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WADING BIRD USE OF LAKE OKEECHOBEE RELATIVE TO FLUCTUATING WATER LEVELS

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ABSTRACT.—We surveyed the Lake Okeechobee littoral zone by helicopter between 1977 and 1988 to determine wading bird abundance relative to lake water levels. More birds foraged when nesting season (January–July) water levels were below 4.4 m (mean sea level) compared to higher lake levels. Wading birds were also more abundant when nesting season water levels declined by at least 30 cm over the previous two-month period in comparison to more gradual declines or increases in lake levels. Lake levels and change in lake levels over the previous two-month period explained 60% of variation in wading bird abundance. Nesting effort did not appear to be affected by changes in water levels. However, fewer nesting attempts were observed when lake levels were above 4.9 m or below 3.9 m. Peak numbers of nesting wading birds occurred in April and May when lake levels were between 3.9 m and 4.4 m. In general, nesting effort declined during the survey period from over 6000 nests in 1977 and 1978 to between 725 and 1812 nests during the last five years of the study. One possible explanation for this decline is the impact of higher water levels due to increased rainfall and a change in the Lake Okeechobee regulation schedule. Higher water levels reduced the foraging area available to nesting birds and may have contributed to the deterioration of nesting sites comprised of willows. *Received 13 Aug. 1993, accepted 20 March 1994.*

Wading bird populations of the Everglades, including Lake Okeechobee, have declined through the loss or alteration of wetland habitat (Ogden 1978). Changes in wetland hydropatterns, including the timing, duration, and depth of inundation may severely impede the ability of wading birds to forage and reproduce successfully. Shortened hydroperiods can decrease the availability of prey (Loftus et al. 1987), and nesting colonies located in shorter hydroperiod marshes may be exposed to greater nest predation (Frederick and Collopy 1988). Wading birds require a narrow range of water depths in which to forage efficiently (Kushlan 1974, Custer and Osborne 1978), and receding water levels prior to and during nesting are important to concentrate food organisms and create successful foraging conditions in the Everglades (Kushlan et al. 1975, Kushlan 1976).

The South Florida Water Management District (SFWMD) initiated monthly aerial surveys of Lake Okeechobee in 1977 to monitor the effect of the 1978 lake regulation schedule increase on wading bird populations. This paper establishes relationships between lake levels and wading bird use from twelve years (1977–1988) of surveys and supplements previous reports for surveys conducted between 1977 and 1981 (Zaffke 1984) and 1988 (David et al. 1989).

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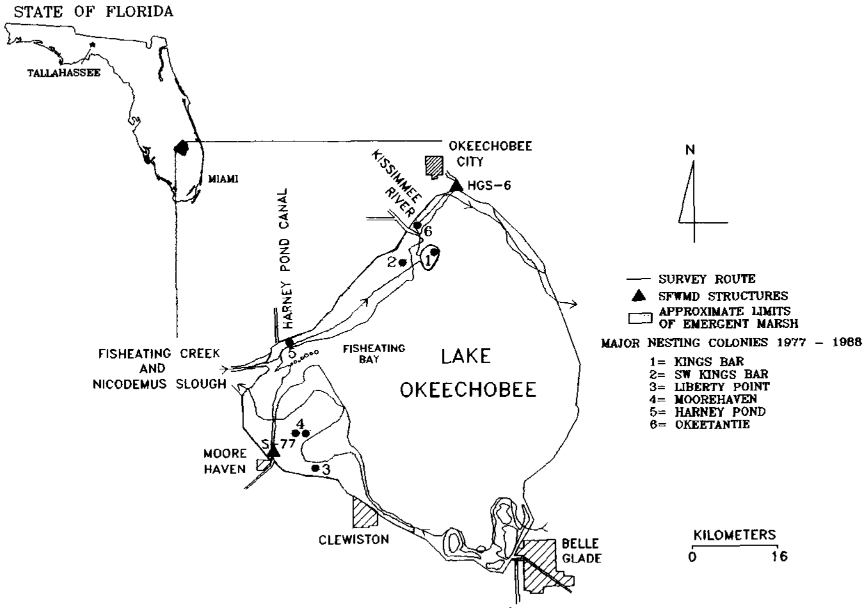

FIG 1. Location of Lake Okeechobee study area, survey route, and major nesting colonies for the period 1977 through 1988.

