.

Table 1. Peak colony size observed at Lake Okeechobee February through June 2021.

Colony	Peak Month[1]	Latitude	Longitude	GREG	SNEG	TRHE	ROSP	WHIB	LBHE	GLIB	GBHE	CAEG	WOST	ANHI	Total[2]
Clewiston Spit	March	26.777	-80.909	148	202	67	2								419
Clewiston Marsh	June	26.766	-80.898		45			205				120			250
Eagle Bay Island	April	27.171	-80.846	3	206	50		137		137		343			533
Gator Farm	March	27.023	-81.061	175	4	3	16	25					25		248
Gun Range	March	26.893	81.125	40											40
Lakeport Marina	April	26.973	-81.114	187	19	9						277			215
Little Bear Beach	April	26.721	-80.842	115	120	56			3		5				299
Moonshine Bay	June	26.928	-81.035	15	101	14		998		71					1199
Moorehaven East 4	April	26.893	-81.051	56	5						4				65
Pahokee	June	26.779	-80.698		298	100		127				26			525

[1]Peak month refers to the month during which combined Nest Effort peaked and does not refer to species-specific peak nest numbers

[2]Does not include CAEG or ANHI

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 2021. Peak nest abundance was 693, 758, and 1,573 for GREG, SNEG, and WHIB respectively (3,024 nests; **Table 2**). This was 9% lower than the average since 2008, when the current lake schedule went into effect (3,309 ± 1,910; all averages use SD). GREG and SNEG nest abundance were 2% and 47% lower, and WHIB was 25% higher, than the average since 2008, respectively (707 ± 458 GREG; 1,423 ± 1,016 SNEG; 1,179 ± 842 WHIB).

Mean nest abundance of the three focal species on the Lake was higher from 2008-2021 (3,331 ± 1,910) 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. Since 2009, the Lake has supported approximately 53% of SNEG nesting in the Greater Everglades, suggesting that Lake Okeechobee provides critical habitat for SNEG nesting in South Florida.

We also ran species-specific nest abundance models (Essian et al. 2019) that rely on measures of environmental conditions within foraging flights of each colony during the nesting period to better match the spatial and temporal scale of resource acquisition by nesting wading birds. Predicated nest abundance for all species was within 12% of what was observed during 2021, with the exception of small herons which were within 25% of what was observed. This discrepancy may in part be explained by small heron’s use of the Rock Island Colonies as nesting habitat. Because the Rock Island Colonies are largely unavailable during periods of high water, as was observed during 2021, the model inflated our predicted nest abundance estimates. One direction for future models would be to include thresholds using empirical models that better account for the availability of colonies to nesting wading bird species.

Table 2. Timing and nest numbers for species breeding in wading bird colonies at Lake Okeechobee in 2021.

Month	GREG	WHIB	SNEG	WOST	ROSP	GBHE	LBHE	TRHE	GLIB	CAEG	AHNI
Feburary	432	--[a]	--[a]	19	--[a]	**5**	--[a]	--[a]	--[a]	--[a]	--[a]
March	**693**	25	361	16	18	5	3	133	--[a]	50	--[a]
April	548	562	**758**	28	**21**	5	--[a]	**239**	**457**	647	--[a]
May	284	739	462	**40**	9	--[a]	**8**	171	381	1030	--[a]
June	109	**1573**	635	11	6	--[a]	--[a]	156	91	**1456**	--[a]

[a]Large number of roosting birds present, but not on nests

Note: Bold Values denote peak nest effort for species.

