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FORAGING ECOLOGY OF WADING BIRDS USING AN ALTERED LANDSCAPE IN CENTRAL FLORIDA

Prepared By

University of Florida
Department of Wildlife and Range Sciences

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FORAGING ECOLOGY OF WADING BIRDS USING AN ALTERED LANDSCAPE IN CENTRAL FLORIDA

FINAL REPORT

by

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PERSPECTIVE

Florida Institute of Phosphate Research
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In 1986, the Florida House of Representatives passed a bill initiated by Fred Jones of Auburndale that authorized the Department of Natural Resources and the Institute to study the feasibility of reclaiming Lake Hancock. Hancock is a large lake centrally located in Polk County's Lakeland/Bartow/Winter Haven triangle. It is relatively undeveloped and supports large wildlife populations, particularly wading birds. Over the years, however, Lake Hancock received large quantities of nutrients from the overflow of the Lakeland sewage treatment plant which stimulated aquatic growth. This biotic growth died, accumulated as a bottom sludge, consumed dissolved oxygen and caused the lake to become highly eutrophic. The objective of the DNR study was to investigate several strategies for reclaiming the lake including the possibility of mining the phosphate ore reserves under the lake. None of the options appeared to be economically viable under the conditions prevailing at the time of the study.

During the early part of the Lake Hancock study, many citizens were concerned as to the impact of the strategies on the bird colonies that nested around the lake. To address these concerns FIPR contracted with the University of Florida to study how the wading birds actually used the lake environs during and after the breeding season.

This report describes the procedures used and the results of the researcher's observations over an 18-month period.

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ACKNOWLEDGEMENTS

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The Florida Game and Fresh Water Fish Commission initiated the project. Everyone at the Lakeland office always pleasantly helped with advice and equipment; We particularly enjoyed the many discussions revolving around the ecology and management concerns of Lake Hancock and the phosphate mines. In particular, we thank Tim King, Jim Feiretag, Greg Holder, Brian Millsap, Joyce Ellerby, Doug Runde (Tallahassee) and the fisheries biologists. The FGFWFC pilots conducted many of the radio-tracking and colony survey flights. These pilots were outstanding. Ronnie Potts literally learned alongside how to aerial radio-track, and Jan Spangler taught how to do it well. Other private pilots also learned how to track and aided the study greatly.

The Florida Department of Natural Resources provided funding through the FGFWFC for the field assistant in the first year. IMC Fertilizer, Inc. generously provided funding during the second year, as well as maps, information, and access to their properties. The Florida Ornithological Society through their Cruickshank Research Award also financially supported the project.

Both field assistants, Martha Desmond in 1988 and Janice Osmond in 1989, were exceptional. They expertly captured and handled the egrets, and conducted all other aspects of the field work with pleasure and commitment. They also contributed greatly to the design and comprehension of our field efforts. Nancy Dwyer and her field assistants also helped at critical times. Many others assisted us in the field and we appreciate all their contributions.

The National Audubon Society, particularly Tom Bancroft and Su Jewell, provided essential advice on trapping, tagging, and tracking Snowy Egrets. Cypress Gardens allowed us to practice handling their egrets and some of their staff helped on the boat surveys. The Polk County Water Resources Division supplied limnological information and equipment. Jim Spalding of Zeller-Williams, Inc. graciously determined by computer the area of shallow water at Lake Hancock. The Lake Region Audubon Society kindly furnished a place for Naomi to sleep on Gainesville to Winter Haven runs during the non-breeding season, and several Audubon members contributed important information.

We thank Peter Frederick for his generous assistance and interest throughout the entire study. We thank G. Ronnie Best, James Rodgers, Jr. and Melvin Sunquist for contributing to the study's design. All of the above plus Bobbi Ausubel reviewed this report. Advice on statistical analysis and SAS was provided. by Steve Linda, John Smallwood and John Wood at the University of Florida.

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EXECUTIVE SUMMARY

We conducted a field study during 2 consecutive breeding seasons (1988 and 1989) on the foraging ecology of wading birds (Ciconiiformes) in a highly disturbed landscape. In particular, we examined the foraging ecology of wading birds using Lake Hancock, a hypereutrophic lake. Our efforts also focused on the relative use of various wetland types, particularly phosphate mines and other altered, nutrient-enriched ecosystems, by Snowy Egrets.

In 1988 and 1989, we conducted boat surveys around the lakeshore quantifying the number of foraging wading birds. We also measured several water parameters. Numbers of wading birds foraging at Lake Hancock increased during both years when water levels were seasonally low. In 1989, the drier of the two years, the number of wading birds was inversely correlated with water level. Furthermore, the total number of wading birds sighted in 1989 was correlated positively with water temperature and secchi depth, and negatively with dissolved oxygen.

Twelve species of wading birds were observed foraging at the lake during the two years. Both Great and Snowy egrets exhibited an irregular, but similar pattern of lake use during both years. As most of the lake was too deep to wade into, foraging birds took advantage of numerous perch substrates: this included floating mats of red maple and willow, dense cattails, and fishing nets. They also obtained fish from deep water areas by foraging aerially. The effects of poor water transparency and a limited littoral zone may be offset by the substantial fish population and limited human disturbance at the lake.

Through radio-tracking, we identified the foraging areas used by Snowy Egrets nesting at the colonies at Lake Hancock. We located 17 radio-tagged Snowy Egrets 567 times at 98 different foraging sites during the 2 breeding seasons. During the 1988 and 1989 breeding seasons, radio-tagged Snowy Egrets foraged more often, foraged in larger groups, and flew farther to feed in artificial habitats associated with phosphate mining than they did in natural habitats. The use of these artificial sites is likely due both to their temporal and spatial availability and their high biological productivity.

The patterns of use of this hypereutrophic lake and nearby phosphate mines by foraging wading birds dispels some of the popular concepts about the foraging habitat requirements of wading birds. Both areas are non-pristine, deep water systems.

In both situations, aerial foraging, an unusual and energetically expensive foraging behavior, was frequent. The results of this study demonstrate the importance of understanding the function of altered and artificially nutrient-enriched wetlands as alternatives to lost natural wetlands in a growth state such as Florida.

CHAPTER I

INTRODUCTION AND OVERVIEW

General Backsround

Florida supports a rich and diverse breeding and wintering long-legged wading bird (Ciconiiformes) population. Wading birds rely on wetlands where they forage primarily on aquatic prey (see review by Kushlan 1978). Wading bird populations are vulnerable to human exploitation and disturbance, as evidenced by their near decimation by plume hunters in the earlier part of this century (Allen 1964), and more recently in south Florida through degradation of their foraging habitat (Kushlan and White 1977, Ogden 1978, Kushlan 1979, Frederick and Collopy 1989).

Whereas many studies in Florida have examined the relationship between nesting habitat and reproductive success in wading birds (Jenni 1969, Kushlan 1976a, Maxwell and Kale 1977, Rodgers 1980a,b, 1987, Black et al. 1984, Frederick and Collopy. 1989), only recently have there been large scale and/or detailed studies of the foraging habitats they require (Rodgers 1983, Kent 1986, Bancroft et al. 1987, Collopy and Jelks 1989, Powell 1987, Bancroft et al. 1988).

The strong association between foraging habitat and wading bird nesting colonies is demonstrated by the influence of habitat availability and quality on the reproductive success, numbers of individuals and species, and location of wading bird colonies. In particular, reproductive success of wading birds can be influenced directly by the availability of prey at their foraging grounds (Owen 1960, Powell 1983, Hafner et al. 1986a, Powell and Powell 1986). Furthermore, the amount of available foraging habitat has been correlated with both population size (Custer and Osborn 1977, Burger 1981, Gibbs et al. 1987) and colony site location (Fasola and Barbieri 1978). Colony site location also may be governed by local foraging habitat conditions (Kushlan 1976a, Ogden et al. 1980). Wading bird species richness also has been correlated with the quality and quantity of available wetland habitat along the coast of the eastern United States (Kushlan 1978, Recher and Recher 1980).

What makes this study of wading birds unusual is its focus on a highly disturbed landscape, and especially the use of severely altered and newly created foraging sites in the area. A secondary focus is its rarely studied location in central Florida's interior freshwater wetlands, a different landscape habitat than the more frequently studied coastal and Everglades regions.

The importance of studying the foraging habits of wading birds in a disturbed landscape lies in the dramatic loss of natural foraging areas. From 1950 to the mid-1970s, there was a tremendous loss of palustrine emergent wetlands (freshwater marshes, wet prairies, and the Everglades), accounting for 74% of the total wetland loss in the state (Hefner 1986). What is left are fragments of the original landscape interspersed with the newly created "disturbed landscape." Wading birds therefore are constrained to rely on remnant original and altered palustrine. wetlands, non-palustrine wetlands (e.g. lakes, rivers, wooded swamps), and reclaimed wetlands. Newly created wetlands and water bodies such as phosphate mines, Wastewater treatment ponds, roadside ditches, irrigation canals, and agricultural fields provide other foraging opportunities.

Wetland losses have been most heavily concentrated in the Everglades region of south Florida (Hefner 1986); however, most of Florida has experienced a dramatic loss of its breeding populations of wading birds (Ogden 1978). The Wood Stork (Mycteria americana) is now federally listed as an endangered species and the Snowy Egret (Egretta thula), Little Blue Heron (E. caerulea), Tricolored Heron (E. tricolor), Reddish Egret (E. rufescens), and Roseate Spoonbill (Ajaia ajaja) are designated as Species of Special Concern by the state of Florida (Wood 1988).

Because quality and amount of foraging habitat is so central to reproduction of wading birds, the replacement of natural wetlands with altered ones is of concern. The role of altered wetlands in wading bird feeding and reproduction is therefore a primary research need in the development of a conservation strategy.

This study was designed to address the use and importance of an anthropogenically altered, hypereutrophic lake by foraging and nesting wading birds. The lake is situated within the heavily disturbed, phosphate mine landscape of central Florida. The relative use of nearby natural and altered wetlands as foraging habitat also was pivotal to the study.

Study Organization

My study is organized into 3 sections comprising 3 chapters. The first section (Chapter II) is an examination of the foraging ecology of wading birds using a hypereutrophic lake. Many water bodies in Florida have become increasingly eutrophic due to nutrient enrichment from either point sources such as sewage discharge or non-point sources such as storm water run-off. For 2 field seasons (1988 and 1989), I quantified the numbers of wading birds foraging on the lakeshore, examined possible relationships with several water parameters, and documented habitats used. The size, species composition, and location of wading bird colonies on and immediately adjacent to the lake also are characterized.

The second section (Chapter III) concerns the foraging ecology of Snowy Egrets. It focuses on Snowy Egrets using altered, nutrient-enriched ecosystems, particularly phosphate mines. Phosphate mining activity creates new wetlands and they are a dominant landscape feature in central Florida. During 2 breeding seasons, I captured, tagged, and radio-tracked adult Snowy Egrets at nesting colonies at Lake Hancock, to determine their relative foraging use of various wetland types.

The final section (Chapter IV) synthesizes and discusses the previous 2 chapters. It compares the similarities between Lake Hancock and the phosphate mines and contrasts them against nearby lakes.

CHAPTER II

WADING BIRD USE OF LAKE HANCOCK, A HYPEREUTROPHIC LAKE

Introduction

Large nesting colonies of wading birds often occur in proximity to large lakes (Parris and Grau 1979, McCrimmon 1982, Nesbitt et al. 1982, Yee 1985, Edelson in press), but only a few studies have closely investigated wading bird use of these lacustrine habitats (Jenni 1969, Parris and Grau 1978, Whitefield and Cyrus 1978, Zaffke 1984, Pyrovetsi and Crivelli 1988). Lakes appear to be seasonally important and in periods of drought take on increased significance (Heitmeyer 1986, Jelks and Collopy 1987). Wetland areas associated with and influenced by lake levels also can be important foraging habitat (Whitefield and Cyrus 1978, Zaffke 1984).

Unlike marshes, which are frequently used as foraging habitat by wading birds, lakes are available for foraging temporally, but they are restricted spatially. Although lakes are permanent water bodies, remaining available for foraging throughout a season or year, much of the open water region of a lake is too deep for a heron to wade into; commonly there is only a narrow littoral zone available to wading birds.

The use of a particular habitat and foraging strategy by a given species is influenced by the species' morphological features, foraging behavior (e.g. visual vs. tactile, stalker vs. active pursuer) and prey selection (reviewed by Kushlan 1978). At lake sites, heron leg length, for example, could be a major factor influencing the use of these relatively deep water systems by different species (Powell 1987). Lakes typically support fish populations, but due to the narrow littoral zone they may have limited vulnerability to wading birds. Even though most lakes fluctuate annually and become shallower with lower water levels, they rarely become so shallow that they concentrate prey. Instead, predatory fish species may drive smaller fish to inhabit the vegetated littoral zone (Werner et al. 1983) enhancing the prey's availability to wading birds.

Several environmental variables also may influence use of lakes by wading birds. Wind, wave action, rain, and turbid water may interfere with the ability of visually feeding herons to forage efficiently (Owen 1960, Krebs 1974, Recher and Recher 1980, Rodgers 1983). In addition, limnological parameters such as water temperature and dissolved oxygen govern fish distribution (Moyle and Cech 1982), potentially influencing their availability to herons.

There are 7,783 lakes in Florida, encompassing 927,273 ha (Heath and Conover 1981). Florida has many naturally occurring eutrophic lakes, but many of the lakes in the central Florida region have become increasingly eutrophic due to human related activities such as sewage and industrial discharge and stormwater run-off (Edmiston and Myers 1984). Eutrophic systems are generally associated with high nutrient concentrations, high chlorophyll-a concentrations, high primary productivity, and reduced water transparency (Wetzel 1983). This results in increased algal bloom frequencies, high algal, benthic and fish biomass: but low algal, benthic, and fish species diversity.

The use of lakes by wading birds in Florida, particularly the use of eutrophic lakes, has not been studied adequately. Three studies have examined the use of lakes by foraging wading birds in Florida (Jenni 1969, Jelks and Collopy 1987, Zaffke 1984) ; Zaffke (1984) investigated a eutrophic system focusing on the marshes associated with Lake Okeechobee, and Jenni (1969) conducted a primarily observational study of heron breeding and feeding ecology at a small eutrophic lake in north-central Florida. Consequently, we do not have a clear understanding of the relative importance of lakes in Florida wading bird nesting and feeding ecology.

My objectives in conducting this study were to obtain an index of the number of wading birds foraging at a hypereutrophic lake in central Florida, quantify the habitat types used by the wading birds, and monitor temporal changes in bird numbers related to season, water level and limnological conditions. Another objective was to document the location of wading bird nesting colonies on and immediately adjacent to Lake Hancock and estimate their number of breeding pairs and species composition.

Study Area and Backsround History

Lake Hancock is located about 13 km east of Lakeland in Polk County, Florida. Polk County contains 550 lakes and ranks fourth in number of lakes among all counties in Florida (Heath and Conover 1981). Lake Hancock is one of the largest lakes in the county, encompassing 1,843 ha. It is uniformly shallow with its deepest point being only 1.2 m (Zellars-Williams, Inc. 1987).

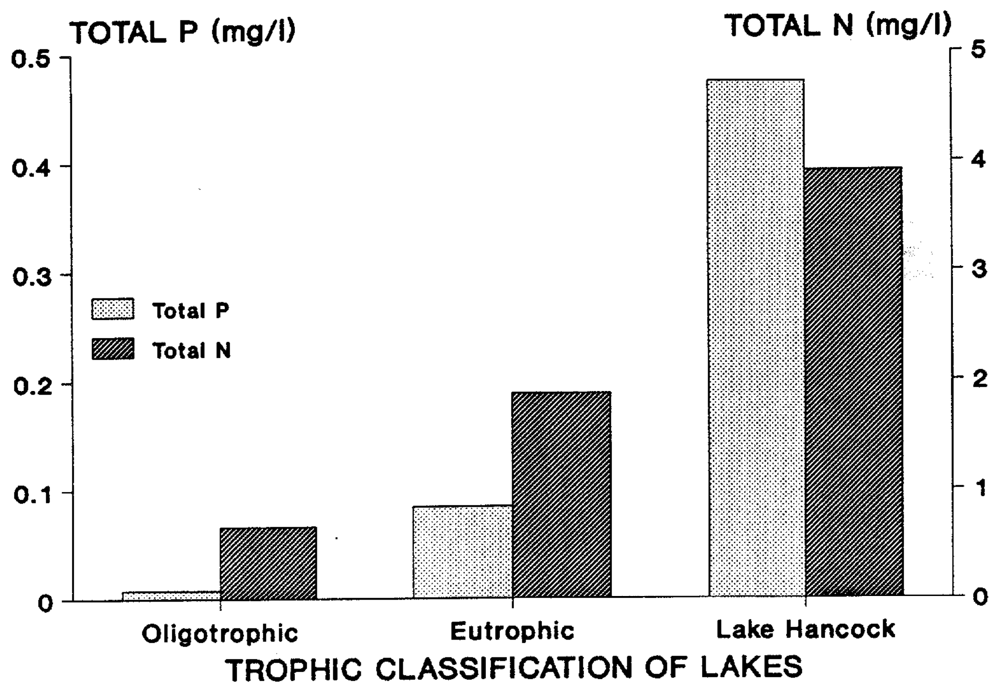
Although Lake Hancock is located in an area with numerous lakes, in its present condition it is an atypical lake. From 1926 to 1987, the lake received effluent from the city of Lakeland's sewage treatment facility. It continues to receive discharge from citrus processing Wastewater facilities, a distillery, and the city of Auburndale's sewage plant. Historically, phosphate mining and other activities within the watershed also have contributed high levels of phosphorus, nitrogen, and suspended solids (Zellars-Williams, Inc. 1987). Due to the input of these additional nutrients, the lake contains extremely high levels of phosphorus, nitrogen and chlorophyll-a and has reduced water transparency (Zellars-Williams, Inc. 1987 and PCWRD 1990). Based on these conditions, it is classified as a hypereutrophic system (Figure 2.1) (Wetzel 1983). According to the Florida trophic standard index (TSI), which also is based on a lake's state of enrichment with nutrients and uses a scale of 1-100, Lake Hancock is a "problem lake" with a TSI greater than 60 (Brezonik 1984). Before the suspension of Lakeland's sewage discharge into the lake, the TSI went over the scale reaching 103, but it has since improved with a recent TSI value of 87 (PCWRD 1990).

Because of its hypereutrophic condition, Lake Hancock has been identified for restoration under the state's Surface Water Improvement and Management program (SWFWMD 1989; also see Edminston and Myers 1984) and its restoration was mandated by the state legislature in 1986 (House Bill 1057). This study was funded and initiated by several state agencies that were interested in assessing the lake's importance to wildlife in order to design a restoration plan for the lake.

Lake Hancock's water level is controlled by a dam located at its southern outflow. The water level normally is maintained between 29.3-30.2 m above mean sea level (MSL) (SWFWMD 1987), limiting the lake's natural fluctuations. Water levels at Lake Hancock, however, normally reflect central Florida's sub-tropical rainfall patterns, with the lake stage increasing during the summer wet season and receding during the dry spring months.

The lake supports an abundance of fish (FGFWFC 1986), which in turn supports high densities of piscivorous predators including American alligators (*Alligator mississipiensis*), Ospreys (*Pandion haliaetus*), Bald Eagles (*Haliaeetus leucocephalus*), Double-crested Cormorants (*Phalacrocorax auritus*), and numerous long-legged wading birds (Ciconiiformes).

The lake's shoreline is bordered by an extensive floating mat dominated by red maple (*Acer rubrum*) and willow (*Salix* spp.), and a narrow littoral zone dominated by pickerelweed (*Pontederia cordata*), cattails (*Typha* spp.) and bald cypress (*Taxodium distichum*). Less than 5% of the shoreline is developed for human uses and includes three pastures which border the littoral zone.



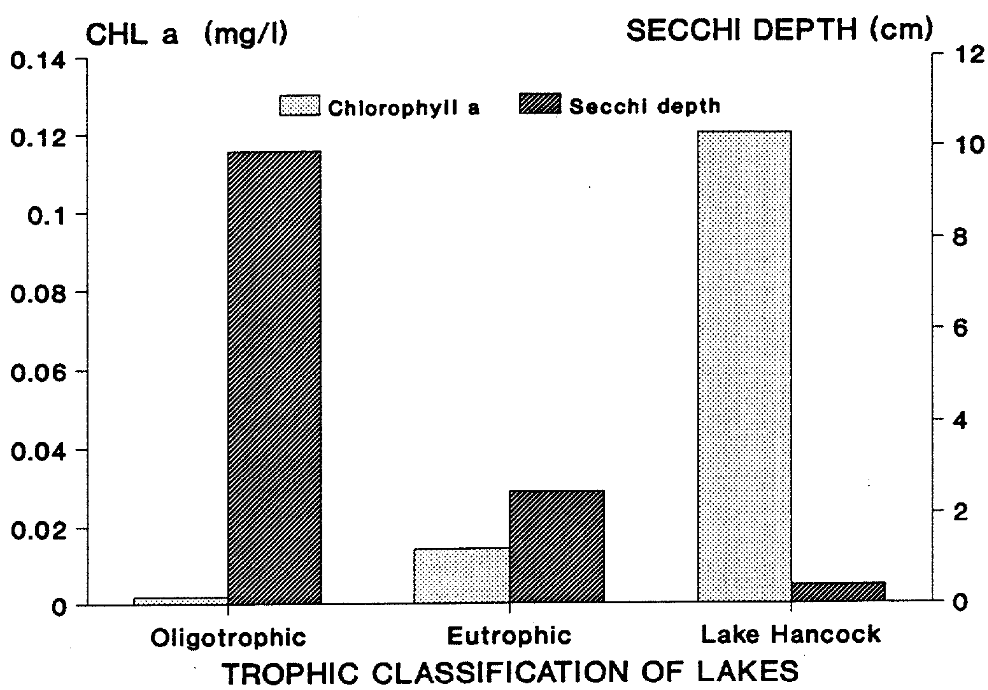


Figure 2.1. Trophic classification of lakes; Lake Hancock is considered hyper-eutrophic. a) total phosphorus and total nitrogen: b) chlorophyll-a and secchi disk transparency depth (from Wetzel 1983, PCWRD 1990).

Methods

Estimates of Breeding Pairs

Aerial and ground estimates were made of the number of breeding pairs in each colony on and immediately adjacent (0.5 km) to Lake Hancock. Aerial estimates for white-plumaged birds were obtained by circling about 60-90 m above the colony in a single-engine, fixed-wing aircraft. Species composition and counts were verified from the ground by walking through colonies, circling them in a canoe, and using a spotting scope and binoculars from the shore. Ground counts were essential for accurate counts of the number of dark-plumaged wading birds as well as to verify the number of white-plumaged species. All counts were conducted before 10:00.

Lakeshore Surveys of Foraging Wading Birds

Surveys were conducted from a 4.3 m boat propelled by a 15 hp outboard motor with a boat operator and observer present; I acted as the observer for all surveys throughout both years. We drove close to the shoreline to detect and/or flush hidden wading birds out of the heavily vegetated habitats (e.g. forested and cattail areas). Data were recorded by speaking into a cassette recorder. Each wading bird and the vegetation type it was standing in was recorded. Cattle Egrets (*Bubulcus ibis*) were not included in the counts as they are considered primarily terrestial foragers (Kushlan 1978). To avoid double counting the same individuals, we attempted to monitor where flushed birds landed and avoided recording any second sightings.

Surveys began in the morning usually within an hour of daybreak; occasionally, due to dense morning fog, surveys were. delayed until 2 to 3 hours after daybreak. The entire lakeshore including Saddle Creek outflow to the dam was surveyed in about one and two hours. The direction of travel was alternated each time. Surveys were conducted under calm (less than 24 km/h winds) and relatively sunny conditions.