METHODS

Lake Okeechobee encompasses 1893 km^2 of fresh water in southcentral Florida (Fig. 1), including a 390 km^2 littoral zone located primarily along the western shore between Clewiston and the Kissimmee River (SFWMD 1989). The plant communities within the littoral zone are dominated by cattail (*Typha* sp.); mixed grasses, beakrush (*Rhyncospora* spp.), spikerush (*Eleocharis cellulosa*), and bulrush (*Scirpus californicus*) are also prevalent (Richardson et al. 1991). Willows (*Salix caroliniana*), an important wading bird nesting habitat, occur on elevated ridges (above 4.3 m) in the littoral zone. Willows also are prominent on Kings Bar, an island situated at the mouth of the Kissimmee River, where wading birds historically established large nesting colonies (David 1994).

The littoral zone extends lakeward to nearly the 3.0 m contour; the outward extent is limited by a levee encircling the lake, which was constructed at approximately the 4.7 m contour elevation (Zaffke 1984). Located outside the levee on the west side of the lake are two wetland systems, Nicodemus Slough and Fisheating Creek, which drain into the lake and tend to be inundated at higher lake stages. Nicodemus Slough contains 898 ha of emergent marsh mixed with unimproved pasture, and it is owned and managed by the SFWMD. Fisheating Creek is an extensive riverine system encompassing approximately 17,400 ha of privately owned cypress slough, hardwood swamp, emergent freshwater marsh, and upland habitat.

The SFWMD conducted the Lake Okeechobee surveys by helicopter from 75–80 m in altitude on a specified route around the lake littoral zone marsh, Nicodemus Slough, and Fisheating Creek (Fig. 1). I selected a flight pattern that maximized visibility of the entire littoral zone. Two observers counted all groups of birds sighted and recorded locations of bird assemblages ($\geq$12 birds) on a map of the lake. Birds were categorized as foraging (i.e., dispersed and feeding in the marsh) or nesting, if assembled in colonies with nests present. Large flocks of foraging or nesting birds were circled several times to improve count accuracy. Total numbers of nests (or nesting pairs) at each colony were recorded. Surveys were designed to establish trends in wading bird abundance relative to water conditions and were not intended to provide a quantitative estimate of bird populations on the lake.

Surveys were conducted at approximately monthly intervals from January 1977 until October 1981, excluding the period of June through September 1978. Beginning in 1982, surveys were completed between April and July when greatest bird use of the lake was anticipated. Four surveys were made each year in 1982, 1983, and 1984; six surveys (February–July) were conducted in 1985 and 1986; seven (January–July) in 1987; and eight (December 1987–July 1988) were completed during the final year of the study, for a total of 93 surveys.

We regularly counted eight species of wading birds during surveys. Great Egrets (*Casmerodius albus*), Snowy Egrets (*Egretta thula*), White Ibises (*Eudocimus albus*), and Woodstorks (*Mycteria americana*) were most visible and I believe were counted most accurately. Darker birds (e.g., Great Blue Heron [*Ardea herodias*], Little Blue Heron [*Egretta caerulea*], Tricolored Heron [*E. tricolor*], Glossy Ibis [*Plegadis falcinellus*]) were more difficult to detect, and their numbers may have been underestimated in the counts. In general, only groups of birds were counted, and scattered individuals, particularly Great Blue and Tricolored herons, were excluded. This resulted in an underestimate of the numbers of feeding birds recorded along the survey route.

Daily water level data were obtained from United States Geological Survey hurricane gauge HGS-6 and the South Florida Water Management gauge at Structure 77, located on the western shore of Lake Okeechobee (Fig. 1). These were considered to be the most representative and accurate gauges for the littoral zone and period of record. Stage elevations used by water managers to operate the Lake Okeechobee system are commonly reported as feet above mean sea level. Lake stages and changes in lake levels presented in this paper have been converted to metric.

I used SAS (1990; version 6.04) to perform analyses on an IBM personal computer. Raw data (numbers of birds foraging and numbers of nests) were log transformed to base 10 to minimize heterogeneity (Zar 1974). I used two-way analysis of variance to test for significant differences in nesting effort among months and change in stage (ds) and for interactions between months and stage. I divided lake stages into four treatment levels (1) stages below 3.9 m, (2) stages between 3.9 m and 4.4 m, (3) stages between 4.4 m and 4.9 m, and (4) stages above 4.9 m. Since I made multiple comparisons of stage differences among the seven months of data, Bonferroni's correction for probability levels (P = 0.05/7 = 0.0074) was used. I computed multiple regressions to describe the influence of stage and ds on wading bird foraging abundance during the nesting season. I calculated squared semi-partial correlation coefficients and associated probability levels for stage and ds to determine the relative importance of each of these two variables to the variation in wading bird abundance. This method factored out collinearity which was weak, but a significant correlation (r = 0.27, $P < 0.05$) was observed between stage and ds.