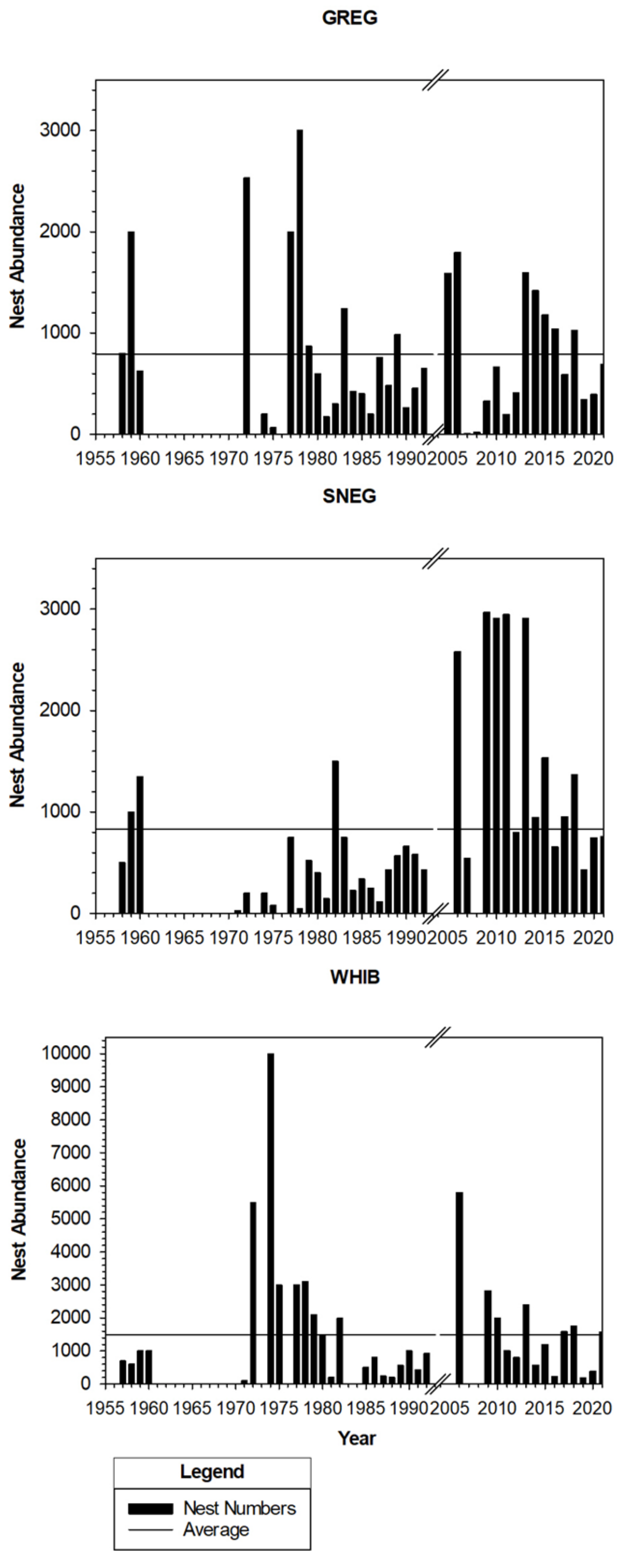

Figure 3. Estimates of nest abundance from Lake Okeechobee aerial surveys during the 1977-1992, 2006-2007, and 2009-2021 nesting seasons. Mean nest abundance is represented by the horizontal line.

Timing

The median clutch initiation date for GREG (7 March ± 13.6 days) was 7 days earlier than the average since 2009 (14 March). Median clutch initiation date for SNEG (3 April ± 11.20 days) was one day earlier than the average since 2009 (4 April) and median clutch initiation for TRHE (29 March ± 15.6 days) was eight days earlier (6 April) than the average since 2009. Median clutch initiation date for WHIB (8 May ± 20.27 days) was nine day earlier than the average since 2009 (17 May). Peak nest numbers were observed in April for GREG, small herons, and WHIB (**Table 2**).

Nest initiations for SNEG, GREG, and TRHE peaked between 07 March and 4 April, which coincides with the first prolonged water recession (**Figure 1**). Nest initiations for WHIB peaked during the second prolonged water recession, 14 April to 17 June, during which the recession rate increased from 1.45 in/wk to 1.85 in/wjk (**Figure 1**). 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).