I conducted 21 boat surveys from March through September 1988, and 25 surveys between February and September 1989. Surveys were conducted at weekly intervals during April-July, but varied between one and three weekly intervals from February-March and August-September 1988 and 1989.

Foraging habitat types

Foraging habitats were classified into 6 types, including emergent vegetation, cattail, forested shoreline, open water, perches, and pastures.

Herbaceous plants such as water pennywort (*Hydrocotyle* spp.), maidencane (*Panicum* spp.), pickerelweed, and elephant-ear (*Xanthosoma sagittifolium*) were classified as emergent shoreline vegetation. Cattail habitat was analyzed separately from the other emergents due to its prevalence and structural difference from the other primarily low and sparsely spaced, emergent vegetation. Cypress, red maple, willow, and oak (*Quercus* spp.) trees, and various shrubs such as buttonbush (*Cephalanthus occidentalis*) were classified as forested shoreline habitat.

A bird was considered to be foraging in open water if it was surrounded by at least 1 m of open water (i.e. non-vegetated area). The transition between the littoral and limnetic zones usually included a limited area of open water. Birds also were considered foraging in open water if they were using the limnetic zone by standing on a low perch site (e.g. dead limb, stump, seine net, or fence post) surrounded by open water.

Wading birds also commonly engaged in aerial foraging behavior. A bird foraged aerially by dipping its bill into the open water to seize prey while flying. This behavior allowed the birds to obtain fish from deep water regions. Birds that foraged aerially were classified as using the open water habitat type.

Wading birds standing on a perch site that was too high to forage from (i.e. about 2 times their height) were put in the perch category. Birds typically departed from a high perch site (e.g. a tree, shrub, fence post) to aerial forage. I assumed that all perched birds were potential aerial foragers and classified them in either forested or perch habitat types. In 1989, I distinguished between high and low forest. A bird wading in water under a forested canopy or standing on a red maple hummock, but able to reach the water, was classified as in low forest habitat. A bird standing anywhere above reachable water was classified as being in high forest habitat.

A wading bird foraging along the emergent or open water edge of a pasture was classified as using emergent or open water. A bird using the upland region was classified as using pasture.

Water parameters

In 1988 and in 1989, at the end of each survey, I recorded the lake's water level from a permanent gauge located at the dam in the southern outflow. Water level data were not obtained for 2 surveys in 1988 (20 March and 13 April).

In 1989, I measured dissolved oxygen, water temperature, and water transparency depth in the lake, at sunrise prior to each survey from 14 April to 1 September. Water temperature and dissolved oxygen were measured in the top 5 cm of the surface water using a YSI oxygen meter. I air-calibrated the oxygen meter in the field just prior to each survey. A secchi disk was used to determine the transparency depth, using the same observer each time. I collected measurements from a total of 8 stations along the southwestern shore; measurements were taken from 2 stations in each of the 4 habitat types (i.e. forested (red maple/willow), cattail, emergent (pickerelweed), and open water).

I tested for correlations among all water parameters and between water parameters and the number of observed birds by species using Spearman's rank correlation coefficient.

Habitat use and availability

I determined the area of visible shoreline for each vegetation type from a large-scale aerial photograph (1:7579) taken in December 1987. Vegetation types were ground verified in July 1989. The shoreline area was calculated as the amount of area visible to me as I conducted the surveys. The width of both cattail and forested areas was based on the average distance (about 3 m) from the water's edge at which I reliably could see a heron. Emergent shoreline and open water areas were entirely visible and their area was calculated directly from the map. Water pennywort, an emergent macrophyte, commonly occurred as sporadic, small (<2 m^2) patches that were not distinguishable on the aerial photograph. Therefore it is probable that the area of emergent shoreline was underestimated.

Assuming a random distribution of birds, I estimated the expected number of waders based on the relative area of the 3 shoreline habitats (forested, emergent, and cattail) for the most conspicuous species [Great Blue Heron (*Ardea herodias*), Great Egret (*Casmerodius albus*), Snowy Egret, White Ibis ~~(Eudocimus~~ *albus*), and Wood Stork], and tested this against the number of observed birds using a Chi-square goodness-of-fit test. The number of observed birds in forested and cattail habitats were likely underestimated due to the difficulty of detecting birds in these densely vegetated habitats.

The area of open water available for wading bird use was calculated by superimposing the vegetative zones deliniated on the aerial photograph onto a bathimetric map of the lake bottom contours. From this map, using 0.31 m and 0.61 m contours (map was in one foot (0.3048 m) contour intervals) determined at a low water stage (29.56 m MSL), the area of open water available for the relatively longer-legged waders (e.g. Great Egret and Great Blue Heron) and shorter-legged species (e.g. Snowy Egret), respectively, was determined.

Results

Breeding Wading Birds

During the 1988 breeding season I estimated that 5,403 pairs of wading birds nested in 6 colonies located on and directly adjacent to the lake (Figure 2.2, Table 2.1). In 1989, 4 colonies containing an estimated 3,867 breeding pairs were located at Lake Hancock (Table 2.2). Though the same 11 species of wading birds nested at Lake Hancock in both 1988 and 1989, individual colonies exhibited interyear variation in nesting species composition and number of pairs.

Foraging Wading Birds

Bird numbers on the lakeshore

In both years, there was an overall trend of increasing bird numbers between March and July, followed by a substantial drop in numbers in August and September (Figure 2.3). The total number of wading birds observed foraging on Lake Hancock ranged from 273 to 873 in 1988, and included 10 species (Table 2.3). The range and total number of observed birds was very similar in 1989, ranging from 216 to 903 individuals of 12 wading bird species (Table 2.3). All species of wading birds nesting in colonies on or immediately adjacent to Lake Hancock were observed foraging at the lake. Three species that did not nest at the lake also were observed foraging at Lake Hancock.

Water parameters

In 1988, Lake Hancock's water level reached its lowest level (29.61 m MSL) between 10-17 June and its highest on 18 September (30.11 m MSL). During the study period in 1989, the water level dropped lower than in 1988, falling to 29.49 m (MSL). In 1989, the water rose to its highest level (29.86 m MSL) on 24 September, the last survey.

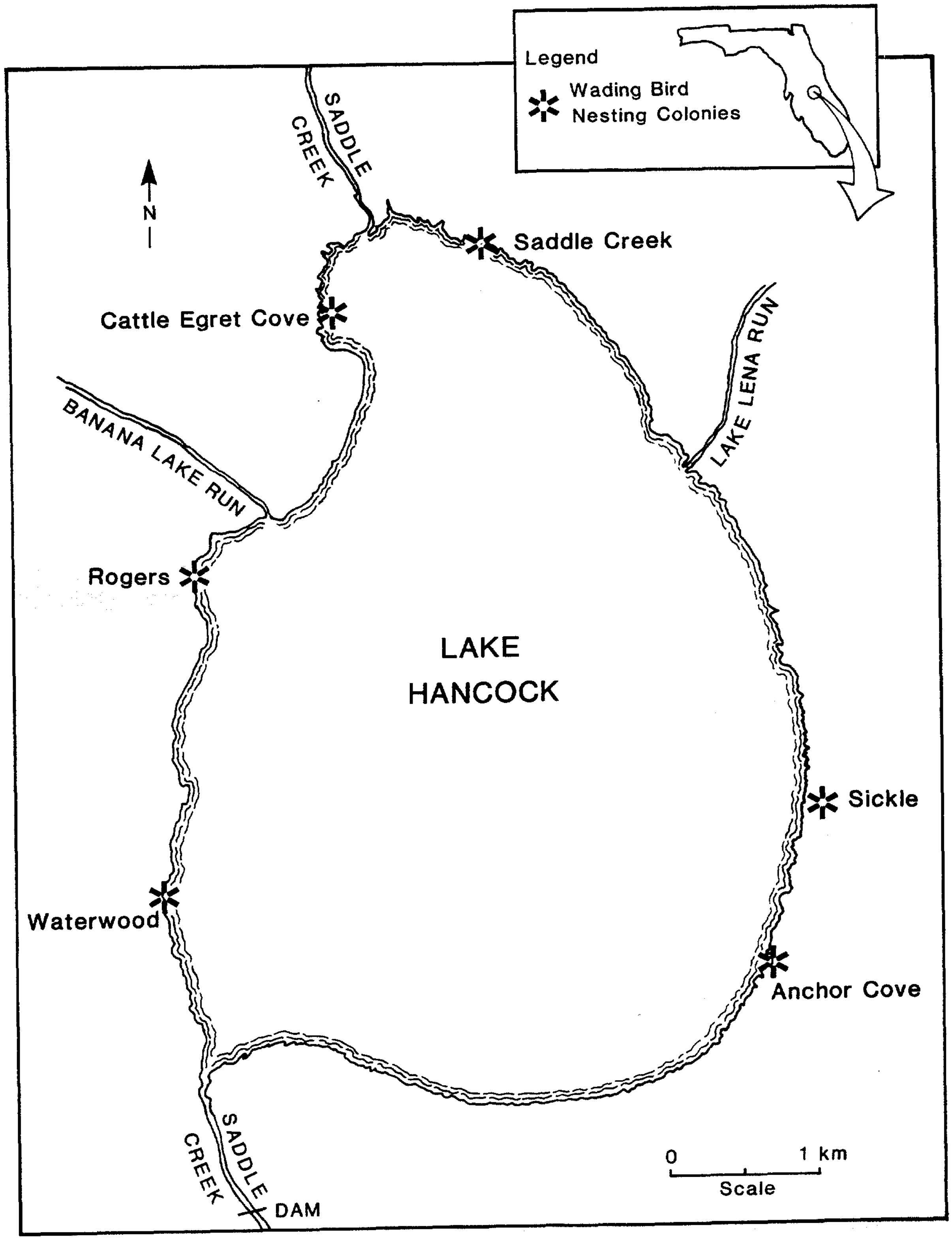


Figure 2.2. Lake Hancock, Polk County, Florida, with nesting colonies of wading birds.

Table 2.1. Size and species composition of wading bird colonies at Lake Hancock in 1988.

Species	SIC	CEC	SAD	ANC	WW	ROG	SCA	Totals
	Colony[1] (Number of Breeding Pairs)							
Great Blue Heron	0	0	60	0	0	10	25	95
Great Egret	90	0	8	0	0	14	0	112
Snowy Egret	40	100	0	5	15	0	0	160
Little Blue Heron	15	50	0	30	15	0	0	110
Tricolored Heron	10	20	0	5	5	0	0	40
Green-backed Heron	0	0	0	0	1	0	UNK[2]	UNK
Black-crowned Night-heron	20	0	0	0	0	0	0	20
Cattle Egret	285	300	0	0	50	0	0	635
White Ibis	4230	0	0	0	0	0	0	4230
Glossy Ibis	UNK	0	0	0	0	0	0	UNK
Colony Total	4690	470	68	40	86	24	25	5403

[1]Colony Abbreviations: SIC=Sickle, CEC=Cattle Egret Cove, SAD=Saddle Creek, ANC=Anchor Cove, WW=Waterwood, ROG=Rogers, SCA=Scattered along lakeshore. See Figure 2.2 for colony locations. [2]UNK=Present but unknown numbers.

Table 2.2. Size and species composition of wading bird colonies at Lake Hancock in 1989.

Species	SIC	CEC	SAD	ANC	WW	ROG	SCA	Totals
	Colony[1] (Number of Breeding Pairs)							
Great Blue Heron	0	1	40	0	0	2	25	68
Great Egret	65	0	8	0	0	10	0	75
Snowy Egret	40	50	0	0	0	5	0	95
Little Blue Heron	15	20	0	0	0	0	0	30
Tricolored Heron	10	10	0	0	0	0	0	20
Green-backed Heron	0	0	0	0	0	0	UNK[2]	UNK
Black-crowned Night-heron	10	0	0	0	0	0	0	10
Cattle Egret	390	150	0	0	0	16	0	556
White Ibis	3000	0	0	0	0	0	0	3000
Glossy Ibis	UNK	0	0	0	0	0	0	UNK
Colony Total	3530	231	48	0	0	33	25	3867

[1]Colony Abbreviations: SIC=Sickle, CEC=Cattle Egret Cove, SAD=Saddle Creek, ANC=Anchor Cove, WW=Waterwood, ROG=Rogers, SCAT=Scattered along lakeshore. See Figure 2.2 for colony locations. [2]UNK=Present but unknown numbers.

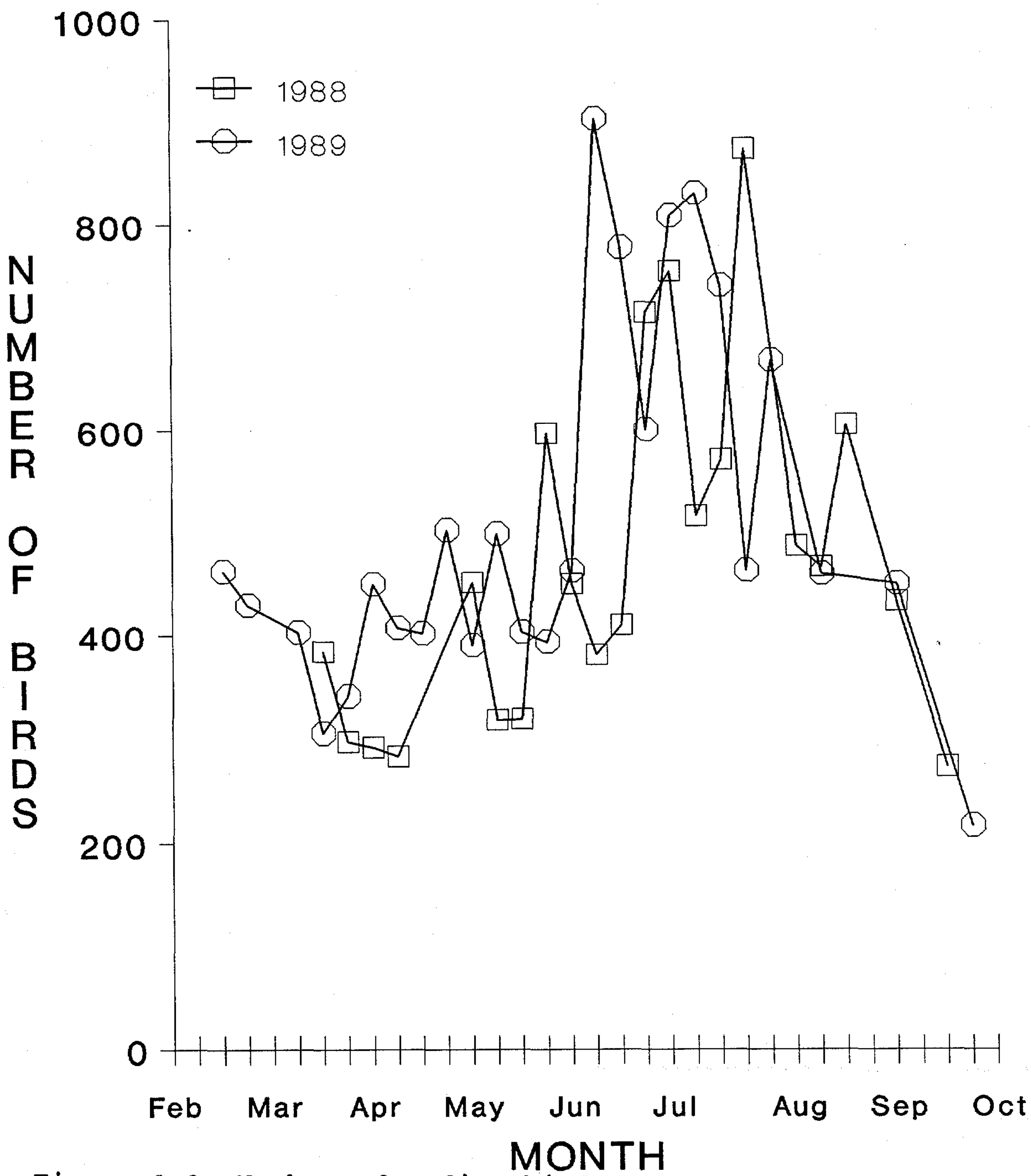


Figure 2.3. Number of wading birds observed foraging at Lake Hancock by month, 1988 and 1989.

Table 2.3. Variation in the number of observed wading birds foraging at Lake Hancock, Polk County, Florida in 1988 and 1989.[1]

	1988		1989	
SPECIES	MIN	MAX	MIN	MAX
Great Blue Heron	90	185	93	207
Great Egret	51	209	52	340
Snowy Egret	14	155	25	224
Little Blue Heron	5	33	7	44
Tricolored Heron	2	13	1	14
Green-backed Heron	0	18	1	17
Black-crowned Night-Heron	2	52	3	59
Yellow-crowned Night-Heron	0	0	0	1
White Ibis	1	39	0	92
Glossy Ibis	0	7	0	13
Wood Stork	0	240	0	73
Roseate Spoonbill	0	0	0	5

[1]See Appendix for number of birds observed for each species by date and year.

Additional water parameters, measured in 1989, also exhibited a seasonal pattern. The lowest mean water temperature (21.6 C) was recorded in April and the highest in September (29.7 C) (Figure 2.4a). Mean dissolved oxygen was recorded at its lowest (0.33 mg/l) on 3 July (Figure 2.4a). The highest dissolved oxygen (6.44 mg/l) was recorded on 22 April when I first began collecting these data. Mean secchi depth reading ranged from 10.75 to 22 cm (n=18 surveys); water transparency was most diminished during the last two surveys in July and the clearest was on 30 April (Figure 2.4b). In general, as water level dropped, water temperature increased, dissolved oxygen decreased, and water transparency diminished. All combinations of water parameters were significantly correlated (Table 2.4) although the direction of correlations varied considerably.

Bird numbers and water parameters

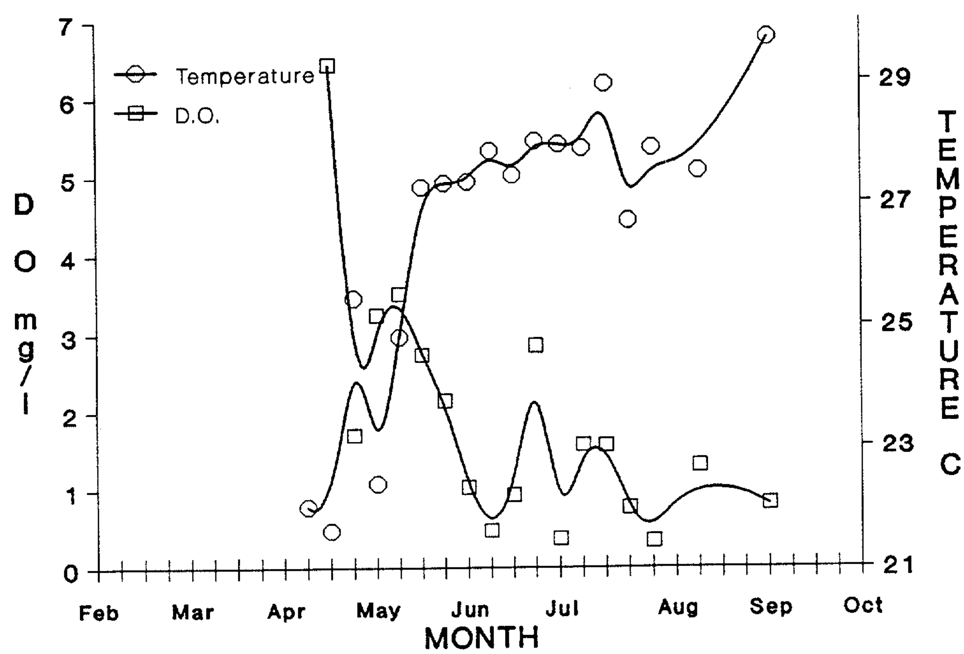
Water level was not significantly correlated with total bird numbers in 1988 (r=-0.31, P=0.20). The highest count of wading birds occurred at the end of July when the water level, while still relatively low at 29.76 m MSL, had been already rising for a month (Figure 2.5a). Two of the next highest counts, however, occurred during the lowest water levels (29.61 m MSL) in mid-June 1988.

In 1989, the total number of wading birds exhibited a significant positive correlation with water temperature and secchi depth, and showed a significant negative correlation with dissolved oxygen and water level (Table 2.4). As the water level fell, the number of wading birds using the lake increased, and as water level rose, the number of wading birds decreased (Figure 2.5b). The highest count of wading birds was recorded in mid-June, when water levels on Lake Hancock were lowest.

In both years, Great Blue Herons, Great Egrets, and Snowy Egrets were observed consistently more often than other wading birds, and they exhibited a greater variation in numbers (Table 2.3). Both Great and Snowy egrets exhibited an irregular, but similar pattern of lake use during both years (Figure 2.6). Great and Snowy Egret numbers were significantly correlated with each other (1988: r=0.859 P=0.0001; 1989: r=0.84, P=0.0001). The greater numbers of these two species probably accounted for most of the variation in total bird numbers.

In 1989, the numbers of Great Egrets and Snowy Egrets exhibited a significant negative correlation with the lake's water level and mean dissolved oxygen, and showed a significant positive correlation with mean water temperature and mean secchi depth (Table 2.4). Both species of egrets not only followed the seasonal pattern of greater numbers during lower lake levels, but also followed the intraseasonal water level fluctuation in 1989 (Figure 2.7).

a



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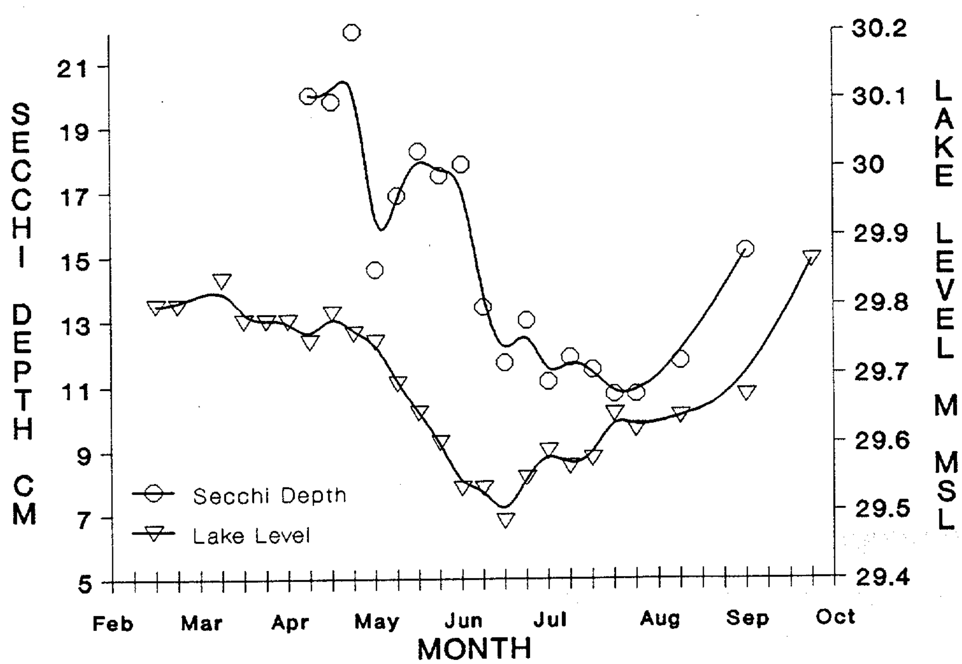


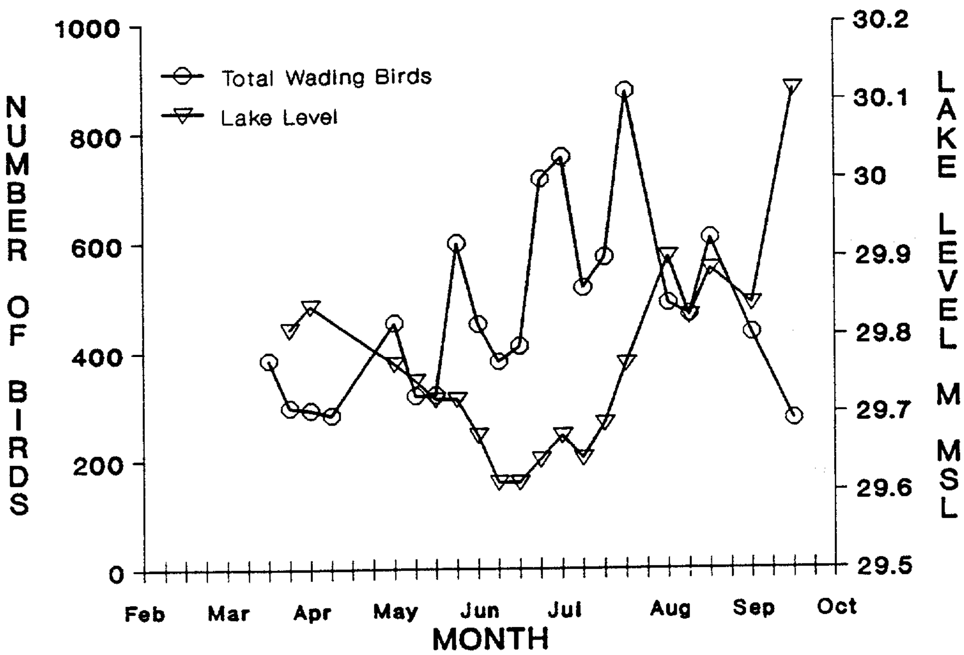
Figure 2.4. Seasonal variation of water parameters at Lake Hancock, 1989. a) dissolved oxygen and water temperature; b) secchi disk transparency depth and lake level. Curves fitted graphically by Harvard Graphics.