I used two sets of data. The first included the entire group of monthly survey flights (N^1 = 93) for eight species. The second data set incorporated only the nesting season surveys (January–July, N^2 = 71) and analyzed data for six species: Great Egret, White Ibis, Snowy Egret, Glossy Ibis, Little Blue Heron, Great Blue Heron, and the total for all six. Wood Storks were included in the analysis of on-lake (littoral zone) and off-lake foraging, while Great Blue Herons were excluded from analysis of off-lake data.

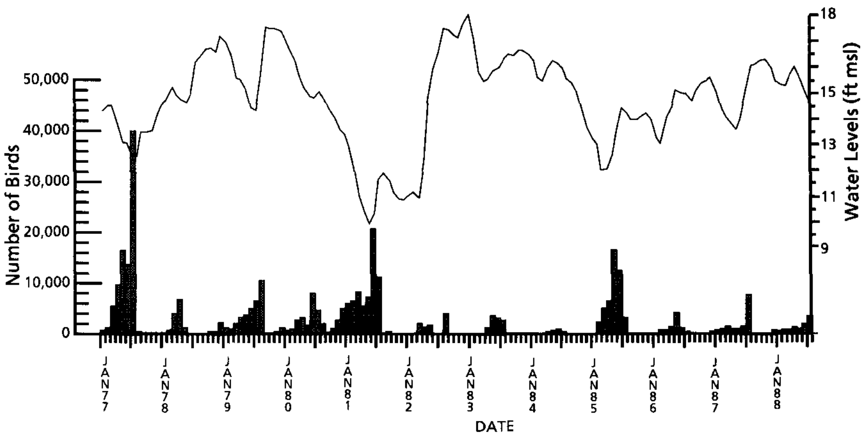

FIG. 2. Total numbers (bars) of birds (foraging and nesting) vs water levels (line) at Lake Okeechobee for the period January 1977 through July 1988.

RESULTS

Wading bird use of the lake varied considerably in relation to fluctuating water conditions, which ranged from drought in 1981 to extremely high water levels in 1979, 1980, and 1982 (Fig. 2). In general, the greatest abundance of foraging wading birds occurred on the lake in the spring or summer when water levels had receded to 3.9 m or lower. For example, in 1977 water levels declined gradually from around 4.4 m in January and February to well below 3.9 m in June and July, which attracted large numbers of wading birds to the lake. In contrast, water levels were extremely high (exceeding 5.2 m) in 1979 and 1980 following implementation of the higher Lake Okeechobee regulation schedule and above average rainfall. In general, these years were characterized by higher numbers of birds feeding off-lake (Fisheating Creek and Nicodemus Slough), with few birds observed on the lake until stages had declined below 4.6 m.

Rapid declines in water levels over a two-month period were associated with greater abundance ($P < 0.01$) of foraging wading birds on the lake during the nesting season (Fig. 3). A two-month decline of between 30 cm and 91 cm in lake levels corresponded to maximum bird counts in July 1977 (39,017 birds), June 1981 (20,620 birds), and May 1985 (15,125 birds). Less distinct differences were detected for total numbers of birds when comparing change in water levels over a two-week or one-month period.