WOST and ROSP abundance

Forty-one WOST nests and 24 ROSP nests were detected at Gator Farm, an off-lake colony located north of the Moonshine Bay area (**Figure 2**). Three ROSP nests were also detected at Clewiston Spit, and one ROSP nest was detected at Moonshine Bay. While this is the first time since 2015 that ROSP have been observed nesting in on-lake colonies, all nests outside of Gator Farm failed. From the detected nests, we counted 41 WOST fledglings in photos taken during the aerial survey on 17 May, and 24 ROSP fledglings in photos taken during the aerial survey on 17 June. WOST have nested at the Gator Farm in 10 of the last 15 years (2007-2010 and 2016-2021) and have successfully fledged chicks every year nesting has occurred. ROSP have nested at natural colonies in the littoral marsh (*n* = 3 in 2009; *n* = 2 in 2013, n = 1 in 2021), at a created spoil island colony (*n* = 1 in 2015; n = 3 in 2021), and at the Gator Farm (*n* = 4 **-** 24 nests from 2016-2021) where they successfully fledged chicks from 2018-2021.

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.

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 ($DSR^{\text{interval length}}$). 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 2021 was 0.86 ± 0.04 (n = 67), which is 16% higher than the overall survival since 2011 (0.60 ± 0.20; n = 600). Nest survival for small herons in 2021 was 0.76 ± 0.08 (incubating small heron, n = 155; fledgling TRHE, n = 78; and fledgling SNEG, n = 212), which is which is 1% higher than the survival rate since (0.75 ± 0.09; n = 2,845). Nest survival for WHIB in 2021 was 0.76 ± 0.05 (n = 67), which is 14% higher than the overall nest survival since 2011 (0.62 ± 0.08; n = 405).

Since 2011, GREG survival rates ranged between 0.10 in 2019 and 0.86 in 2021 (Gswlik et al. 2019). However, low predicted survival rates in 2019 may not be representative of survival rates at the lake because only a small number (n = 13) of GREG nests were monitored at a single colony (Little Bear Beach). Since 2011, nest survival for GREG was below 55% in 2011 (53%) and 2019 (10%), which were both dry years (mean lake stages of 11.7 ft, 12.1 ft, respectively). Similarly, 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) (Gawlik 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 2021.

Since 2011, small heron nest survival rates ranged between 0.60 in 2015 and 0.83 in 2019. Small heron survival in 2021 (76%) was similar to 2013 (78%) and 2018 (79%), hydrologically similar years. Small heron nest survival has been correlated to the hydrological regime of the current year (Gawlik et al. 2019), with higher survival rates observed during years with high recession rates and available foraging habitat.

Since 2011, WHIB nest survival rates ranged from 0.48 in 2011 to 0.76 in 2021. WHIB survival in 2021 (76%) was similar to 2016 (74%), a hydrologically similar year. Frederick and Ogden (2001) hypothesized that drought promotes prey availability in subsequent years in the Everglades, perhaps through an increase in nutrients released from sediments upon reflooding, or through predator release during droughts and 2019 and 2020 were both years characterized by low water levels. While the increased survival may be a response to increased prey abundance, this seems unlikely. Previous studies

(Gawlik et al. 2019) have found a weak relationship between days dry in the previous two water years and prey densities within the foraging ranges of wading birds ($F = 2.87$, $R2 = 0.03$, $p = 0.09$).

CONCLUSION

Above average lake stages in January preceded by a moderate drydown, resulted in relatively wet conditions in the littoral zone during the 2021 breeding season. GREG, SNEG, and WHIB initiated an estimated 3,024 nests, 9% lower than the average since 2008, as the recession rate of the lake during the 2021 breeding season was moderate throughout the breeding season, resulting in less available foraging habitat during the beginning of the breeding season, and a reduced capacity to concentrate prey later in the breeding season. However, nest abundances and nest survival of the focal species have been higher under the current lake management schedule (2008–2021) compared to the previous period (1977–1992), supporting management of lake stages at moderate levels.

ACKNOWLEDGMENTS

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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.