Table 2.4. Correlations between water parameters and wading bird numbers, 1989.[1]

	Water level	Water temperature	Dissolved oxygen	Secchi transparency depth
Water temperature	r=-0.636 P= 0.005			
Dissolved oxygen	r= 0.471 P= 0.056	r=-0.560 P= 0.019		
Secchi transparency depth	r= 0.512 P= 0.030	r=-0.588 P= 0.012	r= 0.649 P= 0.005	
Total wading birds	r=-0.704 P= 0.0001	r= 0.587 P= 0.011	r=-0.533 P= 0.027	r=-0.542 P= 0.020
Snowy egrets	r=-0.785 P= 0.0001	r= 0.688 P= 0.002	r=-0.647 P= 0.005	r=-0.684 P= 0.002
Great egrets	r=-0.795 P= 0.0001	r= 0.641 P= 0.004	r=-0.575 P= 0.016	r=-0.475 P= 0.047

[1]r=Spearman's rank coefficient. See Appendix for water parameter data by date.

a



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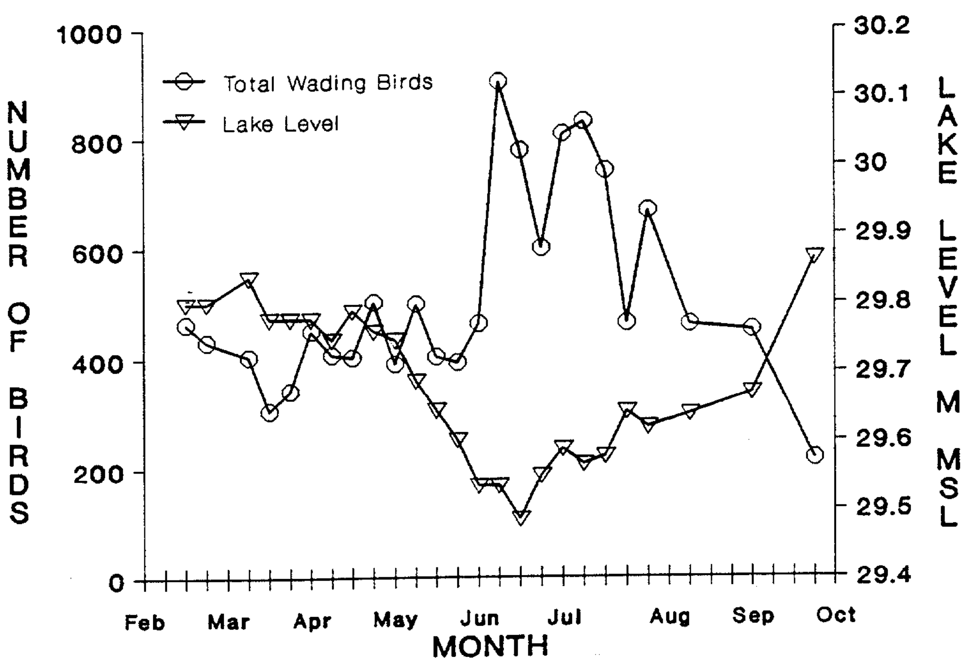


Figure 2.5. Number of wading birds observed foraging at Lake Hancock in relation to lake level and month. a) 1988; b) 1989.

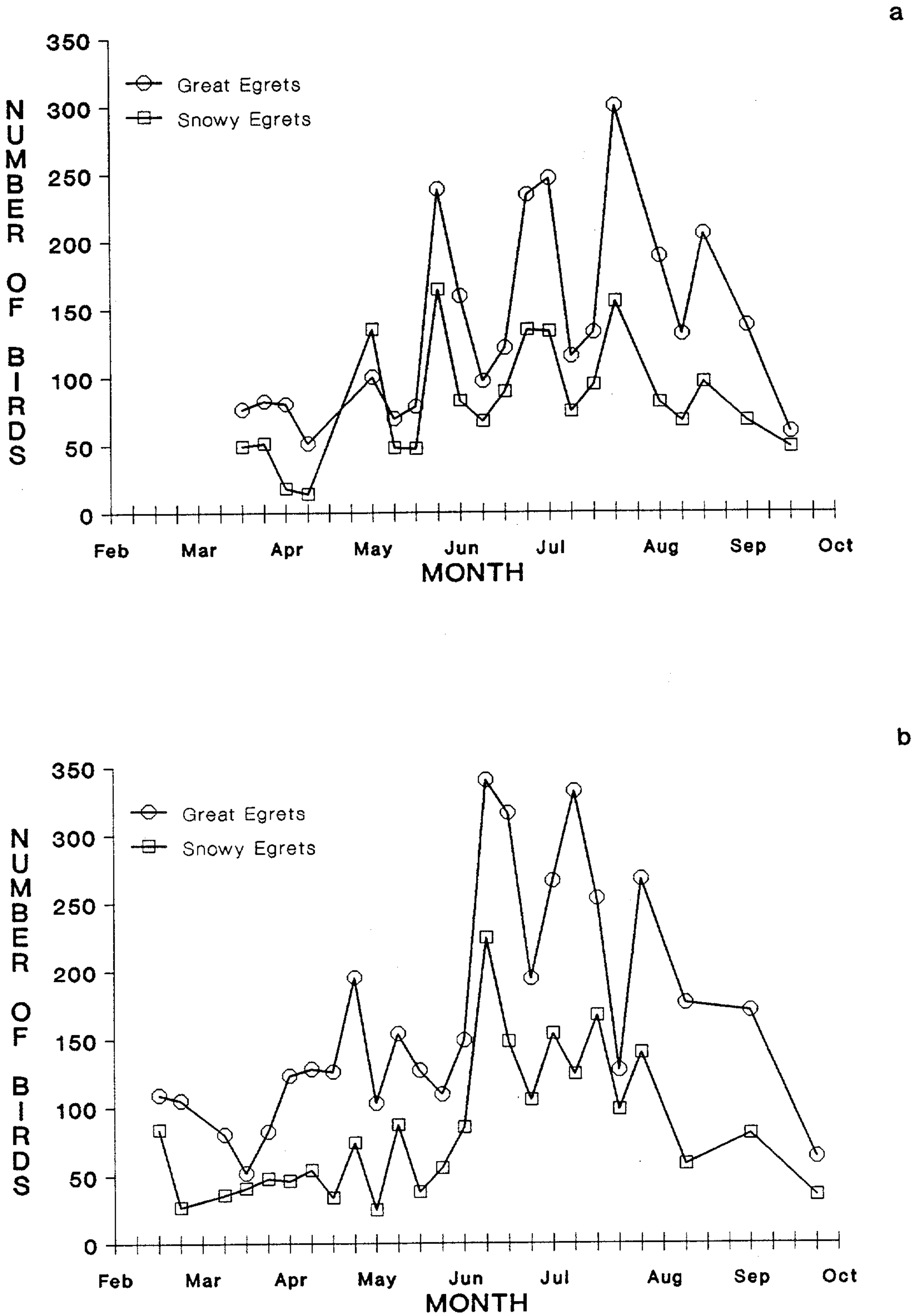


Figure 2.6. Number of Great and Snowy egrets observed foraging at Lake Hancock. a) 1988; b) 1989.

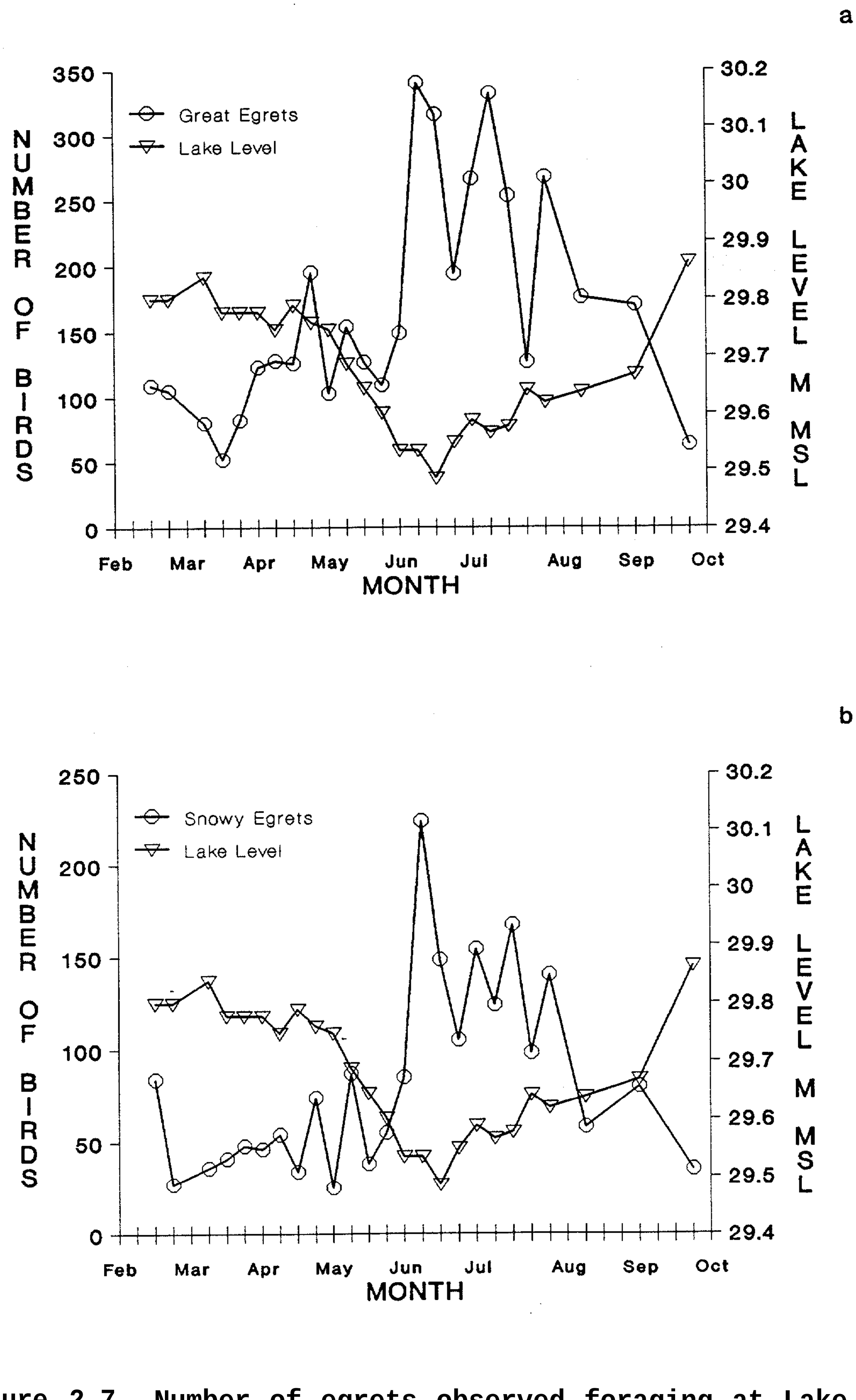


Figure 2.7. Number of egrets observed foraging at Lake Hancock, 1989. a) Great Egrets: b) Snowy Egrets.

The number of egrets observed in 1988 also fluctuated widely: however their presence on the lake was not significantly (P>0.05) correlated with water level (Figure 2.8).

In contrast to the temporal pattern of egret abundance on the lake, the number of Great Blue Herons observed remained relatively constant (Figure 2.9), usually varying by less than 30 individuals from survey to survey. Over the study period, Great Blue Heron numbers doubled whereas Great and Snowy Egret numbers showed a four- and eight-fold difference, respectively. Water level was not significantly negatively correlated with the observed number of Great Blue Herons in either year (1988:r=-0.29, P=0.24; 1989:r=-0.12, P=0.58). None of the water parameters I measured were correlated significantly (P>0.05) with Great Blue Heron numbers.

Less than 45 Little Blue Herons were observed each year. In 1989, the number of Little Blue Herons was significantly correlated with mean water temperature (r=0.55, P=0.02) and mean secchi depth (r=-0.79, P=0.0001), but not with water level or mean dissolved oxygen (P>0.05).

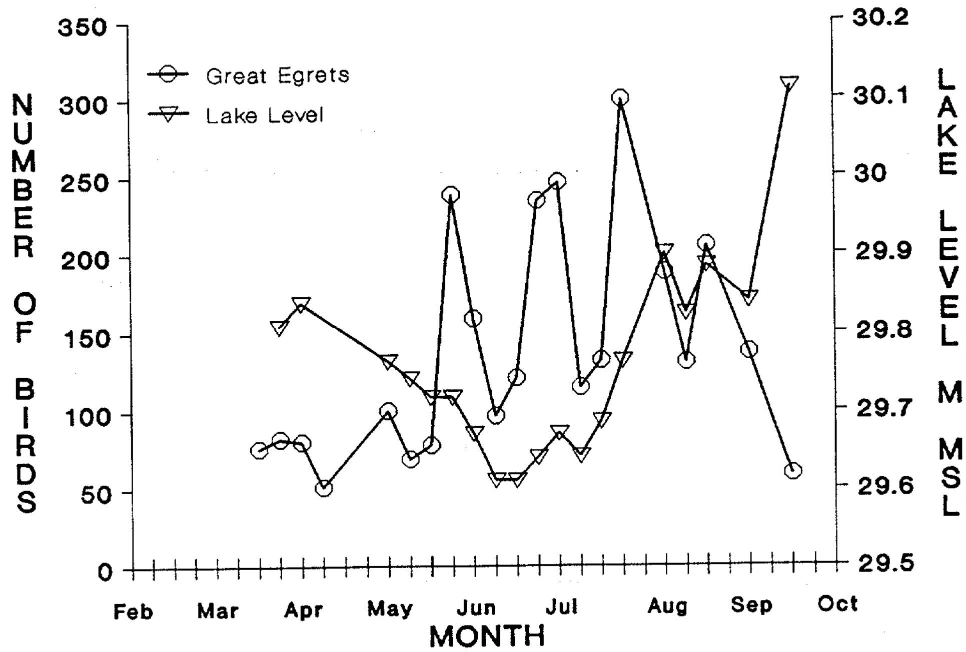
Both Tricolored Herons and Green-backed Herons (Butorides striatus) also were observed in low numbers. Because of their low numbers and relatively low detectibility, I did not analyze the numbers of these species in relation to water parameters. Many of the Black-crowned Night-herons (Nycticorax nycticorax) I observed during the boat surveys may have been disrupted from their day-time roosts in the willows along the shore. Consequently, I did not analyze the numbers of night-herons in relation to water parameters.

Both White and Glossy Ibises (Plegadis falcinellus) were observed foraging at the lake. White Ibises were the only species whose numbers correlated significantly with lake level in 1988 (r=-0.71, P=0.0007). More White Ibises were observed using Lake Hancock in 1989 than 1988, with the highest number being counted during the period of lowest water level; however, overall there was no significant correlation (P>0.05) with water level or any other water parameter.

Glossy Ibises were observed infrequently, occurring on 7 surveys in 1988, and 3 surveys in 1989. On all occasions, with the exception of a single bird, Glossy Ibises were observed at a sandbar near an inflow (Lake Lena Run) into Lake Hancock that becomes exposed at low water.

Wood Storks were observed using the lake primarily during their non-breeding season; they did not nest in any of the lake colonies. In both years they were present both in late winter (February-March) and re-appeared again during June (Figure 2.10). Stork summer-time use of the lake coincided with low water levels

a



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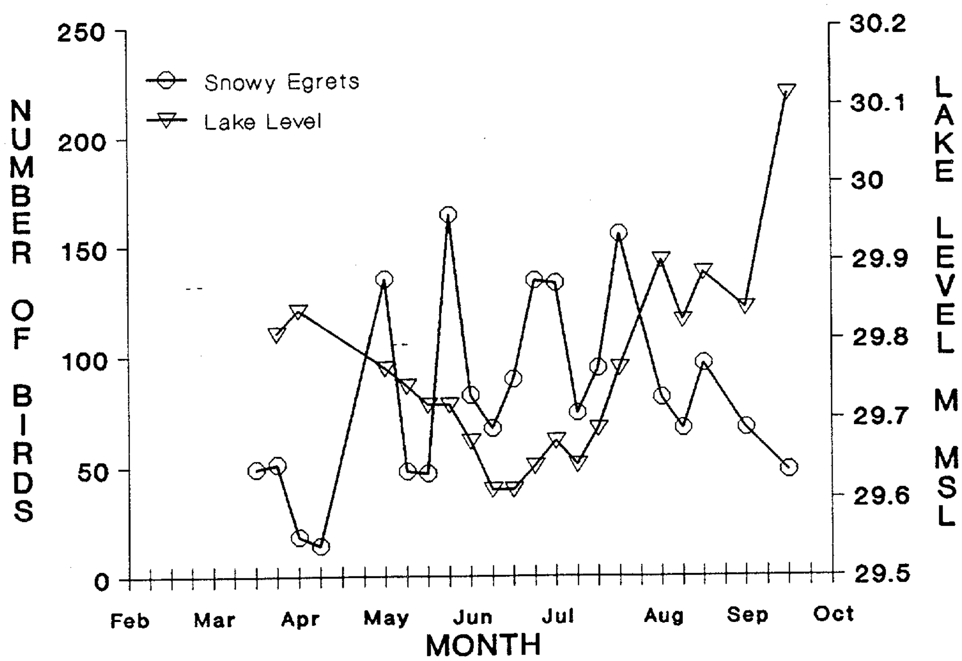


Figure 2.8. Number of egrets observed foraging at Lake Hancock, 1988. a) Great Egrets: b) Snowy Egrets.

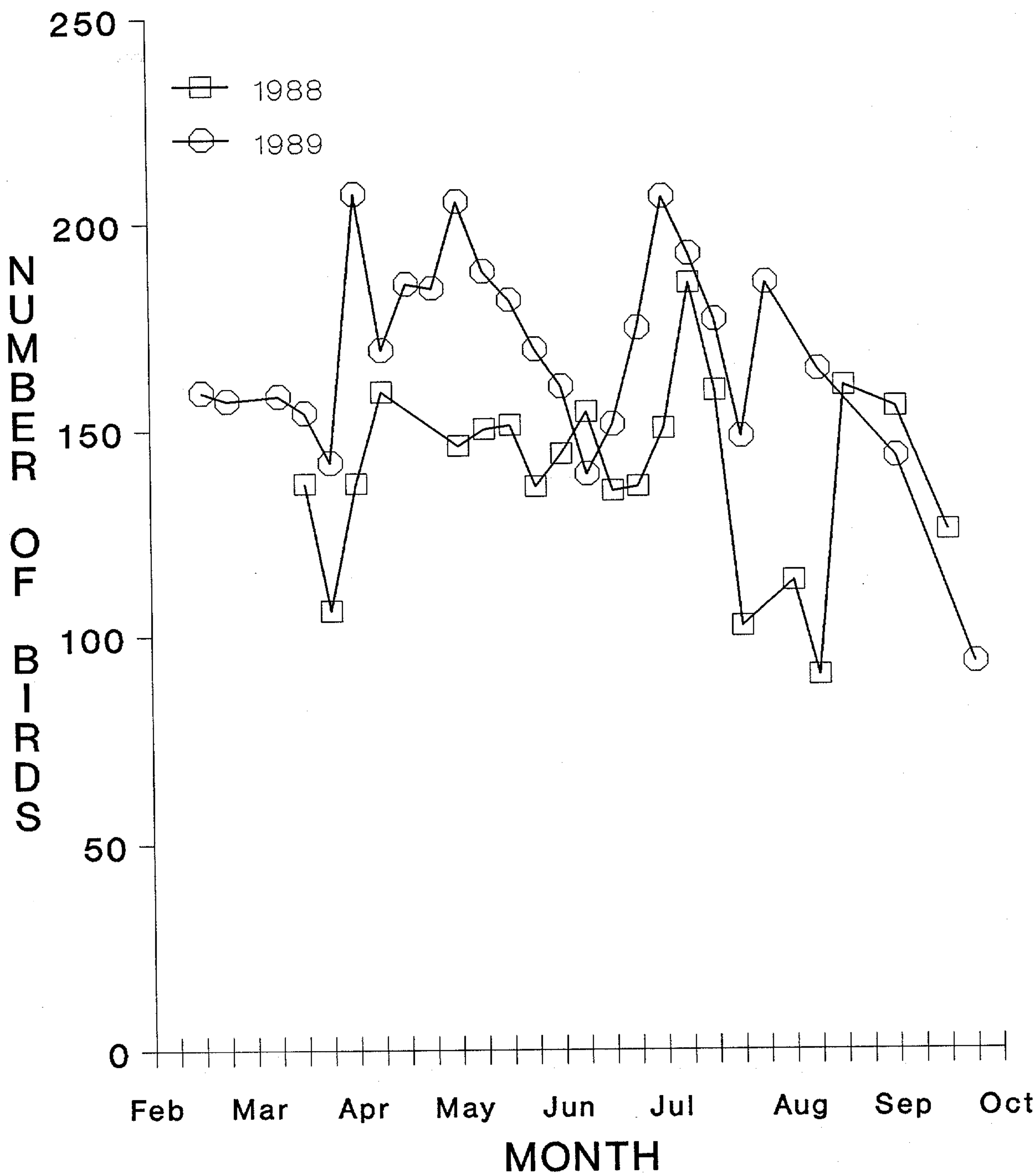


Figure 2.9. Number of Great Blue Herons observed foraging at Lake Hancock in relation to month, 1988 and 1989.