Lake levels were correlated negatively ($r = -0.54$, $P < 0.01$) with

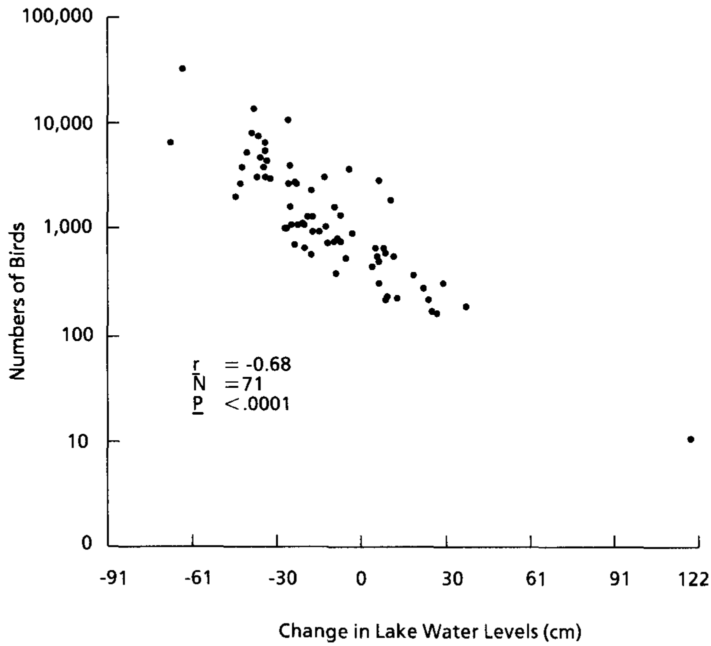

FIG. 3. Relationship between numbers of birds foraging during the nesting season (January–June) and changes in lake levels (cm) at Lake Okeechobee over the two-month period preceding each monthly survey.

wading bird abundance during the nesting season (Fig. 4). Lake levels below 3.3 m continued to provide favorable foraging conditions in the littoral zone along the drying edge of the lake. Wading birds were twice as abundant at these low water levels compared to lake stages above 4.6 m.

Multiple regression equations indicated that water level and changes in water level (*d*s) were significant ($P < 0.05$) predictors of abundance and explained from 25 to 49% of the variation in wading bird abundance among the six species (Table 1). The change in stage over a two-month period was a more important determinant of Great Egret and Little Blue Heron abundance than was lake level. For Snowy Egret, White Ibis, and Wood Stork, stage was a more important variable predicting abundance than the two-month change in water levels. Stage and *d*s explained 60% of the variation in total wading bird abundance with *d*s being a more important predictor than lake level. Similarly, wading bird abundance for all months ($N^1 = 93$) varied with lake levels and *d*s, but these differences were less definitive.

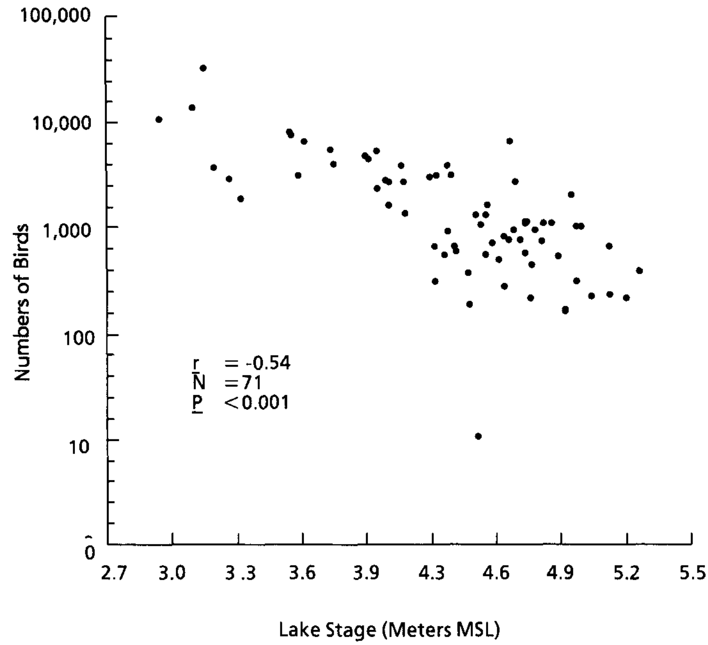

FIG. 4. Relationship between numbers of birds foraging during the nesting season (January–June) and Lake Okeechobee stage.

Using the regression equation to relate total wading bird abundance to stage and *d*s over the previous two months, surface response curves were produced to predict wading bird use on Lake Okeechobee (Fig. 5). Large numbers of wading birds were attracted to the lake at low lake stages, only if water levels had declined rapidly over the previous two months. In addition, these curves indicated that total wading bird use was influenced more by fluctuating lake levels than by stage level.

Temporal changes in wading bird numbers were not evident as two-way analysis of variance revealed no significant differences among the months ($P > 0.5$). There were no significant ($P > 0.5$) interactions between month and *d*s, suggesting that *d*s acted independently in explaining variation in individual and total species abundance.