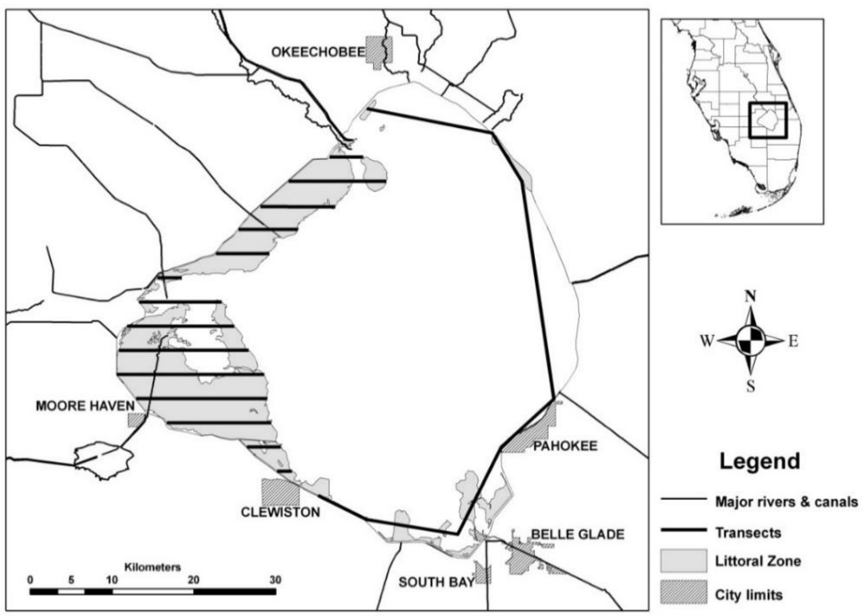

Figure A1. Map of systematic aerial transects flown over Lake Okeechobee during the 2021 wading bird breeding season.

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).

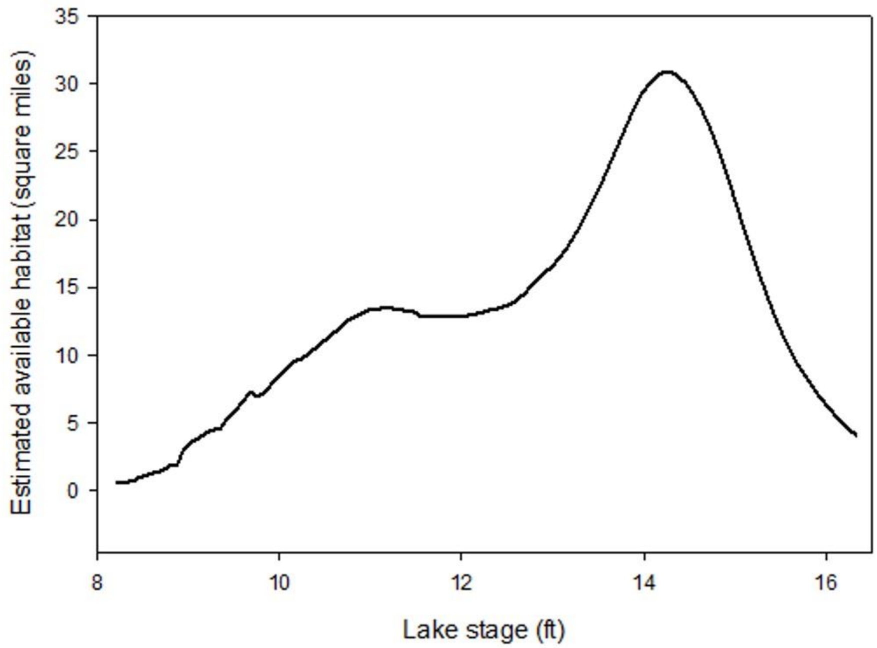

Figure A2. Habitat suitability curve for Lake Okeechobee. Habitat availability was estimated based on vegetation mapping last updated in 2012 and LIDAR depth estimates last updated in 2011.