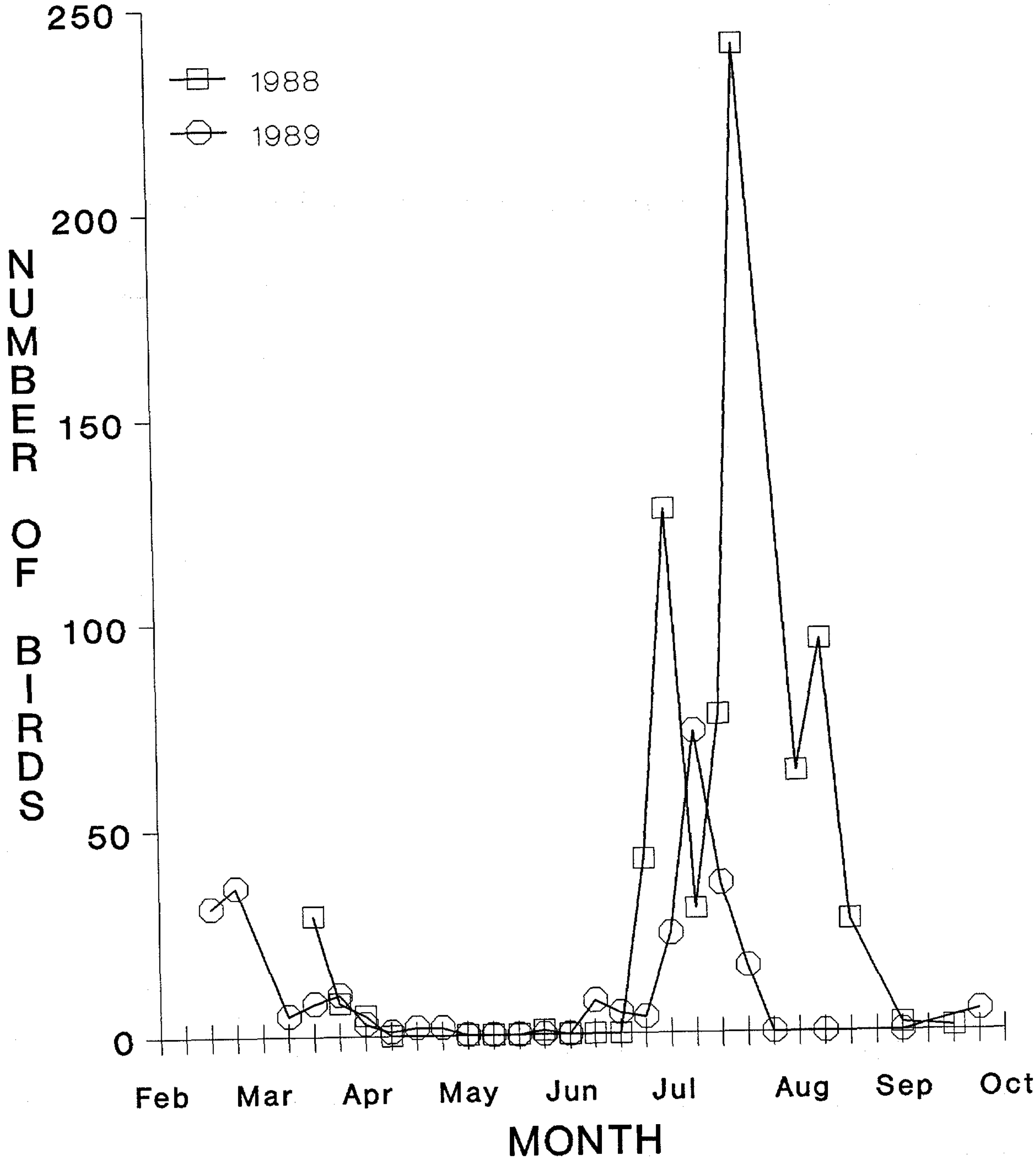


Figure 2.10. Number of Wood Storks observed foraging at Lake Hancock in relation to month, 1988 and 1989.

in 1989; however, the number of observed Wood Storks was not significantly (P>0.05) correlated with water level or any of the water parameters. There also was no significant (P>0.05) correlation with water level in 1988. There may not be a correlation with water levels and Wood Stork numbers because of the low frequency of observations. In 1988, the highest number of Wood Storks coincided with a massive fish kill on 27 July. Two species uncommon to the region were observed on several occasions in 1989. On 3 consecutive surveys, a Yellow-crowned Night-heron (Nycticorax violaceus) was observed, and on 3 other consecutive surveys 5, 3, and 2 Roseate Spoonbills, respectively, were sighted foraging at the lake.

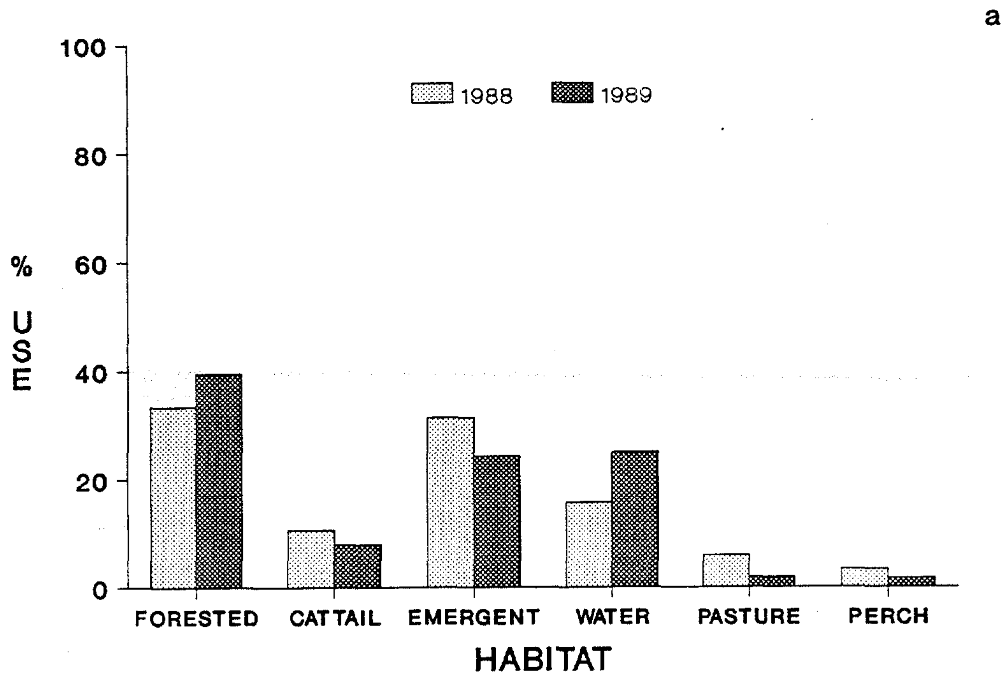
Foraging habitat

During low water (29.56 m MSL), an estimated 350 ha of open water < 0.31 m deep and 641 ha >0.31<0.61 m deep were available as foraging habitat for shorter-legged and longer-legged wading birds, respectively. The other dominant foraging habitats included the 3 shoreline vegetated habitats. Forested vegetation dominated the 3 shoreline habitats, covering 62% (14.5 ha) of the visible area. Emergent and cattail shoreline comprised 27% (6.3 ha) and 11% (2.4 ha), respectively.

In both years, forested, emergent, and open water habitats were the habitats used most frequently by Great Blue Herons, Great Egrets (Figure 2.11), Snowy Egrets, and Tricolored Herons (Figure 2.12). Little Blue Herons were observed primarily in forested and emergent habitats (Figure 2.13). Seventy-five percent of both Black-crowned Night-herons and Green-backed Herons were observed in forested habitat (Figure 2.14). Wood Storks and White Ibises were observed more frequently using pastures than any other species (Figure 2.15); all other species rarely were seen using pastures.

During 1988 and 1989, Great Blue Herons were observed significantly (P<0.05) more often than expected in the emergent shoreline habitats of Lake Hancock (Figure 2.16), and significantly (P<0.05) less than expected in forested habitats based on availability. In 1988, herons were observed significantly (P<0.05) more often than expected in cattails, but in 1989 use of cattails did not differ significantly (P>0.05) from expected.

Great Egrets were observed using all three shoreline habitats similar to their available area in 1988 (P>0.05) (Figure 2.17a). In 1989, egrets were observed in cattails and emergent vegetation less than expected and forested habitats more than expected (P<0.05) (Figure 2.17b).



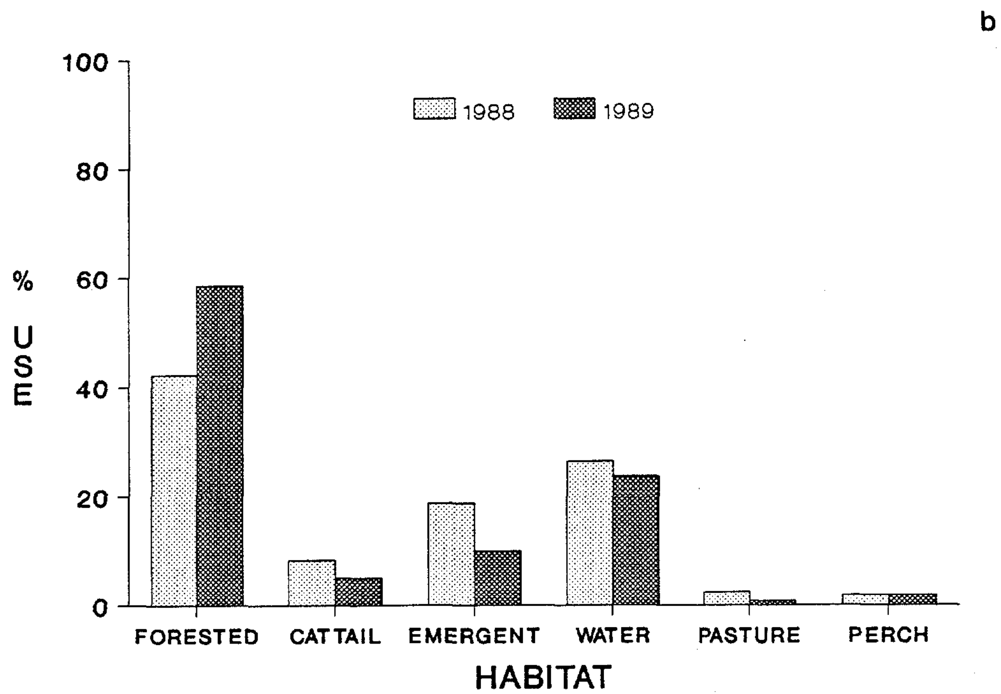


Figure 2.11. Percentage of use by foraging wading birds in 7 habitat categories associated with Lake Hancock in 1988 and 1989. a) Great Blue Herons; b) Great Egrets.

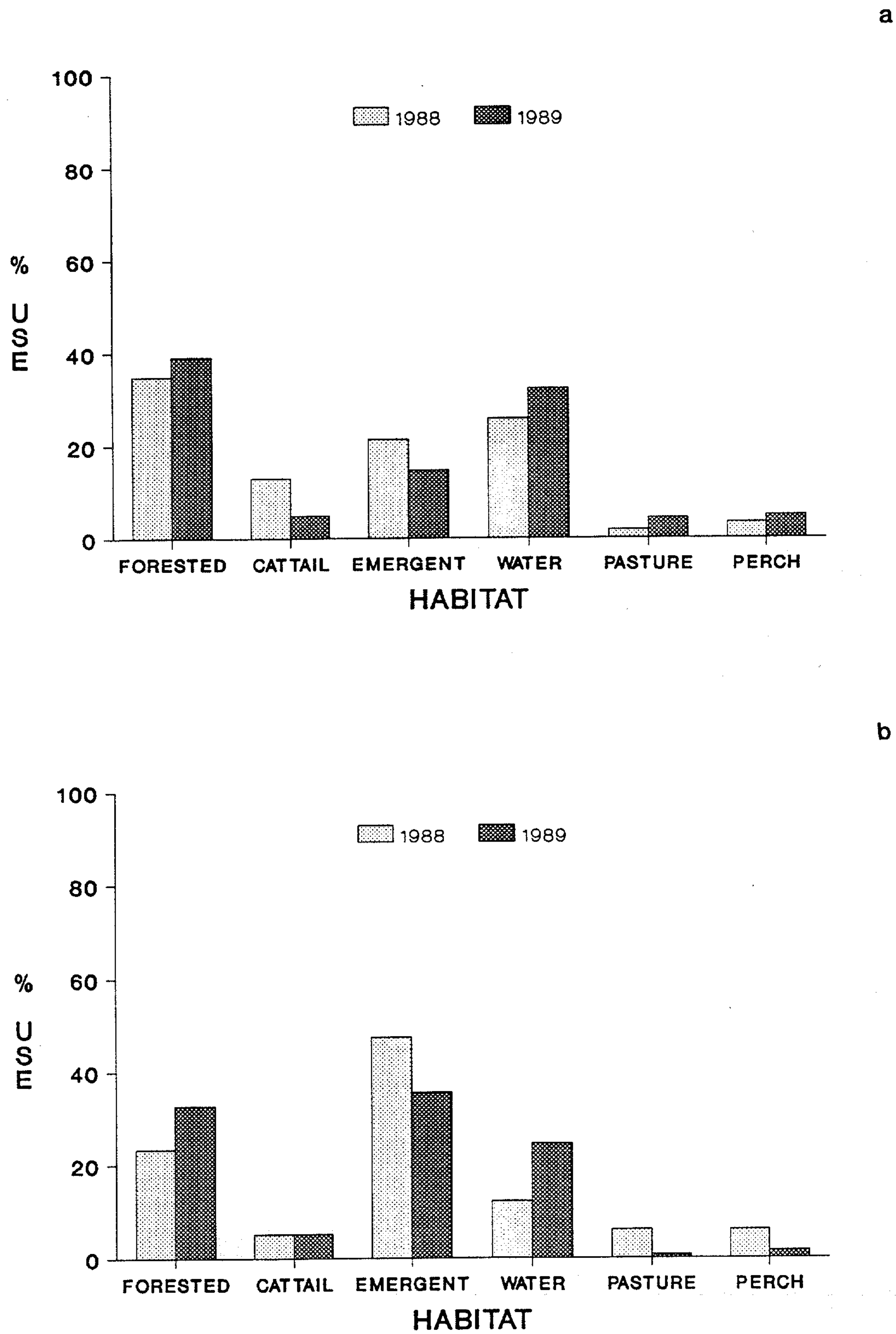


Figure 2.12. Percentage of use by foraging wading birds in 7 habitat categories associated with Lake Hancock in 1988 and 1989. a) Snowy Egrets: b) Tricolored Herons.

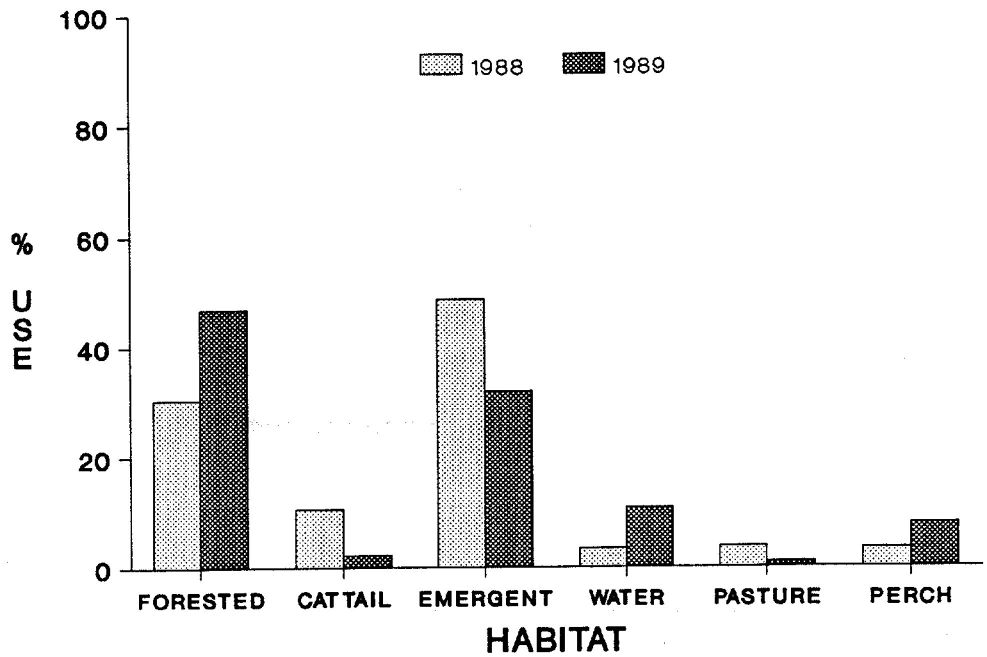
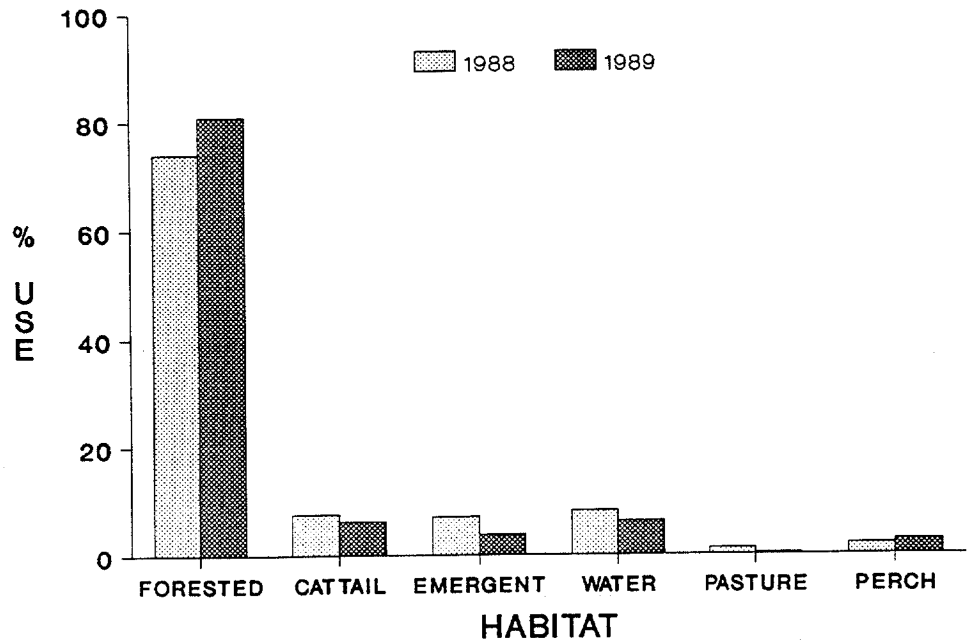


Figure 2.13. Percentage of use by foraging Little Blue Herons in 7 habitat categories associated with Lake Hancock in 1988 and 1989.

a



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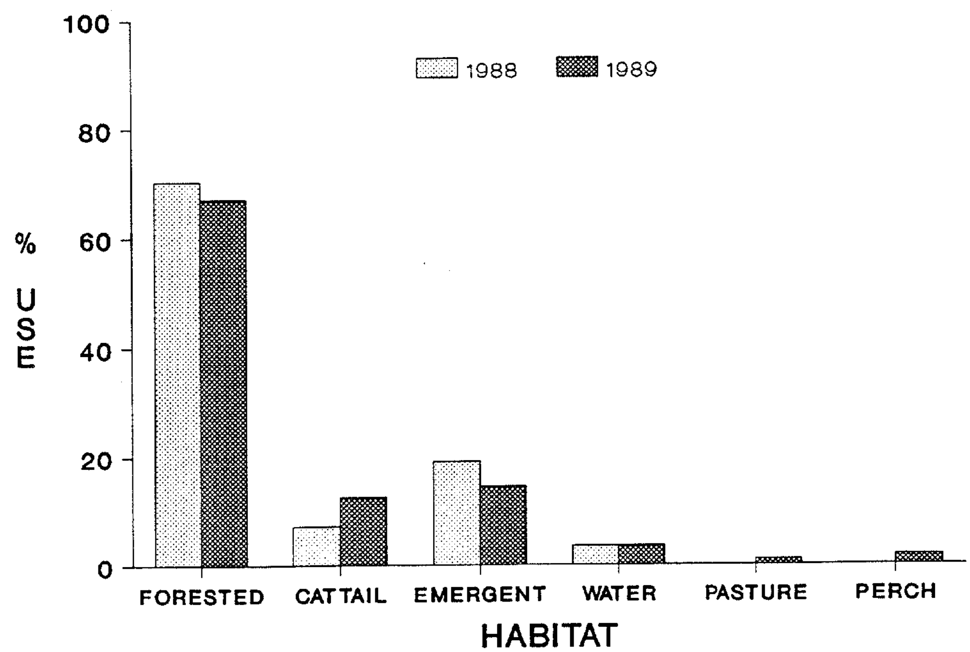


Figure 2.14. Percentage of use by foraging wading birds in 7 habitat categories associated with Lake Hancock in 1988 and 1989. a) Black-crowned Night-herons; b) Green-backed Herons.

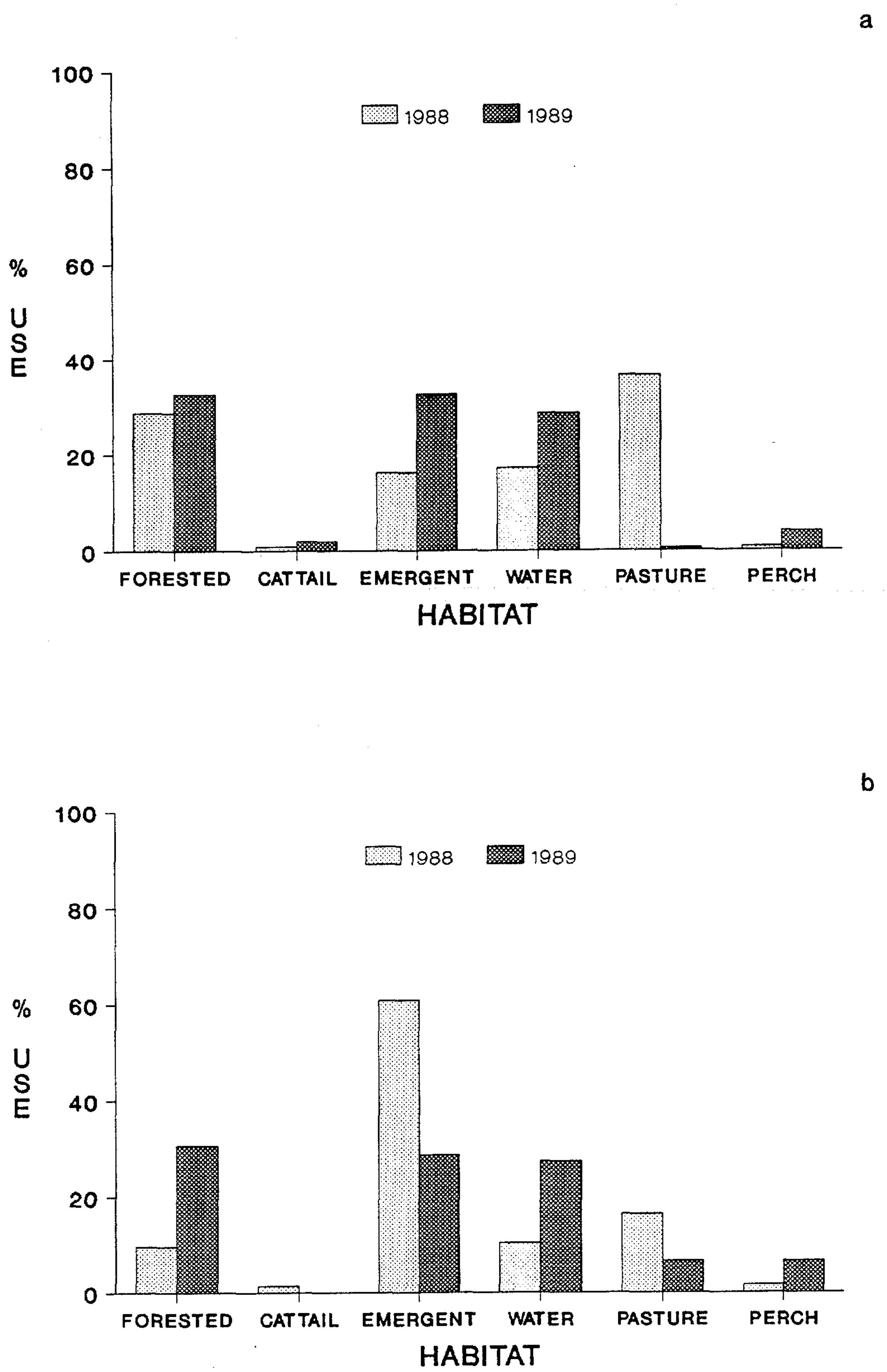


Figure 2.15. Percentage of use by foraging wading birds in 7 habitat categories associated with Lake Hancock in 1988 and 1989. a) Wood Storks; b) White Ibises.