There were distinct seasonal trends in White Ibis numbers during several years and considerable variation in ibis populations at the lake among years. For example, in 1977 over 19,000 White Ibises were foraging and nesting on the lake through July, but by August most of these birds had emigrated from the lake. Post breeding season exodus of White Ibises also occurred in August or September during the years 1979 through

TABLE 1

REGRESSION COEFFICIENTS FOR COMPARISONS BETWEEN FORAGING ABUNDANCE AND STAGE AND CHANGES IN STAGE (*DS*) FOR TWELVE NESTING SEASONS (1977–1988) AT LAKE OKEECHOBEE

Species	Total model R^2	Independent variable	Squared semi-partial r	P^a
Great Egret	0.49	Stage	0.04	0.0220
		ds	0.35	<0.0001
Snowy Egret	0.33	Stage	0.16	0.0002
		ds	0.09	0.0041
White Ibis	0.44	Stage	0.25	0.0001
		ds	0.09	0.0017
Glossy Ibis	0.26	Stage	0.12	0.0015
		ds	0.08	0.0098
Little Blue Heron	0.25	Stage	0.08	0.0087
		ds	0.10	0.0032
Wood Stork	0.44	Stage	0.26	0.0001
		ds	0.07	0.0046
Great Blue Heron	0.35	Stage	0.31	0.0001
		ds	<0.01	0.6383
Total birds	0.60	Stage	0.14	<0.0001
		ds	0.31	<0.0001

[a] All abundance data was transformed to $\log_{10}$ values prior to analysis. Squared semi-partial R^2 values and probability (P) levels are given.

1981, and in July during the years 1984 through 1986. From 1977 to 1981, this species was abundant in the lake vicinity through the breeding season, but during the remainder of the survey period, with the exception of 1985, large numbers of White Ibis were seldom observed at the lake during the nesting season.

Use of Nicodemus Slough and Fisheating Creek by wading birds increased at higher lake water levels. Wading birds were more abundant at off-lake areas during high lake stages than during low lake stages ($P < 0.001$) when all months were included in the data analysis (Fig. 6). Off-lake areas were particularly important to White Ibis, which were observed foraging in large aggregations during August 1977 (8000 birds), December 1977 (6200 birds), and October 1978 (10,180 birds). With the exception of White Ibises, these off-lake areas generally received limited use by other species. However, in May 1983 large numbers of Great Egrets (2065) and Snowy Egrets (2000) were observed in Fisheating Creek and Nicodemus Slough. This occurred following an extended period, beginning in the late summer of 1982 and continuing through the winter of

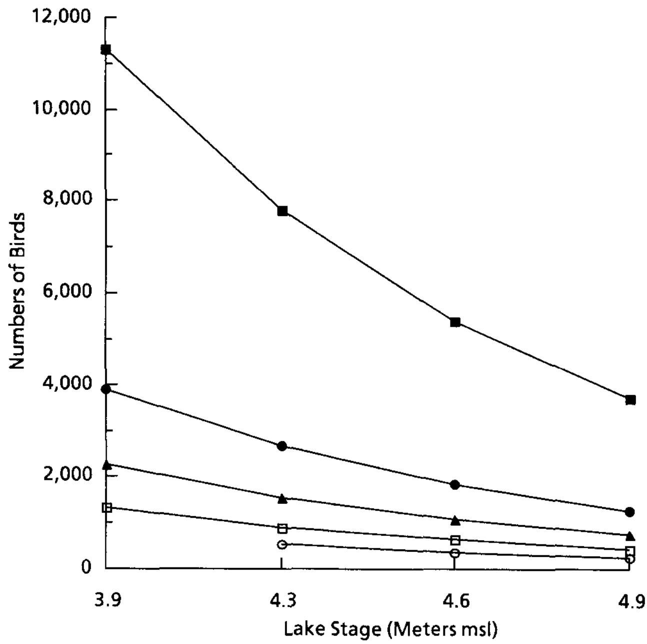

FIG. 5. Simple surface plot predicting total wading bird abundance from Lake Okeechobee stage at five different categories of water level change (over previous two-month period). Solid squares represent change of −61 cm; solid circles represent change of −30 cm; solid triangles represent change of −15 cm; open squares represent no change; and open circles represent change of 15 cm.

1983, when water levels in the lake exceeded 5.2 m. In contrast, only 67 birds were recorded foraging in off-lake areas in 11 surveys conducted between January 1981 and July 1982, which coincided with low lake levels during the drought. Although the low sample sizes precluded statistical comparisons, wading bird use of off-lake areas appeared to be greatest during August and October, with considerably less use occurring during the peak nesting period (March through June).

Twelve different Lake Okeechobee wading bird colony sites were documented. Five of the sites—King's Bar, Liberty Point, Moorehaven, Southwest Kings Bar, and Harney Pond—were used consistently during all or some of the survey years (Fig. 1). Numbers of nesting wading birds, primarily White Ibises and Great Egrets, declined during the survey period from over 6000 in 1977 and 1978 to less than 2000 in 1987 and 1988 (Fig. 7). Although the decline in nesting appeared to be continuous, there were several years characterized by extremely poor nesting effort,

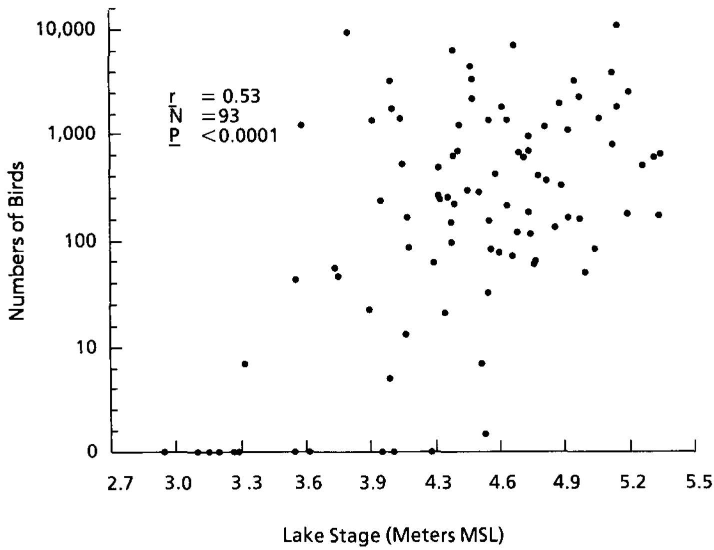

FIG. 6. Relationship between the number of wading birds foraging off-lake and Lake Okeechobee stage for all months (N^1 = 93).

including 1981 (520 nests) and 1984 (725 nests), years which had extremely low and high water levels, respectively. Despite favorable water levels and increased foraging activity during the 1985 season, the numbers of wading bird nests increased only slightly. For the remainder of the study period, lake stages remained high (above 4.6 m) throughout the nesting season (1988) or exhibited reversals (i.e., lake water levels increased during the normal dry season recession) during the nesting season (1986 and 1987).

Rate of water level decline did not appear to influence nesting effort, since total nesting effort did not differ significantly ($P > 0.8084$) with *d*s over a two-month period. However, a two-way ANOVA indicated that water levels and month significantly ($P < 0.01$) affected nesting effort such that birds temporally varied nesting effort in response to water levels (Fig. 8). In general, peak nesting occurred when lake levels were between 3.9 m and 4.4 m, compared to higher or lower lake stages. In most years, peak nesting effort occurred in April or May, and dual peaks were observed in 1983 (May and July) and 1987 (March and May).

DISCUSSION

Wading bird foraging and nesting at Lake Okeechobee were related to lake stages and changes in water levels prior to, and during the nesting