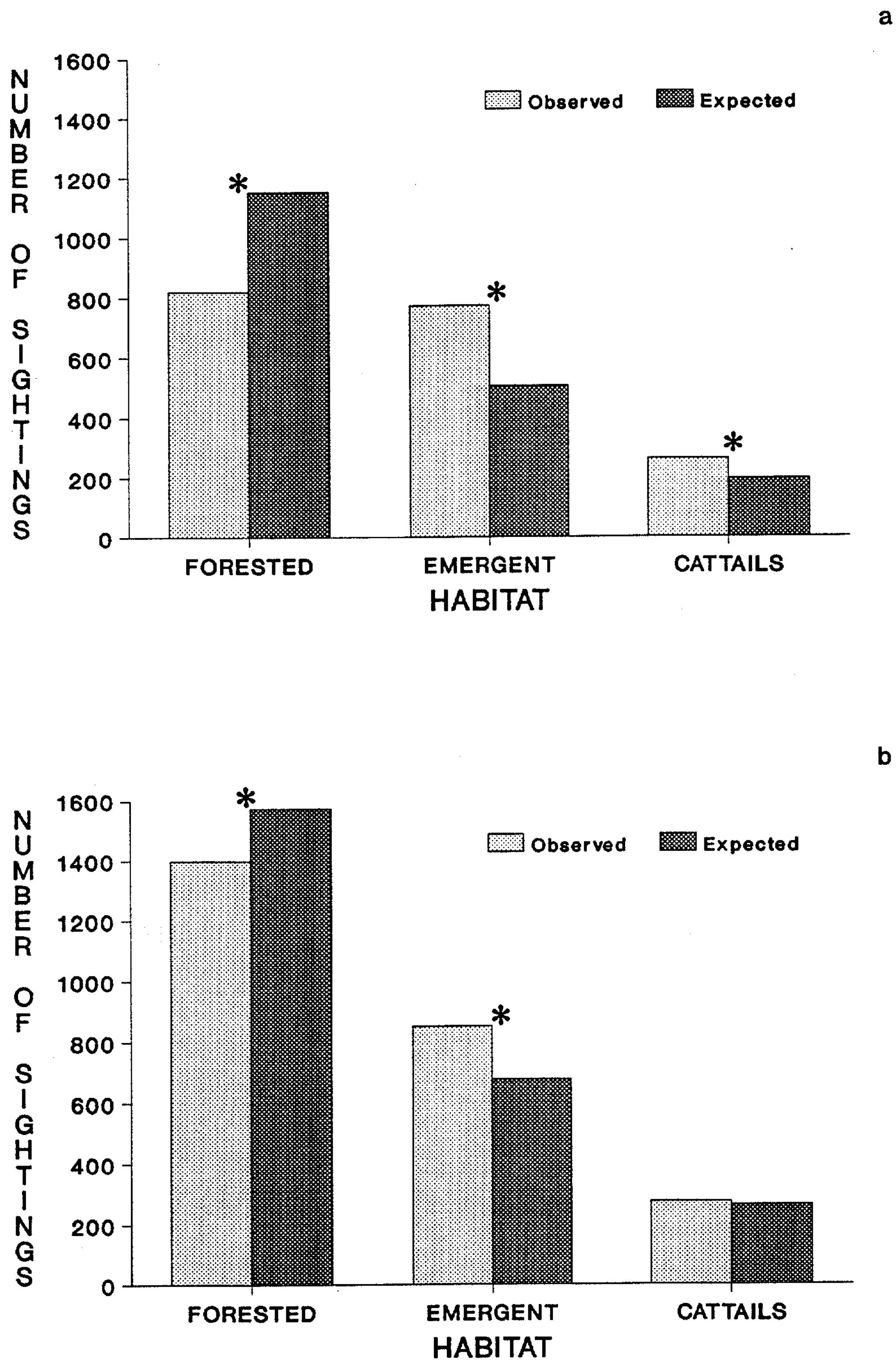


Figure 2.16. A comparison of observed and expected number of sightings of Great Blue Herons in 3 shoreline habitats on Lake Hancock. a) 1988; b) 1989. An asterisk (*) indicates significant difference (Chi-square, P<0.05) between observed and expected values.

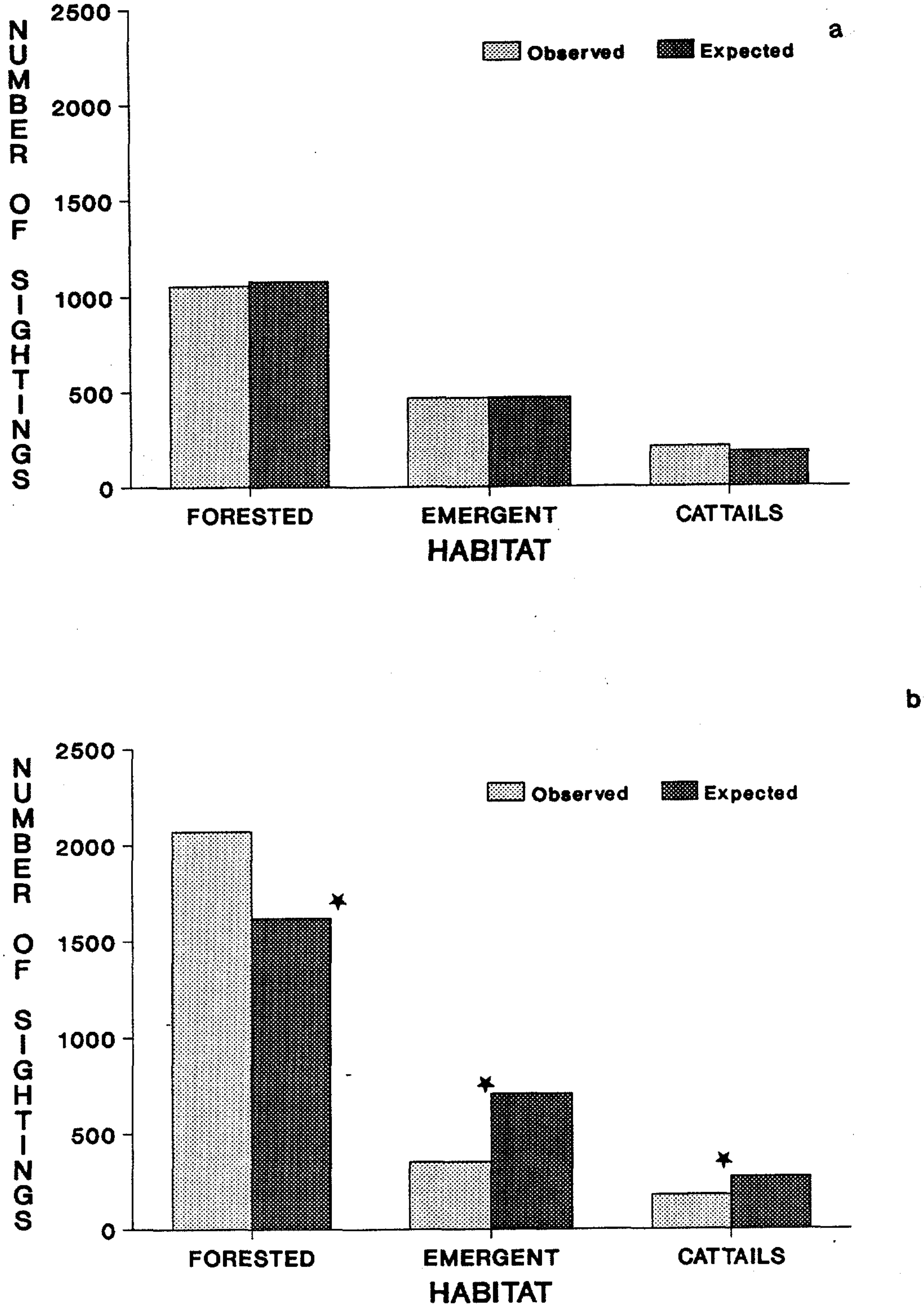


Figure 2.17. A comparison of observed and expected number of sightings of Great Egrets in 3 shoreline habitats on Lake Hancock. a) 1988; b) 1989. An asterisk (*) indicates significant difference (Chi-square, $P<0.05$) between observed and expected values.

In 1988, Snowy Egrets were observed significantly ($P<0.05$) less than expected in cattails and forested habitats based on their availability (Figure 2.18a). The number of Snowy Egrets observed in emergent vegetation did not differ significantly ($P>0.05$) from expected. In 1989, the number of Snowy Egrets observed in the 3 shoreline habitats (Figure 2.18b) did not differ significantly ($P>0.05$) from expected.

In both years, White Ibises were observed significantly ($P<0.05$) more often than expected in emergent vegetation, but use of forested habitats did not differ ($P>0.05$) from expected (Figure 2.19). They were not observed in cattails in 1989 and use in 1988 did not differ significantly ($P>0.05$) from expected.

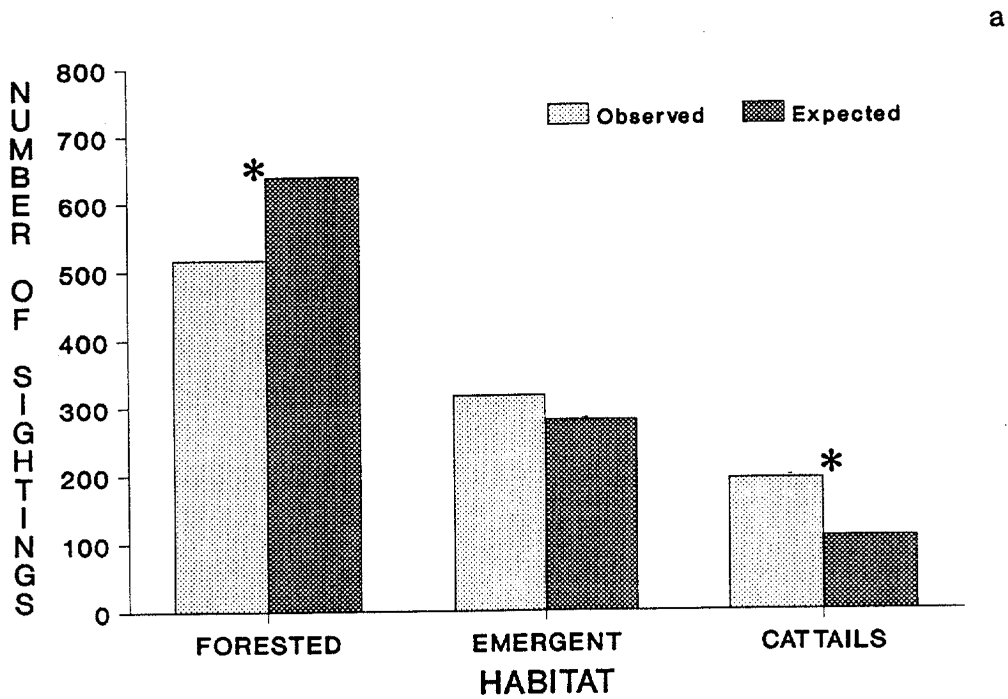
The number of Wood Storks observed foraging in forested habitats did not significantly ($P>0.05$) differ from the expected number in either year (Figure 2.20). In 1988, they were observed less than expected in cattails ($P<0.05$), but in 1989 this use did not differ significantly from the proportion of available cattail ($P>0.05$). In 1989, Wood Storks used emergent vegetation significantly ($P<0.05$) more than expected, but in 1988 observed numbers did not differ significantly ($P>0.05$) from expected.

Wading birds foraged in open water by wading in shallow water, by perching on branches, nets, and other substrates, and by aerial foraging in areas too deep to wade. Wading birds regularly aggregated in open water during low lake levels in two areas. The birds foraged on alluvial bars associated with inflows into the lake (Banana Lake Run and Lake Lena Run). Aggregations of over 100 birds were seen at the confluence of Lake Lena Run.

Great Blue Herons, Great Egrets, Snowy Egrets, and Black-crowned Night-herons were observed foraging from seine nets set across large areas of the lake. Sometimes there were 3 to 5 nets set at different locations on the lake, each fringed with birds. In 1989, 111 birds were counted on nets on a single survey. The birds foraged both away from and inside the netted area.

With the exception of the 2 ibis species and the Roseate Spoonbills, all wading bird species were observed aerial foraging at Lake Hancock. Large aggregations also were observed when birds were aerial foraging. These aggregations typically ranged between 30 to over 100 birds. Birds frequently foraged aerially at specific sites, including along the northwestern shore, midway on the southern shore, and at the confluence of the lake and Saddle Creek outflow and inflow.

Birds typically used an elevated perch site, such as a cypress tree, from which to depart to forage aerially. In 1989, 33% of the total number of birds sighted were observed standing high in trees or on some other high perch. The predominant



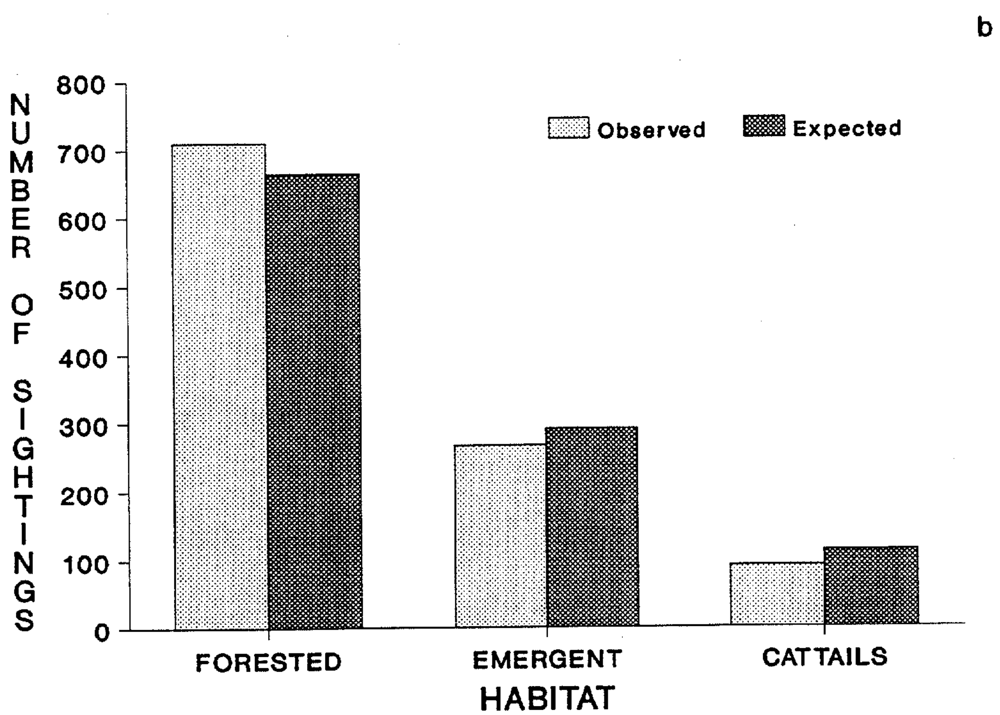
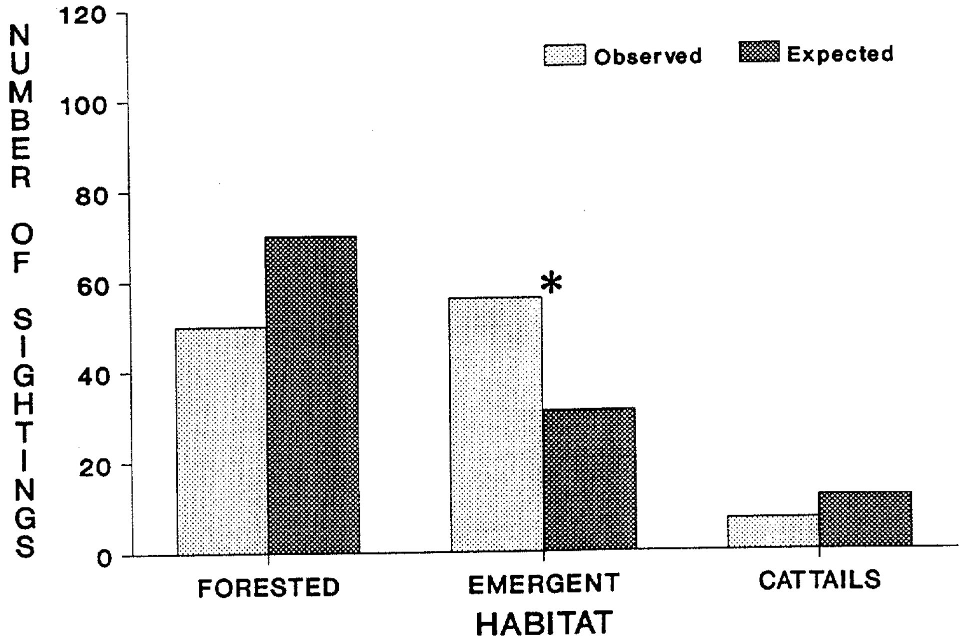


Figure 2.18. A comparison of observed and expected number of sightings of Snowy Egrets in 3 shoreline habitats on Lake Hancock. a) 1988; b) 1989. An asterisk (*) indicates significant difference (Chi-square, P<0.05) between observed and expected values.

a



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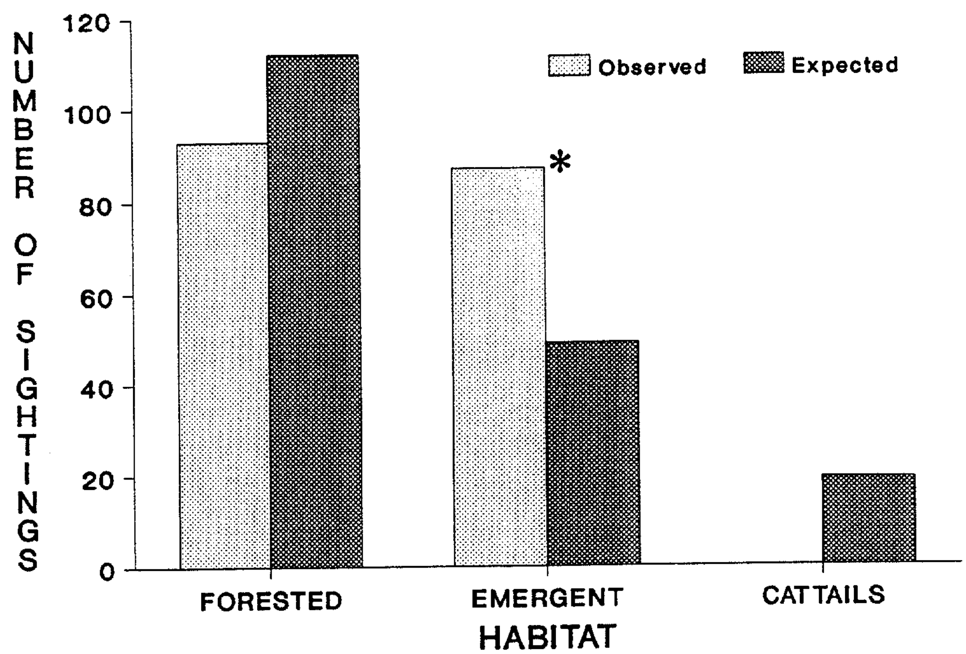
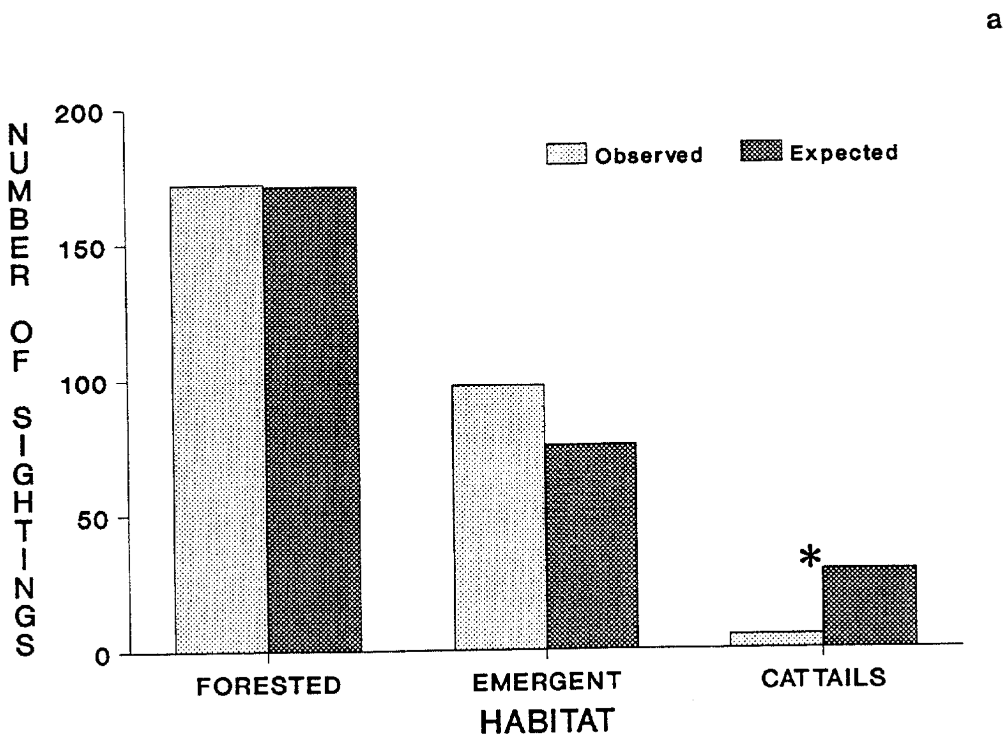


Figure 2.19. A comparison of observed and expected number of sightings of White Ibises in 3 shoreline habitats on Lake Hancock. a) 1988; b) 1989. An asterisk (*) indicates significant difference (Chi-square, P<0.05) between observed and expected values.