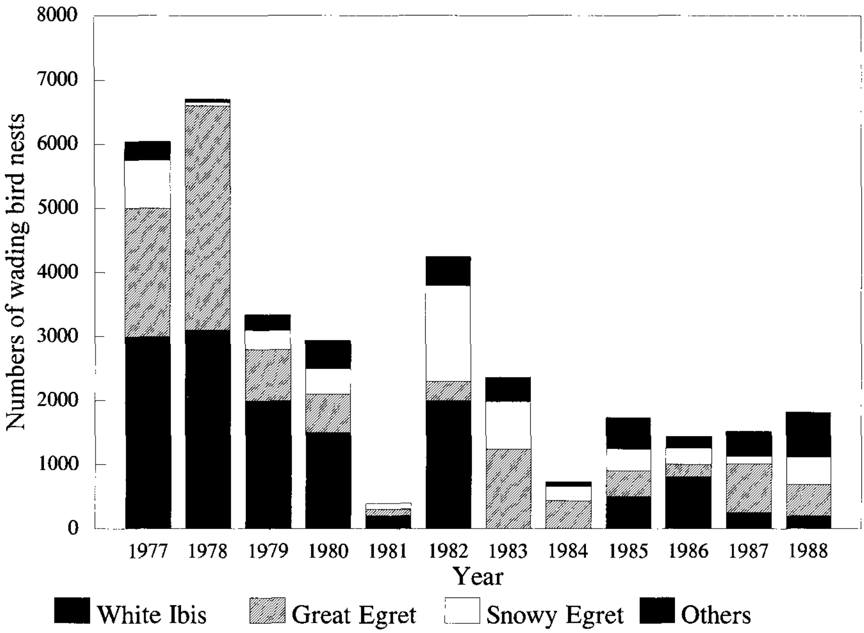

FIG. 7. Maximum numbers of wading bird nests at Lake Okeechobee for each year of surveys. (Others represents Tricolored Heron, Little Blue Heron, Glossy Ibis, and Great Blue Heron nests combined.) Wood Storks did not nest on the Lake during the study period.

period. Nesting wading birds responded favorably to lake levels that were sufficient to inundate littoral marshes, and that then receded to concentrate food in pools along the edge of the exposed littoral zone. A gradual, but continuous receding of lake stage attracted birds to the lake, particularly during the nesting season (January to July). The largest concentrations of birds occurred during dry conditions, indicating that Lake Okeechobee represents critical foraging habitat for wading birds when drought pervades South Florida.

Lake levels may influence the availability of fish and other prey organisms for foraging wading birds. Most wading birds require shallow water (i.e., less than 15 cm for small herons and less than 25 cm for Great Egret and Great Blue Heron) to forage successfully (Custer and Osborne 1978). In addition, Kushlan (1974) indicated that White Ibises avoided foraging in water deeper than 10 cm. Due to the presence of the lake levee, deeper water levels occurred when lake stages exceeded 4.6 m, creating conditions in the littoral zone that were not conducive to wading birds' foraging.

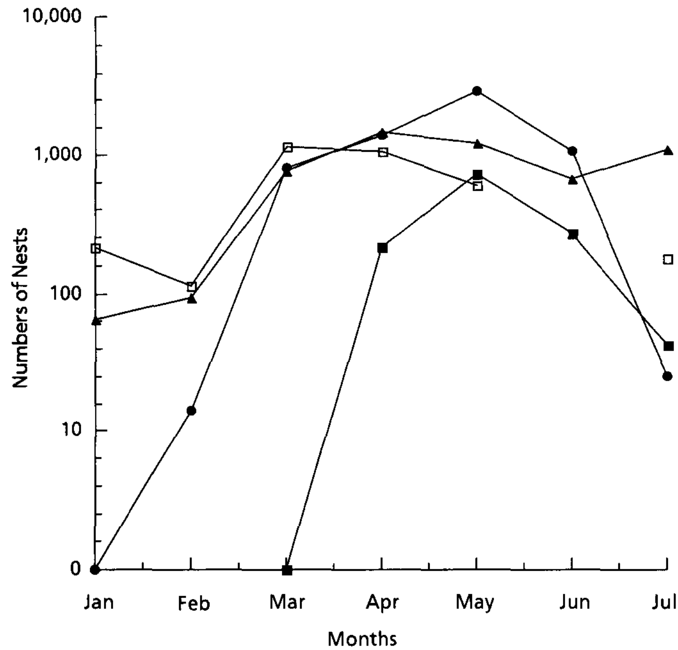

FIG. 8. Relationship between numbers of bird nests by month for four Lake Okeechobee stage categories. Open squares represent stage >4.9 m; solid triangles represent stage between 4.5–4.9 m; solid circles represent stage between 3.9–4.5 m; and solid squares represent stage <3.9 m.

Wading birds were much more likely to use off-lake areas when water levels exceeded 4.6 m. Browder (1976) estimated that the higher lake regulation schedule would reduce by more than 40% the amount of wading bird foraging habitat in the littoral zone. This may be reflected by the movement of White Ibises and Great Egrets from on-lake sites to Nicodemus Slough and Fisheating Creek at higher lake stages. Kushlan (1979) reported that the diet of White Ibises varied, depending on habitat and prey availability, and perhaps being less dependent upon fish in their diet since these birds were able to capitalize on macroinvertebrates in temporarily flooded off-lake areas. Minimal use of off-lake areas during the nesting season by species other than the White Ibis may reflect poor productivity of fish in these short hydroperiod marshes. Loftus et al. (1990) suggested that wetlands may require extended hydroperiods at greater depths to produce larger size classes and sufficient biomass of marsh fish to support wading birds. Consequently, these temporary wetlands were less likely to provide high quality forage for Great Egrets and other species which have a diet comprised primarily of fish.

Large concentrations of wading birds in Nicodemus Slough or Fisheating Creek occurred infrequently during the breeding season, regardless of lake levels, suggesting that the remoteness of these areas precluded their use by nesting wading birds. During periods of high lake water levels, nesting birds would have been required to fly at least 30 km from Kings Bar and 10 to 15 km from the Moorehaven colonies to feed in the vicinity of Fisheating Creek and Nicodemus Slough. By comparison, wading birds nesting in the Everglades that were required to fly an average of 27 km to forage were unlikely to reproduce successfully (Bancroft et al. 1990), and foraging flights in excess of this distance may contribute to colony abandonment (Frederick and Collopy 1988).

The survey data indicated a considerable decline in Lake Okeechobee wading bird nesting populations over the course of the study period, which was at least partially due to degradation or loss of dense willow communities as primary nesting sites (David 1994). The decline was most noticeable at King's Bar, which historically had been the largest colony at the lake. Comparisons of lake habitat maps indicated that areal coverage of willow had declined by 35% between the period from 1977 to 1989 (Pesnell and Brown 1977, Richardson et al. 1991). This loss of nesting habitat could account for the poor nesting effort in 1985, despite the large number of birds that foraged at the lake between March and July. In addition, higher water levels may have prompted nesting wading birds to relocate from the large established colony at King's Bar to smaller more remote nesting sites closer to favorable foraging at the lake perimeter (David 1994).

Water management and natural hydrologic conditions can influence wading bird foraging and nesting at Lake Okeechobee. Significantly fewer wading birds foraged on the lake when lake stages were in excess of 4.6 m, suggesting that water levels in the littoral zone were too deep to provide favorable foraging habitat. In contrast, birds were attracted to the lake primarily in the breeding season when water levels exhibited steady decline below 4.6 m. Wading birds avoided nesting under extreme high or low water levels, although fluctuations in water levels did not appear to directly influence whether wading birds nested. The impact of water levels on vegetative community structure influences wading bird reproductive effort. The loss of nesting habitat and the reduction of seasonally inundated wetland communities used by foraging wading birds has probably contributed to the decline in utilization at the lake. Future management plans for the lake should include varying the regulation schedule to allow lake stages to periodically recede (at least every three years) below

3.9 m during the growing season to encourage reproduction and growth of willow communities. In addition, management should provide for the recession of water levels to below 4.3 m beginning in January to create conditions that are more conducive to foraging by nesting wading birds.

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THIRD INTERNATIONAL PENGUIN CONFERENCE

Cape Town, South Africa, 2–6 September 1996

FIRST ANNOUNCEMENT

Following on the successful First and Second International Penguin Conferences held in Dunedin, New Zealand and Phillip Island, Australia in 1988 and 1992, respectively, the Third International Penguin Conference will be held at the Breakwater Lodge, Cape Town, South Africa during 2–6 September 1996.

The conference is being organized by the African Seabird Group, with the support of local organizations and societies, under the broad theme of "Penguins: science and management". It is intended that there will be four days of formal talks and poster sessions, all in plenary, broken in the middle by an excursion to historic Robben Island in Table Bay, home of an expanding population of Jackass or African Penguins *Spheniscus demersus*. Pre- and post-conference excursions are planned to seabird colonies in the West Coast National Park and to a mainland penguin colony on the Cape Peninsula. The proceedings of the conference will be published as a special issue of the African Seabird Group's journal *Marine Ornithology*.

Persons interested in attending should write to the Organizing Committee, Third International Penguin Conference, African Seabird Group, P.O. Box 34113, Rhodes Gift 7707, South Africa, to be placed on the mailing list for the second circular, which it is planned to mail in mid-1995. The second circular will give full details of registration fee, accommodation, excursions, publication plans, etc. It would be helpful if the organizers could be informed of their intent to make a presentation when replying to the first circular. Please also include full postal and electronic mail addresses and an international fax number.

Further information may be obtained from John Cooper, Chairperson of the Organizing Committee, at the above address, or by electronic mail (jcooper@botzoo.uct.ac.za), fax (+27-21-650-3295) or phone (+27-21-650-3294). Other members of the Organizing Committee, from whom information may also be obtained, are Robert Crawford, Bruce Dyer, Norbert Klages and Tony (AJ) Williams.