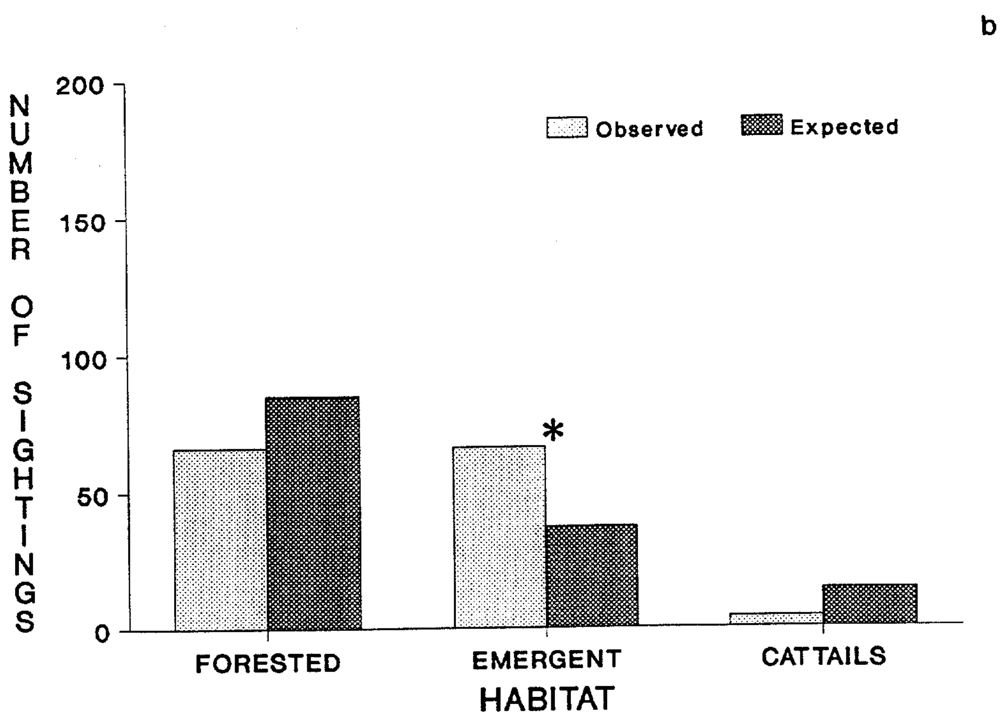


Figure 2.20. A comparison of observed and expected number of sightings of Wood Storks in 3 shoreline habitats on Lake Hancock. a) 1988; b) 1989. An asterisk (*) indicates significant difference (Chi-square, P<0.05) between observed and expected values.

species observed high in the trees along the shoreline were Great Egrets (46%). Great Blue Herons and Snowy Egrets comprised 24% and 15% of the observations, respectively. All other species made up less than 5% of the sightings each. Over 3 times as many Great Egrets and 2 times as many Snowy Egrets were observed using high versus low forested habitats. Great Blue Herons were observed high in trees 58% of the time. Some of the birds categorized as "high" could be roosting rather than perching temporarily before departing to forage aerially, although in all cases where there were large aggregations (>l0) birds were observed foraging aerially nearby.

Discussion

Numbers of wading birds foraging at Lake Hancock increased during both years when water levels were seasonally low. In the dryer year of 1989, the number of wading birds was inversely correlated with water level. Lower water levels should increase the amount of shallow area available to foraging herons and increase their opportunity to find prey.

Other studies in Florida wetlands have found wading birds increased their use of deep water foraging areas during the dry season (Kushlan 1976, Zaffke 1984, Jelks and Collopy 1987). The pattern of use at Lake Okeechobee in southern Florida was similar to Lake Hancock with maximum numbers of wading birds observed in May-July and counts declining sharply during August-September (Zaffke 1984). At some lakes, fluctuations in water levels resulted in exposing or inundating associated marshes or other shallow water areas, influencing how and when wading birds used the lake (Whitfield and Cyrus 1978, Zaffke 1984).

Alternatively or simultaneously, off-lake foraging areas during the dry season may dry up, forcing the birds to forage in deeper wetlands. In southwestern Florida, wading birds congregated in the larger and deeper wetlands during periods of low rainfall and thus low water levels (Collopy and Jelks 1989). Furthermore, a lake within their study area was the primary foraging habitat of wading birds during a drought period with use of the lake increasing as the drying conditions continued. Wading birds did not rely on the lake during a wetter year of the study.

Another possible explanation for some of the increase in number of birds seen in June and July on Lake Hancock is that newly fledged young from the colonies at the lake or elsewhere were now foraging at the lake. The number of unidentifiable small white herons (i.e. juvenile Little Blue Herons are white and could be confused with Snowy Egrets) increased on the lake in mid-June both years. Fledglings may forage in proximity to their colonies (Rodgers and Nesbitt 1979). Additionally, the decrease in number of birds observed in August corresponds with the post-breeding season and may reflect, in part, post-breeding dispersal of both adults and young.

Temporal and habitat use of Lake Hancock varied by species. Some of the differences among species use of the lake may be attributed to differences in leg length, prey selection, and foraging behavior. The most striking finding was that numbers of both Great and Snowy egrets followed the fluctuating water levels so closely in 1989. The numbers of both species dramatically increased when the water level dropped below 29.56 m MSL and decreased when water levels rose above 29.6 m MSL. In contrast, water levels in 1988 never fell below 29.61 m MSL and there was no significant correlation with egret numbers. This water level appears to have a minimum threshold effect on drawing wading birds to the lake. This suggests that the mechanism is absolute water depth rather than drying rate as has been found in a number of marsh studies (Kushlan 1979, Frederick and Collopy 1989).

Great Egrets were always more abundant than the shorter-legged Snowy Egrets, although Great Egrets also were somewhat more conspicuous due to their size. Because of their differential leg lengths, however, as water levels begin to drop, Great Egrets should use the lake in large numbers before Snowy Egrets. This did not happen suggesting that water depth may not be the driving force alone. Both egrets are visual foragers, feed primarily on fish, and tend to occur in foraging aggregations. These habits increase their likelihood to forage in the same areas, and specifically to forage at a lake at all compared with some other wading bird species. The number of foraging Snowy and Great Egrets seldom exceeded the estimated number of breeding individuals in the Lake Hancock colonies: however, during the low water period in 1989, numbers of both species sighted on the lake exceeded the number of breeding egrets in the colonies suggesting the lake was used by egrets nesting at non-lake colonies.

Great Blue Herons were observed in relatively high numbers on all surveys and were not correlated with any of the water parameters. Specifically, there was no increase in the number of Great Blue Herons seen during lower water levels. Great Blue Herons can be territorial and tend not to be in aggregations (Kushlan 1978) which may explain the relatively low variation in observed numbers. Also, presumably, the relatively long legs of Great Blue Herons permitted them a greater opportunity to forage over a wider range of water levels.

The range in numbers of Great Blue Herons foraging at the lake was generally similar to the number of breeding individuals nesting in trees on Lake Hancock's shore. It is likely that Great Blue Herons nesting at the lake also foraged at the lake.

After the local fledging period, juvenile Great Blue Herons frequently were observed feeding at the lake.

Wood Storks did not nest at Lake Hancock. Like Great Blue Herons, Wood Storks have relatively long legs; however, they are tactile feeders and typically forage in shallow depressions containing high prey concentration (Kushlan 1978). Although they did tend to forage at the lake during lower water levels, they were not frequent users, only foraging at the lake in high numbers once (e.g. 240 birds). The extensive nature of this shallow lake may not be conducive for tactile foraging.

White Ibises were never observed foraging in large numbers, although they were the dominant species nesting at the colonies. White Ibises are relatively short-legged, tactile foragers which rarely feed on fish (Kushlan and Kushlan 1975, Nesbitt et al. 1975). White Ibis nesting at another central Florida location foraged in pastures, marsh praries, and lake edge marshes and it was suggested that water depth governs their habitat selection (Kushlan 1979); they only were present in large numbers at Lake Hancock during low water levels.

Tricolored, Little Blue, and Green-backed herons have relatively short legs. Being small and dark, they also were difficult to detect; their numbers were certainly underestimated, although I do not believe that any were numerous as foragers at the lake. Among these 3 herons, only the Little Blue Heron nested in relatively large numbers at the lake colonies.

Whereas water level was a characteristic that often could predict a change in the number of wading birds, other aspects of Lake Hancock were unusual and affected the birds. Lake Hancock has extremely poor water transparency year round. The greatest numbers of wading birds occurred when water turbidity was twice as much as other times (22 cm vs. 11 cm Secchi depth). Food intake decreased as water turbidity increased for foraging Great Blue Herons in Vancouver (Krebs 1974), but water clarity was correlated with prey density, suggesting food intake may have reflected prey quantities rather than water clarity. This also may be true for Lake Hancock.

Large numbers of wading birds also were associated with summertime fish kills. The combination of high concentrations of algae in the lake and overcast conditions caused by afternoon thunderstorms can result in a dramatic reduction in the photosynthetic activity of algae. This is further enhanced by the strong winds associated with the thunderstorms that mix the decaying organic matter on the lake bottom into the water column. By early morning the dissolved oxygen can fall below a critical level causing a fish die off. One of the lowest mean dissolved oxygen readings (0.46 mg/l) was recorded the morning of a massive fish kill. This also was the day we observed the greatest number of wading birds (903), especially Great and Snowy egrets (340 and 224, respectively). One of the highest number of Great Blue Herons (206) sighted on the lake occurred on another day of extremely low mean dissolved oxygen (0.36 mg/l), although this day was not associated with a fish kill.

Herons should be expected to use the habitats most available or most favorable for foraging. At Lake Hancock, the most abundant heron species (Great Blue Herons, Great and Snowy egrets) often used the 3 most common habitats (forested, emergent, and open water), and sometimes used the 3 shoreline habitats (forested, emergent, and cattail) about in proportion to their availability.

Wading birds characteristically forage in shallow water (Jenni 1969, Recher and Recher 1980). Different species forage at different depths according to the length of their tarsi, with larger herons having the deepest mean wading depth (Whitfield and Blaber 1979, Horn 1983, Powell 1987). At Lake Hancock, the cattails and floating mats of red maple and willow often were in areas of the lake too deep for any species to wade in (e.g. 21 m). Most of the emergent vegetation habitat was shallower than the other habitat types. Based on water depth, emergent vegetation should be preferred relative to the other habitat types particularly by shorter-legged species. Unexpectedly, Great Blue Herons, the longest-legged wader, were the only species observed to forage in emergent vegetation significantly ($P<0.05$) more than expected.

As most of the lake was too deep for wading, birds took advantage of almost any substrate to forage from. This included the floating mats of red maple and willow, dense cattails, and fishing nets. All are atypical foraging habitats for wading birds. Whereas birds could be foraging in the forested habitat because it is the most available type, forested areas also may be used because it allows birds access to deeper water areas. On this lake there may not be any greater benefit to foraging in shallow areas (e.g. emergent vegetation) as long as foraging substrates provide access to deep water.

Aerial foraging clearly is a behavior developed to obtain prey , specifically fish, from deep water. For birds that are typically waders, aerial foraging probably is a relatively energetically expensive means of capturing food. Aerial foraging has been reported elsewhere (reviewed by Kushlan 1978), but never by so many individuals and so frequently (but see Chapter III).

Most studies at other lake sites typically have associated marshes, which were the primary foraging habitat of wading birds (Hoffman 1978, Zaffke 1984, Pyrovetsi and Crivelli 1988). A freshwater lake in Louisiana was used similarly to Lake Hancock in that Great Blue Herons, Green-backed Herons, and Yellow-crowned Night-herons foraged in the lake's forested and shrub habitat, although, no wading birds were observed foraging in deep, open water areas (Ortego et al. 1977). At a drying pond in South Florida, Great Blue Herons were reported more frequently using the open, central section of the pond, whereas Great and Snowy egrets were observed foraging more frequently in the emergent, vegetated areas (Kushlan 1976b). At a freshwater lake in north-central Florida, Tricolored Herons foraged in deep water and from floating vegetation in the deeper areas (Jenni 1969). Like Lake Hancock, Snowy Egrets fed in open areas, and foraged aerially or fed from floating objects, and they did so more than Tricolored or Little Blue herons (Jenni 1969).

The aerial foraging behavior, use of atypical foraging habitats, and use of Lake Hancock by wading birds during poor water opacity may be related to the hypereutrophic condition of the lake. The lake's nutrient-rich condition has strongly influenced the aquatic community, reflected by the high abundance of filter-feeding fish (FGFWFC 1986). Fish species such as Nile perch (Tilapia spp.) and mosquito fish (Gambusia affinis) are able to thrive in these nutrient-rich, but oxygen-stressed conditions. Mosquito fish are morphologically adapted to permit use of oxygen-rich water at the atmosphere-water interface (Lewis 1970). This adaptation allows them to survive under conditions of oxygen depletion, a common occurrence in the early morning during the summer months at Lake Hancock (Zellars-Williams, Inc. 1987; this study).

Lake Hancock supports a dense alligator population relative to other Florida lakes (FGFWFC 1986), ranking third highest in number per kilometer when compared with 23 other lakes. The number of active Osprey nests on the lake (24 in 1988, and 18 in 1989) and 64 more within a 4 km vicinity (M. Desmond, pers. comm. 1988, and pers. obs. 1989) may represent one of the densest Osprey nesting areas in the state (B. Millsap, pers. comm). The large number of alligators and Ospreys suggest that Lake Hancock sustains a high fish population.

Several physical and chemical factors associated with warm water lakes and sub-tropical regions influence fish distribution and abundance, which perhaps reflects wading bird use of lakes as well (reviewed by Moyle and Cech 1982). In turbid lakes, fish, especially pelagic plankton-feeding species, may concentrate in the well-lighted, upper water column where their prey are more visible. Further, during periods of low oxygen fish also may be found at the surface. Typically, fish species living under low oxygen conditions are either air breathers or small fish capable of using the oxygen present in a thin band of water at the surface. When water levels drop fish also may be forced from the desiccated emergent zone into the open water. As fish get forced to the surface, they presumably become more available to herons.

At Lake Hancock, low water levels, low dissolved oxygen levels, and diminished water transparency may be acting on the fish to concentrate them at the surface. Under these conditions, the fish may be more vulnerable to predation by wading birds and may partially explain increased use of the lake by wading birds during low lake levels. Further, wading birds may then forage more successfully in deep water areas, explaining why birds are foraging aerially and using atypical foraging habitats.

The lake's hypereutrophic condition also dissuades human use of the lake. The poor water quality precludes many recreational activities such as swimming and sport fishing; the many large alligators also hinder use of the lake. Further, there is limited access to the lake and most of the shoreline remains undeveloped. The undisturbed nature of the lake also makes conditions favorable for wading bird use (Draulans and van Vessem 1985).

Lake Hancock appears to support many foraging wading birds during the breeding season with total numbers and species richness influenced by water levels. The poor water transparency and limited littoral zone may be offset by the substantial fish population and reduced human disturbance at the lake.

The majority of the birds nesting at the Lake Hancock colonies (e.g. White Ibis) are not foraging at the lake. For some species, the importance of the lake and adjacent areas to nesting colonies appears to be independent of the lake's value as a foraging area.

CHAPTER III

FORAGING ECOLOGY OF SNOWY EGRETS IN AN ALTERED LANDSCAPE

Introduction

The importance of protection and management of wetland habitats for the conservation of herons is recognized internationally (Hafner et al. 1986b, Kushlan 1987), as well as in Florida (Kale 1978). The loss and degradation of Florida's wetlands has increased dramatically in the last 40 years (Hefner 1986), potentially influencing the distribution and abundance of wading bird populations on a state and national scale. One likely result is that wading birds eventually will have to rely on altered or artificial foraging habitats (Kushlan 1986). Already in Europe and in some parts of the United States (including Florida), wading birds are found in association with artificially created habitats such as agricultural and industrial wetlands (Maehr 1980, Fasola 1986, Hafner et al. 1986a, van Vessem and Draulans 1987, Bray and Klebenow 1988, Erwin et al. 1988). It is therefore necessary to understand the use of these habitats to fully evaluate the impacts of altering or losing natural wetlands.

In Florida, some wetlands have become eutrophic or more eutrophic as a result of alterations from human activities. Lake Okeechobee is a good example of the effects of nutrient-enrichment from adjacent agricultural areas (Frederico et al. 1981). Some newly-created wetlands such as the clay-settling ponds of phosphate mines and Wastewater treatment facilities also are highly nutrient-enriched. Due to Florida's extremely rapid growth and development, eutrophic sites will likely become more common in a foraging heron's landscape. To my knowledge, no detailed studies on the use of eutrophic sites by wading birds have been conducted. Ultimately, an understanding of the foraging ecology of wading birds using these nutrient-enriched sites will allow wildlife managers to assess the relative value of nutrient-enriched sites to these species, and the potential problems associated with their creation.

Florida provided 80% of the national and 30% of the world's supply of phosphate in 1988 (Florida Phosphate Council 1989). Phosphate mining companies own or control 218,140 ha of Florida land, which is located primarily in the central part of the state. Wading birds, as well as other waterbirds, nest and forage in large numbers at Florida's phosphate mines (Schnoes and Humphrey 1987, Gilbert et al. 1981, Maehr 1981, 1984, pers. obs.). Yet, there have been few, if any, detailed studies on the use of phosphate mines by wading birds for breeding.

Snowy Egrets, designated a Species of Special Concern by the Florida Game and Fresh Water Fish Commission (Wood 1988), apparently are vulnerable to human alterations of the natural landscape. The decrease in Snowy Egret numbers in peninsular Florida has been attributed to deteriorating interior freshwater wetlands (Ogden 1978).

Snowy Egrets typically nest in mixed-species colonies with other long-legged wading birds (Ciconiiformes). They breed from northern United States to southern South America (AOU 1983), including the interior and coastal regions of Florida (Osborn and Custer 1978, Nesbitt et al. 1982). They are primarily visual feeders pursuing relatively active prey such as fish, insects, amphibians, reptiles and crustaceans (Bent 1926, Kushlan 1978) in freshwater, brackish, and salt-water habitats (Palmer 1962).

Identifying the relative temporal use of various wetland types by wading birds is a method of characterizing their foraging habitat (Erwin 1983, Hafner et al. 1986a, Heitmeyer 1987, Collopy and Jelks 1989, Bancroft et al. 1988). The size of foraging aggregations also may reflect the attributes of a foraging habitat or site (Krebs 1974, Hafner et al. 1982, Hafner et al. 1986a, Bancroft et al. 1987). The distances traveled from a colony to a foraging area has been documented for this species for the Everglades (Bancroft et al. 1988, Frederick and Collopy 1988) and for coastal North Carolina (Custer and Osborn 1978b), but not for interior freshwater wetlands located elsewhere in the United States. Identifying potential foraging areas near a colony can be determined with knowledge of the distances herons are likely to fly to feed. This kind of information provides insight into foraging range, energetics, transport of parasites, nutrient transfer, etc. and allows the identification of potential areas for conservation.

The objectives of this part of my study were to determine the location, type, and relative use of foraging habitats used by nesting Snowy Egrets in the largely altered landscape in and around Lake Hancock.

Study Area

The study area encompassed Lake Hancock, located between Lakeland and Bartow in Polk County, Florida, and about 280 km^2 of adjacent land (Figure 3.1). Lake Hancock is an 1843 ha, hypereutrophic lake (Zellars-Williams, Inc. 1987). The lake and

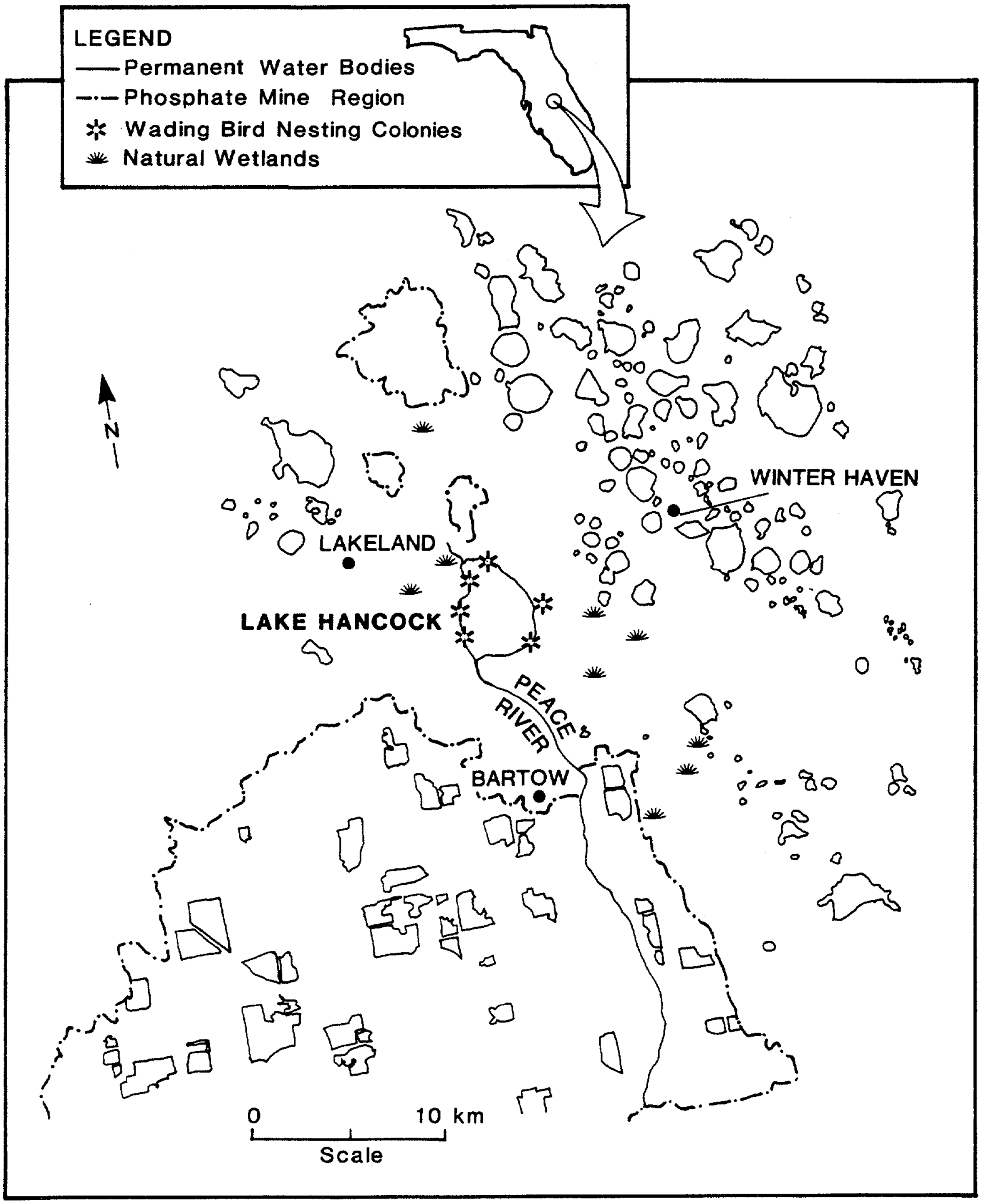


Figure 3.1. Study area showing distribution of foraging areas and location of nesting colonies of wading birds at Lake Hancock, Polk County, Florida.

adjacent study area are located in the center of the state's phosphate-mining district. Many of the natural habitats surrounding the lake have been severely altered and replaced with phosphate-mines, rangeland, citrus groves, and residential and commercial development.

An estimated 5,400 breeding pairs of wading birds, including over 160 pairs of Snowy Egrets, nested in 4 colonies located on or directly adjacent to Lake Hancock in 1988. In 1989, about 95 pairs of Snowy Egrets nested among 3,850 breeding pairs of other waders in 3 colonies at the lake (see Chapter II for a further description of the nesting colonies and lake).

Methods

Foraging Habitat Classification

Due to the large-scale alteration of the region's natural habitat, foraging habitats available to wading birds were identified as artificial or natural, and then further subdivided into several other categories (Table 3.1).

Artificial wetlands were sites that were created by a drastic human-induced physical transformation of the original landscape. These sites were not directly connected to any functioning natural wetland system.

Since much of the study area was composed of phosphate mines, the artificial classification was further sub-divided into phosphate and non-phosphate sites. Phosphate mine sites were identified as either circulatory or isolated. Circulatory phosphate sites were associated with the active phosphate-mining process. They were primarily clay settling ponds (large impoundments, >100 ha) and water recirculation ditches or ponds. As part of the mining process sediments are deposited in the clay-settling ponds and the water is skimmed off and sent through the recirculation systems. Thus, both types have the same water quality (G. Williams, IMC, pers. comm). The mean depth of the clay settling ponds used in this study varied from <0.61 m to 6.1 m according to their age. Isolated phosphate sites were phosphate lands already mined out and isolated from the recirculation process. Isolated sites ranged in size from <1.0 to >200 ha. This category included reclaimed and unreclaimed wetlands at various successional stages.

"Other artificial" or non-phosphate foraging areas, included overflow ponds for adjacent settling ponds at Wastewater treatment facilities for sewage, orange juice, and meat packing; a canal associated with the sewage treatment plant; and roadside

Table 3.1. Classification scheme for Snowy Egret foraging habitat in the Lake Hancock study area.

Artificial	Natural
Phosphate	Permanent
Circulatory	Temporary
Isolated	
Other (Non-phosphate)	

ditches. All sites were in terrestrial settings and were physically isolated from naturally functioning wetlands. All sites received water (and thus extra nutrients) at least occasionally from sources other than rainfall and groundwater.

Areas that had not undergone a major transformation from their original physical state were classified as "natural." Within this study area, there were few, if any, pristine natural areas. Many natural wetlands have been impacted by added nutrients via agricultural or stormwater runoff. Lake Hancock, for example, has received sewage Wastewater since 1926 (see Chapter II). Within pastures, drainage ditches have been constructed and some creeks have been straightened into canals.

Natural sites were subdivided into "permanent" or "temporary." Wetlands and water bodies that were characterized by year-round inundation and relatively stable water levels were considered permanent. This mostly included lakes and ponds. Temporary wetlands were characterized by receding water levels during the dry season creating shallow wet areas. This included palustrine (marshes) and riverine systems (rivers, creeks, drainage ditches, and canals). The availability of these temporary wetlands typically correlated with Florida's wet and dry seasons. Marshes generally were small, isolated wetlands and ranged in size from <l.0 to > 25 ha.

Radio-tracking

I captured breeding Snowy Egrets using a walk-in trap placed on the nest (after Frederick 1986, Jewell and Bancroft in press). I trapped the egrets from late April to late May, during the chick-rearing period when the nestlings were between 2 and 4 days old. Eight Snowy Egrets were captured from 2 of the colonies (Sickle and Cattle Egret Cove colonies; see Chapter II, Figure 2.1) located at Lake Hancock in 1988. An additional 10 Snowy Egrets were captured from the same 2 colonies in 1989. Adults were weighed, measured, banded with aluminum U.S. Fish and Wildlife Service and colored plastic bands, and outfitted with solar-powered radio transmitters (15-17 g; Wildlife Materials No. SPCB-1250-3X) that were attached with a backpack harness of teflon ribbon (4 mm width). Transmitter frequencies ranged from 150 to 152 Mhz.

Movement patterns of the tagged herons were monitored during the breeding season, which continued from the date the first egret was trapped until about 2 months after the last egret was trapped (27 April-2 August 1988 and 27 April-31 July 1989) as parents may continue to feed chicks for up to 2 months (Bancroft et al. 1988, pers. obs.). I attempted to locate each bird at least 3 times per week throughout the 3 month period. The number of times an individual bird was located varied due to its date of capture; earlier nesting birds usually were located more times during the entire study period than those nesting later in the breeding season.

In both years, observations and radio-tracking at the colony confirmed a nest's status (active or failed). In 1989, I attached color-bands and U.S. Fish and Wildlife Service bands to the chicks that were 7-10 days old to confirm the continued activity of the nest. Adults from both successful and failed nests were radio-tracked.

Birds were located from the air using fixed-wing aircraft (Cessna 150 and 174), and from the ground, using a telemetry receiver and scanner. Directional "H" antennae were used on the ground and in the air. Tracking was concentrated primarily in the morning and evening to coincide with active foraging periods of Snowy Egrets. At each foraging site, data were collected on location, foraging group size, and wading bird species composition.

A foraging group was defined as 2 or more wading birds within about 15 m of each other. Aerial estimates often were limited to white-plumed wading birds (e.g. Great and Snowy egrets) due to the difficulty detecting dark-plumed birds (e.g. Little Blue Herons). During visits from the ground, I observed few dark-plumed wading birds at the artificial sites, but they were frequently observed in small numbers (<15) at the natural sites. At natural wetlands, therefore, aerial estimates of group size were likely underestimated. Radio-tracking fixes from the ground where the entire foraging aggregation was not visible were not included in the analysis.

Locations were marked on aerial photographs or maps. Most of the foraging sites located from the air were verified and classified from the ground. Foraging distance between the colony and foraging areas was determined only for birds associated with confirmed active nests. Several birds with failed nests could not be confirmed returning to the colony.

Analysis

I did not assess habitat preference based on availability because it was not feasible to determine the amount of foraging micro-habitat within this large study area. At most foraging areas, wading birds congregated in a relatively small portion of the wetland and these sites changed through time. Instead, I conducted a series of pair-wise comparisons of foraging use of the habitat categories (e.g., artificial vs. natural, temporary vs. permanent).

For purposes of analysis, I assumed there was equal probability of egrets foraging in each of these categories. I tested this null hypothesis of equal probability (0.5) by using a logistic analysis with correction for extra binomial variation (Williams 1982). This analysis takes into account the variability among individuals and within an individual, and generates an estimate of the probability of finding the tagged population of Snowy Egrets in the habitat of interest. A 95% confidence interval (CI) for each estimate of probability was then derived. For the statistical comparison to be significant, 0.5 must fall outside of the CI. In other words, there has to be greater than or less than 50% chance of being in the habitat of interest. The same null hypothesis was tested for each bird individually using an exact 2-tailed test for binomials (when $n<10$) and a 2-tailed z test based on the normal approximation (when $n \geq 10$).

I also examined temporal shifts in foraging use of the phosphate mines, and temporary and permanent habitats for May, June, and July. I combined the two phosphate mine categories as both were permanently available throughout the study period. Differences among these months were tested using analysis of variance (ANOVA) of the arcsin-square root, transformed proportions of individual birds. Comparisons between months were made using pair-wise contrasts of the least square means (GLM procedure, SAS 1985). Sample sizes were too small to statistically evaluate a temporal shift of use of other (non-phosphate) artificial sites.

For each year, the size of feeding groups were analyzed in relation to habitat category, using a weighted ANOVA of the site means of the log transformed, group sizes of the five habitat categories (i.e., circulatory, isolated, non-phosphate artificial, permanent, and temporary). Differences between years were tested similarly (GLM procedure, SAS 1985).

The distance from colonies to foraging areas was measured from aerial photographs and USGS topographical maps. The mean distance to foraging sites in each habitat category was calculated for each colony. Due to the large size of Lake Hancock, foraging locations were recorded as different sites if they were greater than 1 km apart or occurred in different vegetation types (e.g. pasture vs. forest).

Results

Overall Patterns

I trapped 8 Snowy Egrets in 1988 and 10 in 1989. One of the transmitters failed after it was attached to an egret in 1989. Three of the birds trapped in 1988 were present on the study area in 1989, nesting at phosphate mine colonies south of Lake Hancock. Another egret that was trapped in 1989 at a Lake Hancock colony re-nested at one of the phosphate mine colonies after its first chick-rearing effort failed. Two of the transmitters from birds trapped in 1988 failed toward the end of the 1989 breeding season.

I located the 17 radio-tagged Snowy Egrets 567 times at 98 different foraging sites during the 2 breeding seasons: 8 egrets in 1988 were located 155 times at 42 different foraging sites; in 1989, I followed 12 tagged Snowy Egrets, including 3 of which were originally trapped in 1988, locating them 414 times at 73 different foraging sites. Snowy Egrets were observed using 18 (7%) of the 115 feeding sites in both years.

In both years, artificial habitats were used more than natural habitats. In 1988, the average probability of finding a radio-tagged Snowy Egret in an artificial habitat (0.79) was significantly greater than 0.5 [95% CI= (0.563,0.912); Figure 3.2]. Snowy Egrets were found 67% of the time in artificial habitats in 1989; however, this probability was not significantly different from the average probability (0.5) of finding a tagged bird in a natural site [95% CI=(0.463,0.825); Figure 3.21. In 1988, only one bird foraged less than 50% of the time at artificial sites, whereas in 1989, 3 birds foraged less than 50% at artificial sites (see discussion of individual variability).

Egrets using the artificial habitats foraged primarily at phosphate mines (Figure 3.3a). In 1989, the average probability of finding a foraging egret at sites created by phosphate mining activity (0.91) was significantly greater than 0.50 [95% CI=(0.565,0.989)]. Although the average probability of locating egrets at phosphate mines was 0.85 in 1988, it was not significantly different from 0.50 [95% CI=(0.447,0.977)]. A smaller sample size and greater individual variability among egrets probably contributed to the lack of statistical significance in 1988.

At phosphate mines in 1988 and 1989, sites associated with the circulatory system were used more than those isolated from the water system (Figure 3.3b). Of those egrets using phosphate sites, an estimate of the probability of using circulatory sites

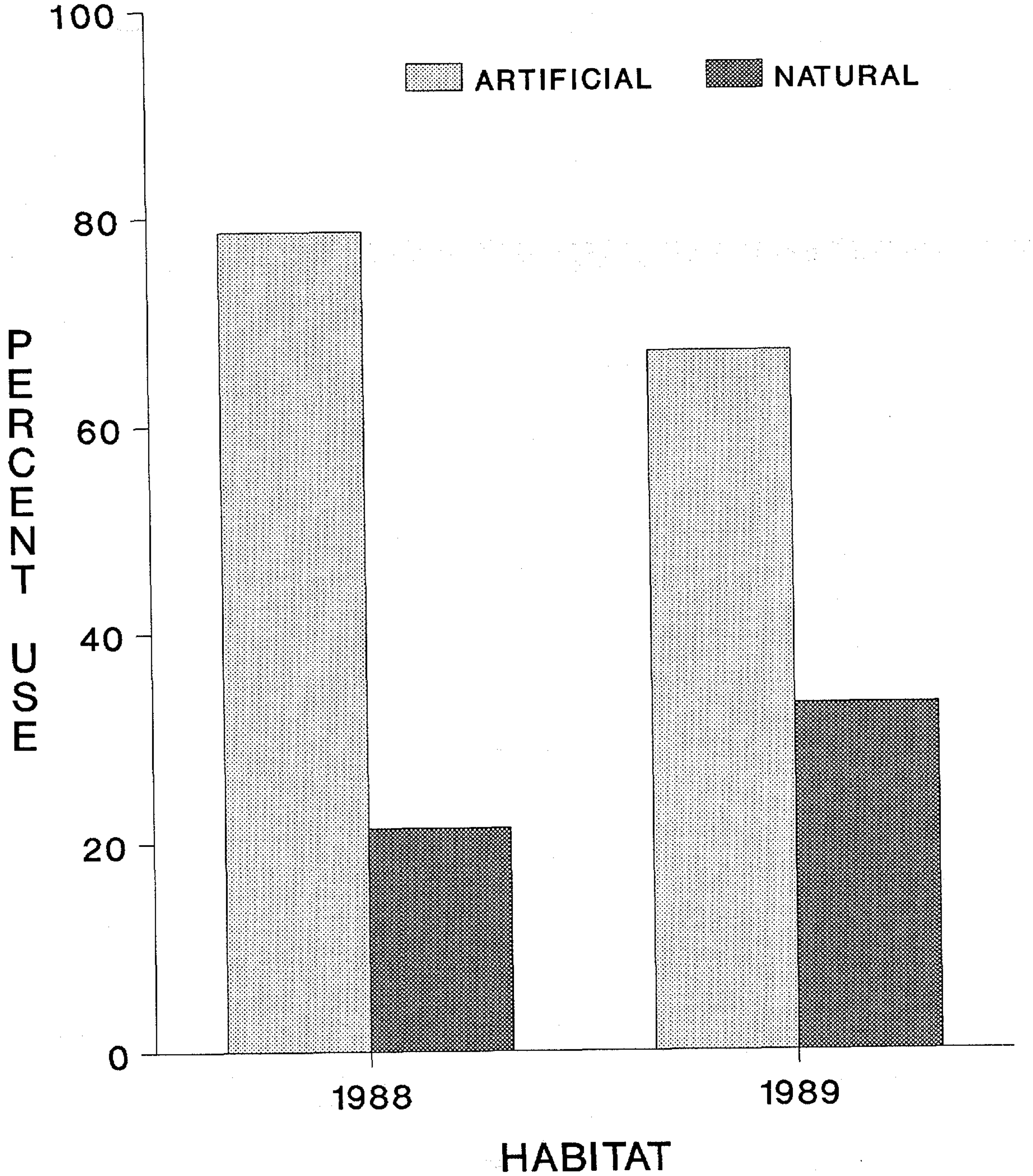


Figure 3.2. Comparison of use of artificial and natural foraging habitats by Snowy Egrets in 1988 (n=8 egrets) and 1989 (n=12 egrets).

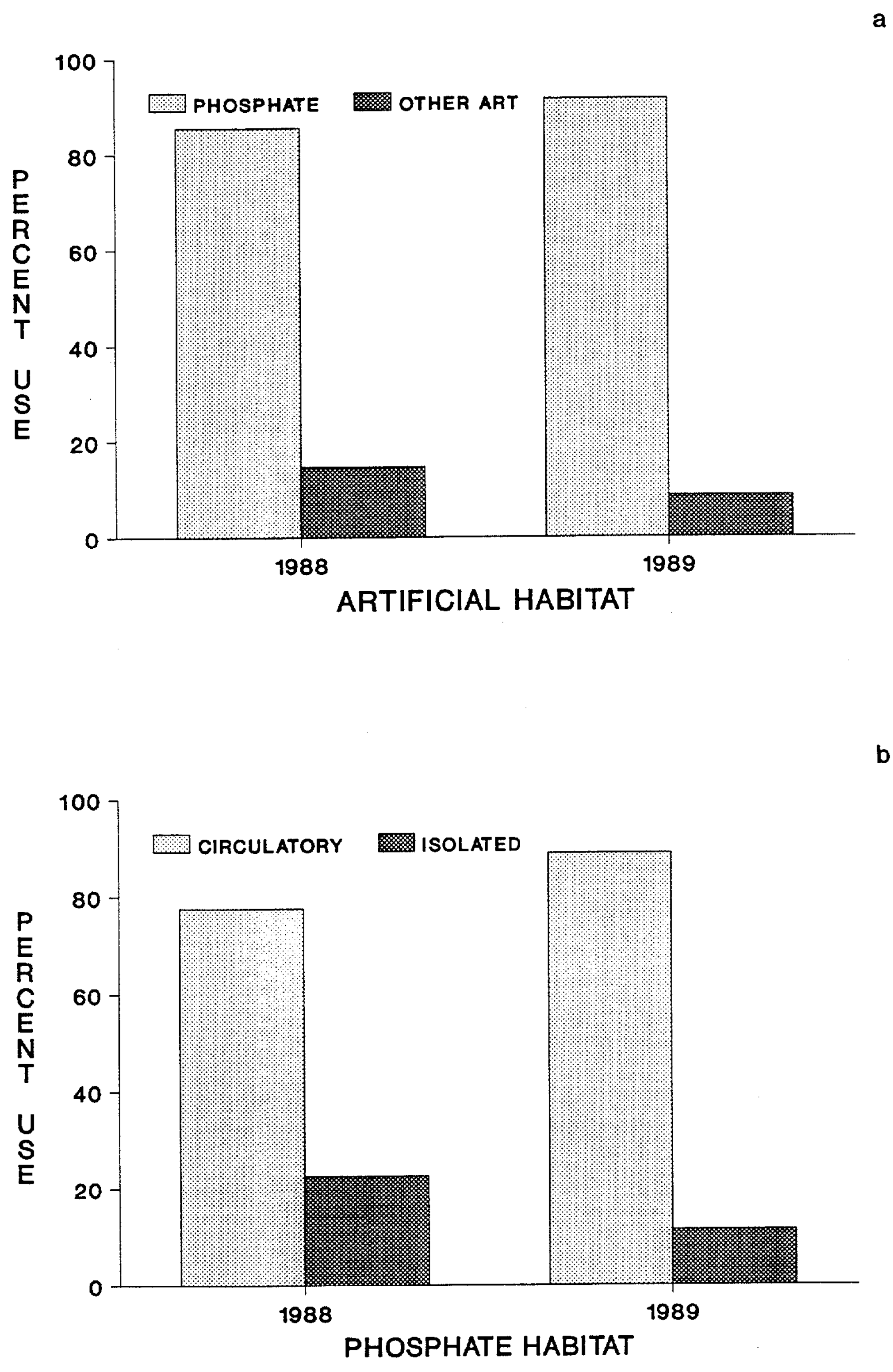


Figure 3.3. Comparison of use of 2 artificial foraging habitats by Snowy Egrets. a) Phosphate and non-phosphate in 1988 (n=8 egrets) and 1989 (n=12 egrets): b) Circulatory and isolated phosphate habitats in 1988 (n=7 egrets) and in 1989 (n=11 egrets).

(0.89) was significantly greater than 0.50 in 1989 [95% CI=(0.749,0.940)]. The probability in 1988 (0.78) was not significantly different from finding a bird at an isolated site [95% CI=(0.415,0.943]. In 1988, only one bird never foraged at circulatory sites, but in 1989 all egrets foraging at the phosphate mines used circulatory sites.

Snowy Egrets foraged predominantly at permanent wetlands (63.3%) in 1988, but in 1989 they foraged slightly more at temporary wetlands (54.8%) when using natural sites (Figure 3.4). The probability of finding an egret in a permanent rather than a temporary wetland did not differ significantly from 0.50 in either year [1988: 95% CI=(0.265,0.677); 1989: 95% CI=(0.277,0.785)].

Individual Variability

Individual radio-tagged Snowy Egret was located between 14 and 23 times in 1988 and between 18 and 48 times in 1989 during the breeding season. The proportion of foraging habitats used varied both among the egrets and within an individual bird. Although the overall patterns described above occurred with many of the individual birds, there was variation that encompassed the entire spectrum of possibilities. One bird in 1988 was found foraging in all 5 habitats, whereas, several birds foraged exclusively in one habitat. The relative use of each habitat (percent of locations in each category) also differed among individuals. Artificial foraging habitats were used by all radio-tagged Snowy Egrets in both years. In 1988, the use of artificial habitats by individual egrets ranged from 31.6 to 100% (Figure 3.5), but in 1989 covered a range from 2.1 to 100% (Figure 3.6). Five of the 8 radio-tagged Snowy Egrets in 1988 foraged significantly ($P<0.05$) more at artificial than natural sites; 4 of these egrets were found foraging only at artificial sites. In 1989, 6 of the 12 radio-tagged egrets foraged significantly ($P<0.05$) more at artificial sites; and 4 individuals were found foraging only at artificial sites.

Active phosphate mines were used by 7 of 8 foraging Snowy Egrets during 1988 (Figure 3.5) and 11 of 12 egrets in 1989 (Figure 3.6). In both years, bird use of phosphate mine areas was high (range = 83-100% in 1988 and 96-100% in 1989) relative to other artificial sites. The only artificial sites used by 6 egrets in 1988 and 10 individuals in 1989 for foraging were phosphate mines: 1 bird in each year did not use phosphate mines significantly more than other artificial sites (1988: no. 6; 1989: no. 11) ($P<0.05$).

In both years, several Snowy Egrets foraged exclusively at phosphate mines; 2 egrets in 1988 and 3 egrets in 1989. The 3

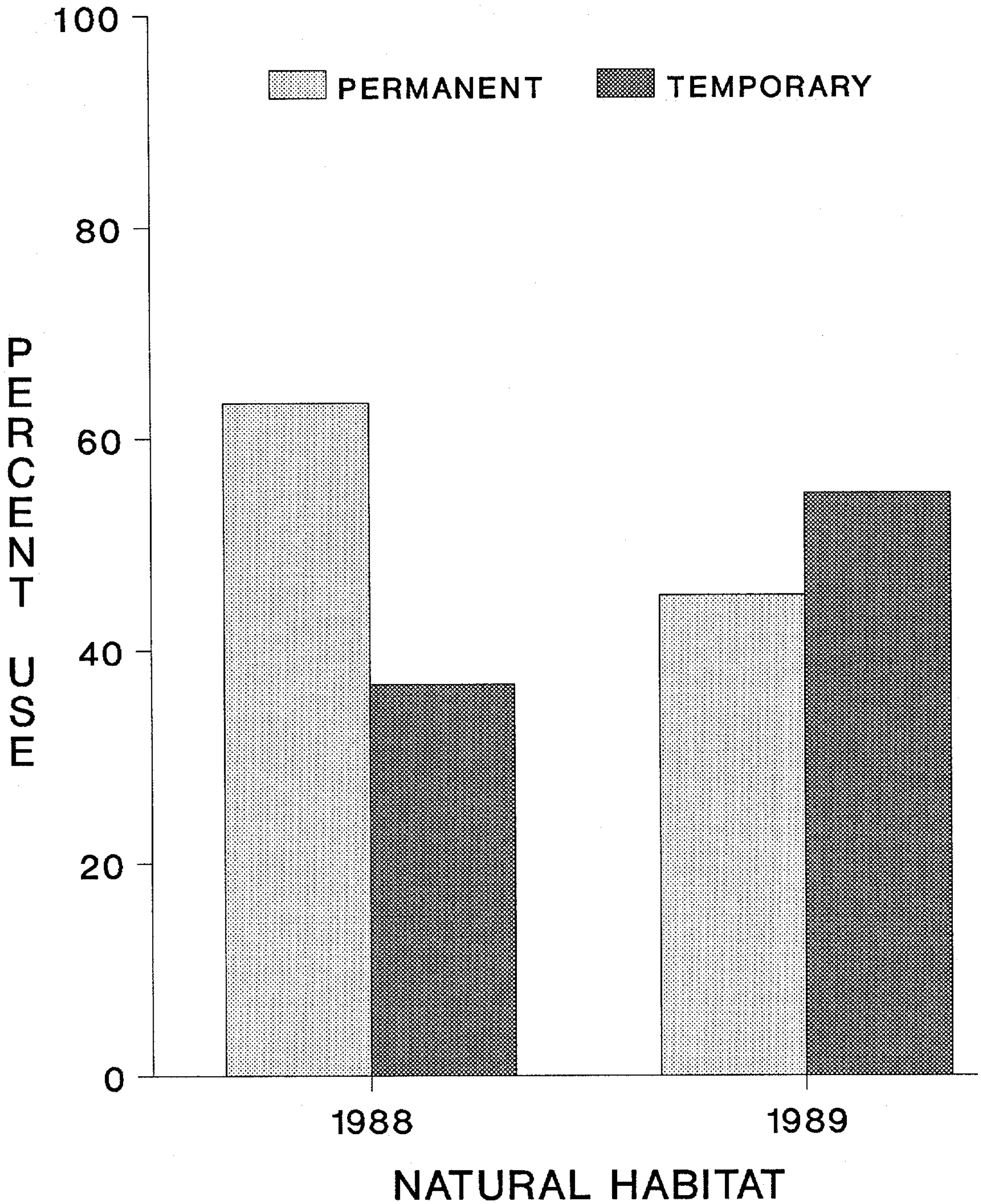


Figure 3.4. Comparison of use of 2 natural foraging habitats by Snowy Egrets in 1988 (n=5 egrets) and 1989 (n=8 egrets).

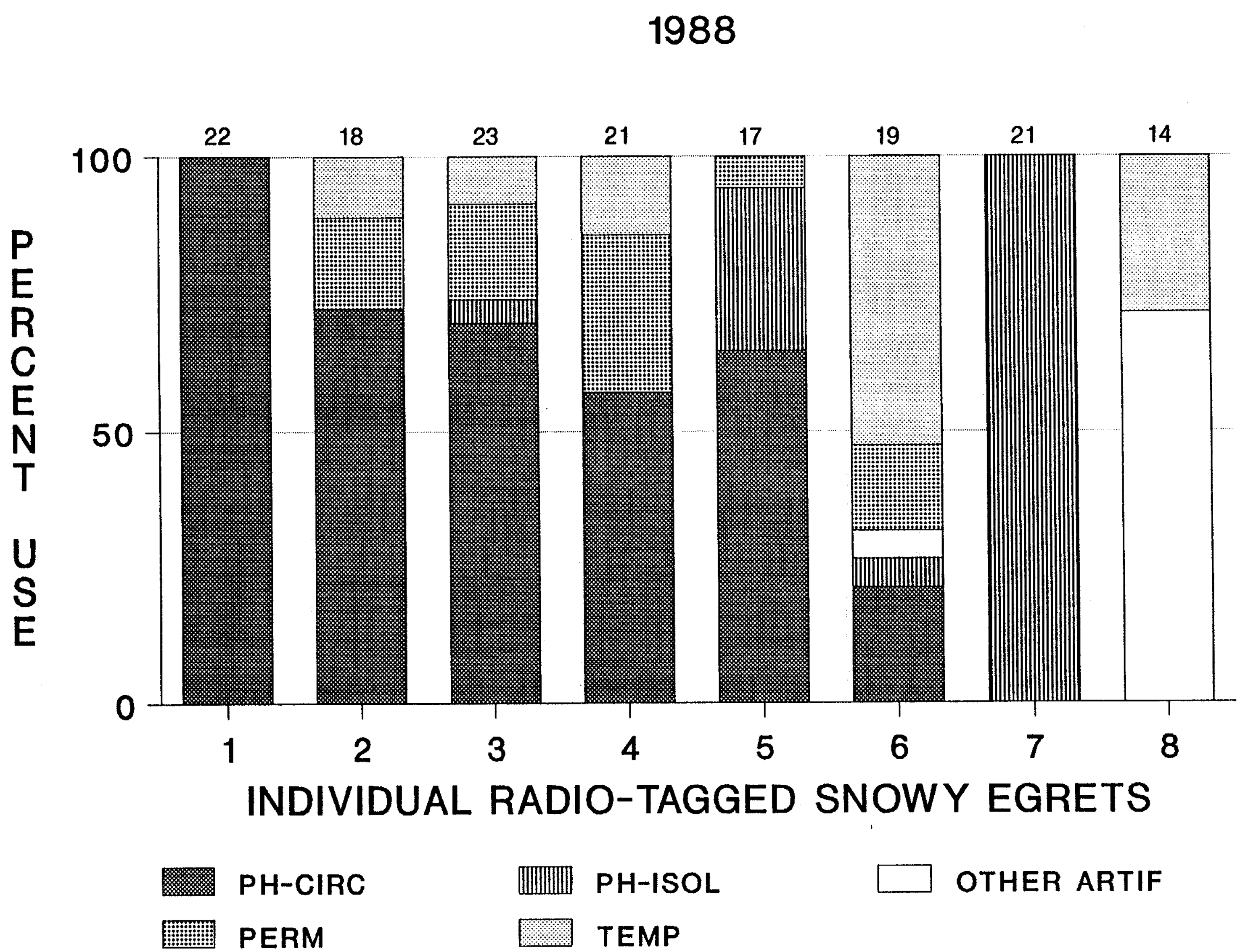


Figure 3.5. Foraging habitat use by individual radio-tagged Snowy Egrets in 1988. Circ=Circulatory, Isol=Isolated, Other artif=Other artificial, Perm=Permanent, Temp=Temporary (see text for definitions). Numbers at bar top represent number of observations.

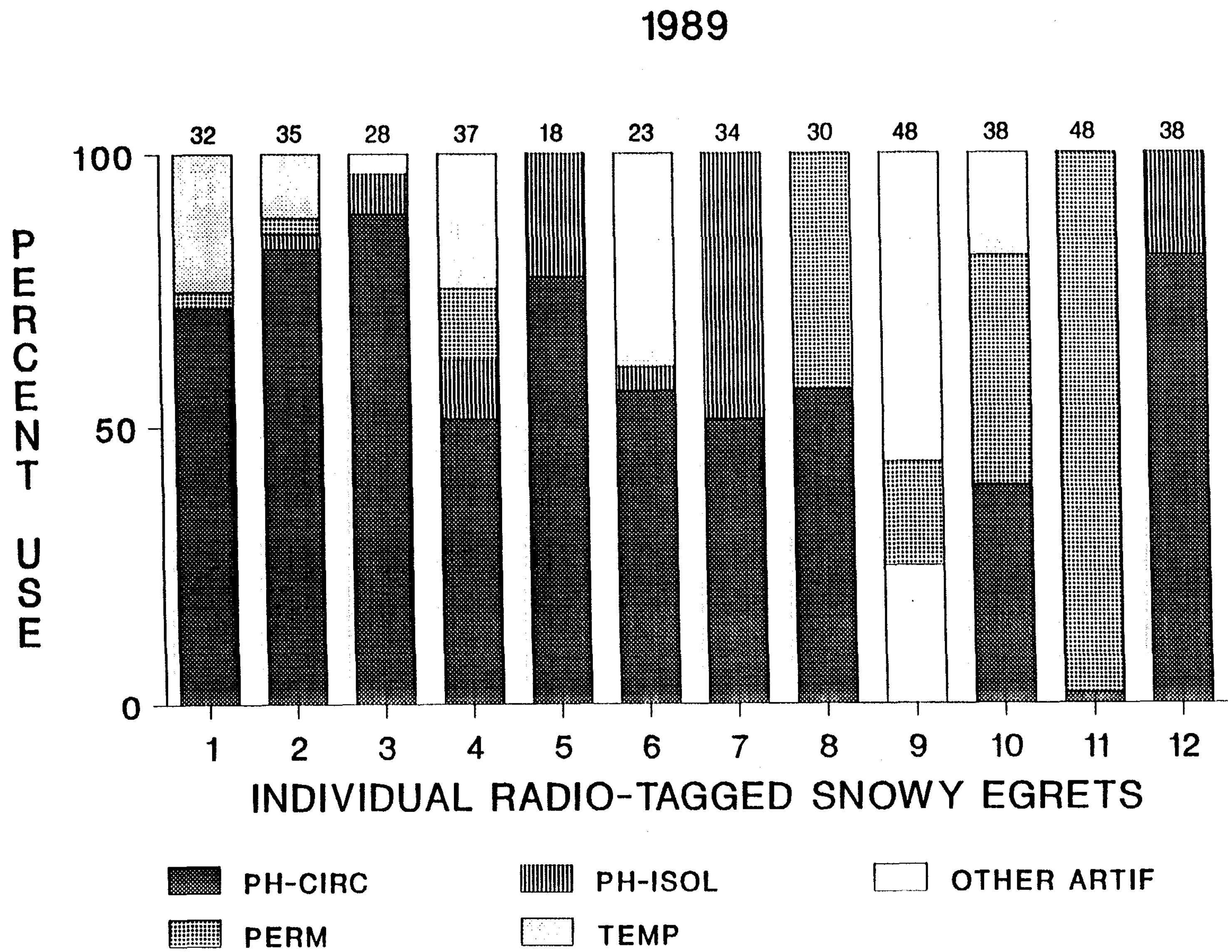


Figure 3.6. Foraging habitat use by individual radio-tagged Snowy Egrets in 1989. Circ=Circulatory, Isol=Isolated, Other artif=Other artificial, Perm=Permanent, Temp=Temporary (see text for definitions). Numbers at bar top represent number of observations.

egrets monitored in 1989 nested in colonies located at mines sites. Two of these birds were radio-tagged in 1988 at Lake Hancock colonies and they foraged predominantly at the mines in that year as well.

Circulatory system sites were used by 6 of the 7 Snowy Egrets foraging at the phosphate mines in 1988 (Figure 3.5). In 1989, all 11 birds foraging at phosphate mines were found foraging at circulatory sites (Figure 3.6). In both years, egrets using circulatory sites were located there more than half the time (1988: 69-100%; 1989: 51-100%) when foraging at phosphate mines. Circulatory sites were used significantly ($P<0.05$) more often than isolated sites by 4 of 7 birds in 1988, and by 9 of 11 birds in 1989. In particular, clay settling ponds were used more frequently than re-circulation ditches or ponds.

Four birds foraged at isolated phosphate mine sites in 1988 (Figure 3.5). In 1989, 7 egrets were located foraging at an isolated site (Figure 3.6). One individual in 1988, (no. 7) foraged exclusively at isolated sites, and was the only bird to forage significantly ($P<0.05$) more at isolated sites. This same bird used isolated and circulatory sites with equal probability in 1989; no birds foraged significantly ($P>0.05$) more often at isolated sites in 1989.

Four egrets, 2 each year, foraged at other artificial non-phosphate habitats (Figure 3.5 and 3.6). One bird each year was found foraging at both phosphate and other artificial categories (no. 6 in 1988 and no. 3 in 1989), but each bird was located only once at an other artificial site. The other 2 egrets were never found foraging at phosphate mines. One bird in 1988 foraged exclusively at other artificial sites. This individual foraged in an urban setting, switching among several locations in a roadside ditch, a nearby sewage treatment plant settling pond, and an associated canal. In 1989, one bird (no. 9) was found foraging 25% of the time at Wastewater treatment settling ponds associated with orange juice processing plants.

Five Snowy Egrets were found foraging at natural wetlands in 1988 and 8 egrets in 1989. Two individuals in 1989 (no. 9 and no. 11) foraged significantly ($P<0.05$) more at natural than artificial sites. Of the birds foraging at natural sites, use varied widely (range = 1988: 6-68%; 1989: 4-98%).

All 5 birds using natural areas were found foraging at a permanent site in 1988 (Figure 3.5). Seven of 8 birds in 1989 used permanent sites (Figure 3.6). Use of these sites ranged from 23% to 100% in 1988, and 11% to 100% in 1989. Two birds in 1989 (no. 8 and 11) foraged significantly ($P<0.05$) more at permanent sites than temporary ones; they were found foraging only at permanent sites when using natural areas. Fifteen permanent natural sites were visited by tagged herons. Lake

Hancock was the most commonly used area each year (1988: 71%; 1989: 78%). One bird in 1989 (no. 11) was found foraging 98% of the time at the lake, primarily in one location.

Four of the 5 birds using natural wetlands were found foraging at a temporary wetland in 1988 (Figure 3.5). In 1989, 6 of 8 birds were located foraging at a temporary wetland (Figure 3.6). Three egrets (no. 1, no. 6, and no. 9) foraged significantly ($P<0.05$) more at temporary ones in 1989. Use of temporary sites ranged from 33 to 77% in 1988, and 30 to 100% in 1989; one bird foraged exclusively in temporary wetlands. Twenty-five temporary wetlands were visited, including 15 marshes and 10 creeks.

Temporal Use of Habitats

Radio-tagged Snowy Egrets used phosphate mines in significantly different proportions among months in 1988 (ANOVA: $F=7.03$, $df=2$, $P=0.0077$) and in 1989 (ANOVA: $F=4.69$, $df=2$, $P=0.0222$). For both years, egret use of phosphate mines increased significantly (least square means) from May to July (Table 3.2). Sample sizes were too small to statistically evaluate a temporal shift in use of the other artificial habitat category.

There was no significant difference ($F=0.81$, $df=2$, $P=0.4649$) in use of temporary wetlands by Snowy Egrets among months in 1988. In 1989, however, use of temporary natural wetlands differed among months ($F=6.94$, $df=2$, $P=0.0055$) with use decreasing over time (Table 3.2). The 1989 dry season was drier than 1988; thus, many of the temporary wetlands dried during June and early July preventing the egrets from using these temporary sites. Locally, the rainy season began about 15-20 June in both years (IMC unpublished data).

Permanent sites were used significantly ($F=12.24$, $df=2$, $P=0.0008$) more often early in the 1988 season; however, there was no difference ($F=2.63$, $df=2$, $P=0.098$) in their use among months in 1989.

Foraging Group Size

The size of foraging groups of wading birds ranged from 1 to 1,750 wading birds (Table 3.3). Circulatory sites possessed the largest mean foraging group in both years and permanent sites had the smallest (Figure 3.7). An analysis of variance using the log-transformed mean group sizes, weighted by site, revealed significant differences among the five habitat categories in each

Table 3.2. Temporal change in use of habitat type by foraging Snowy Egrets in 1988 (n=8) and 1989 (n=12).[1]

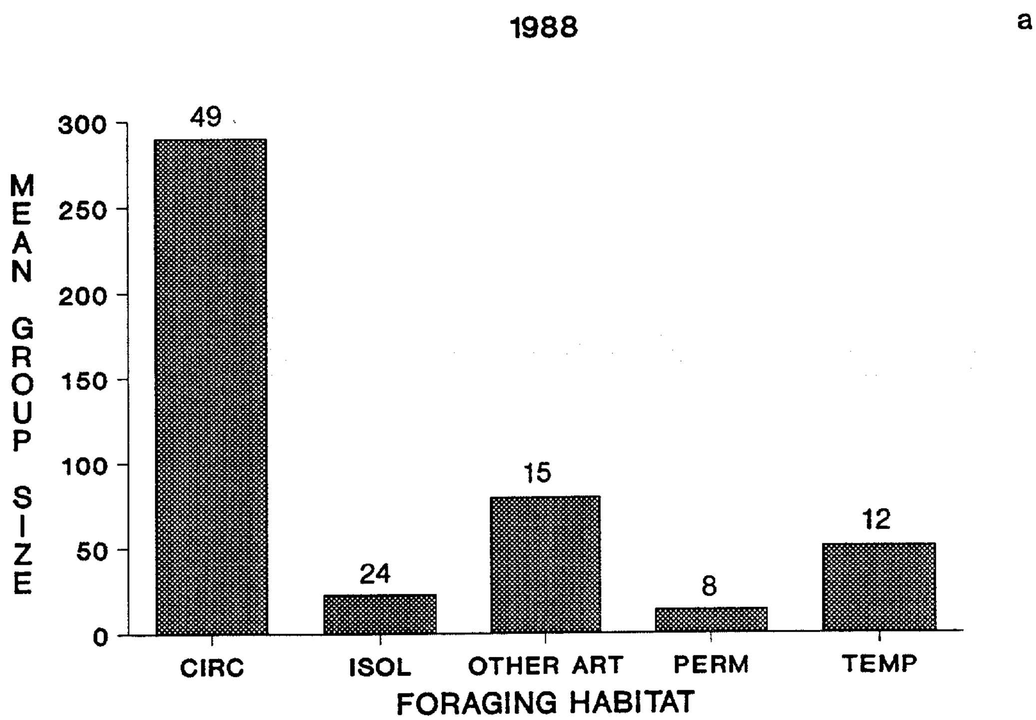
Year	Habitat	May (%)	June (%)	July (%)
1988	Temporary	14.5[a]	11.3[a]	3.1[a]
	Permanent	42.0[a]	1.8[b]	3.1[b]
	Phosphate	30.0[a]	74.5[b]	78.1[b]
1989	Temporary	32.0[a]	16.6[a]	3.4[b]
	Permanent	13.4[a]	24.8[a]	12.5[a]
	Phosphate	37.9[a]	56.1[a]	72.3[b]

[1]Values with different superscripts are significantly different ($P<0.05$) using least square means. Totals do not equal 100% as "other artificial" habitat was not included.

Table 3.3. Foraging group size of wading birds by habitat type[1] and year.

	1989				1988			
Habitat	n	x ± SE	Min	Max	n	x ± SE	Min	Max
Phos-circ	49	290 ± 48	3	1750	128	222 ± 28	1	1550
Phos-isol	24	23 ± 8	1	175	37	56 ± 13	1	349
Other artif	15	80 ± 66	1	1000	13	60 ± 8	30	140
Temp	12	51 ± 12	5	150	59	31 ± 5	1	200
Perm	8	13 ± 7	1	50	75	16 ± 2	1	83

[1]Habitat types: Phosphate circulatory, Phosphate isolated, Other artificial, Temporary, Permanent (see text for definitions).



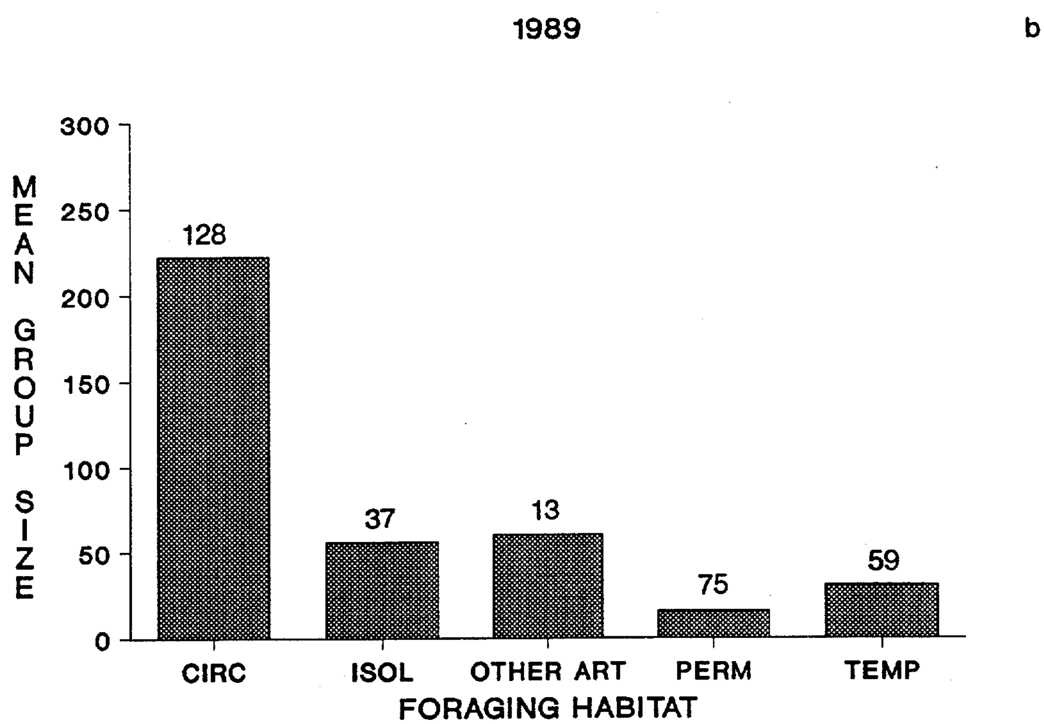


Figure 3.7. Foraging group size of wading birds by habitat type. a) 1988; b) 1989. Circ=Circulatory, Isol=Isolated, Other artif=Other artificial, Perm=Permanent, Temp=Temporary (see text for definitions). Numbers at bar top represent number of observations.

year (1988: F=10.57, df=4, P=0.0001; 1989: F=12.09, df=4, P=0.0001), and significant differences between years (F=3.29, df=4, P=0.0140). Pair-wise comparisons using least-square means showed group size in temporary and permanent habitats did not differ significantly from each other in either year (1988: P=0.1040, 1989: P=0.0557). These categories therefore were lumped and the data subsequently analyzed using four categories.

Mean group size of foraging wading birds at circulatory sites was larger than and differed significantly (P<0.05) from means of any other category in 1988 (Table 3.3). Further, the largest number of wading birds were observed using circulatory sites. There was no significant (P>0.05) difference in mean group size among isolated, natural, and other artificial habitats.

In 1989, mean group size of wading birds foraging at circulatory sites was significantly (P<0.05) larger than those at isolated and natural sites, but did not differ significantly (P>0.05) from group size at non-phosphate artificial sites. The mean group size at circulatory sites was smaller and similar to the mean group size of other artificial habitat in 1989 than in 1988, causing the difference between years. In 1989, in contrast to circulatory phosphate sites, group size at isolated phosphate sites did not differ significantly (P>0.05) from natural or other artificial habitats. The mean group size at other artificial sites differed significantly (P<0.05) from the mean group size of natural sites.

The pattern and behavior of groups of foraging wading birds varied with habitat type. The clay settling ponds of the circulatory sites were large in area (>100 ha.), but the birds foraged primarily in dense aggregations, often using less than one hectare at a time. The same clumping pattern was true for the temporary natural sites. Birds used sites with minimal or no littoral zone (e.g. some permanent, isolated, and circulatory sites) by lining up along the shoreline or perching in trees along the shoreline. Often, wading birds obtained fish from these relatively deep water bodies by aerial foraging (see Chapter II for description of foraging behavior). Aerial foraging occurred almost every day at the clay settling ponds in early morning during the summer, and group sizes regularly reached over 500 birds.

At both artificial and natural sites, a variety of wading bird species (herons, storks, and ibises) were observed foraging. Snowy and Great egrets dominated the aggregations at the phosphate mine sites at which the radio-tagged birds were found foraging, often comprising over 90% of the group. At natural sites, when relatively large aggregations (>20 birds) occurred, both egret species usually dominated, but not to such a large extent. The natural sites also usually had a greater number of wading bird species.

Foraging Distance

Snowy Egrets attending active nests (n=17, 1988 and 1989 combined) flew between 0-3-17.7 km to foraging sites from their colonies (n=96). For egrets nesting in the 2 colonies located at Lake Hancock (n=13 egrets), the mean distance flown to phosphate mine feeding areas (12 and 16 km) was usually at least twice as far as the mean distance flown to natural areas (3 and 7 km) (Figure 3.1). In 1989, other artificial areas frequently used were located 7.9 km from the colony: in 1988, only one such site. was visited and it was located 14.8 km from the colony. At the phosphate mines, circulatory and isolated areas were juxtaposed and thus egrets flew similar distances to forage at these categories. As Lake Hancock was the most frequently used permanent site, distances flown to forage at temporary wetlands were generally farther than permanent sites, but some permanent sites were located almost as far as the farthest temporary site (e.g. maximum distance was 11 km to a permanent site and 11.7 km to a temporary site).

Discussion

During the 1988 and 1989 breeding seasons, radio-tagged Snowy Egrets foraged more often, foraged in larger groups, and flew farther to feed in artificial habitats associated with phosphate mining than they did in natural habitats. Phosphate mines are atypical wading bird foraging habitat. Compared with shallow, drying marshes, they would appear to have less desirable characteristics for wading birds. The deep water at many of the mine sites prohibits birds from being able to wade and does not appear to concentrate prey. Additionally, at points where clay was being discharged into the settling ponds, the water opacity was almost zero, presumably impairing the ability of visually-feeding herons to capture prey.

Despite these disadvantages, there are obviously other factors promoting the use of artificial sites. It may be that the loss and degredation of natural foraging areas is driving the egrets to use artificial sites. Yet, qualities similar to natural foraging areas, but magnified at the artificial sites, also may be encouraging their use.

In southern France, for example, ricefields appeared to produce higher prey densities and were exploited more than nearby natural marshes by foraging Little Egrets (*Egretta garzetta*) during the breeding season (Hafner et al. 1986a). Ricefields in Italy also were important foraging habitat for wading birds (Fasola 1986). Fasola suggested this was due to ricefields being the largest area of feeding habitat available and they supported super-abundant prey. Super-productive fish farm ponds in the United States, Europe, and Israel also attract large numbers of foraging herons (Ashkenazi 1985, Draulans and van Vessem 1987, pers. obs.).

The large foraging aggregations of herons found at the phosphate mines and the other artificial sites exceeded aggregations of herons reported from some natural areas (Willard 1977, Erwin 1983), but were comparable to those found in the Everglades (T. Bancroft, pers. comm.). Wading birds appear to aggregate where food is abundant (Krebs 1974, Kushlan 1976b, Hafner et al. 1982), suggesting that use of the phosphate mines may be related to prey density.

Estimates of prey availability at the phosphate mines or other artificial sites in the vicinity were not measured quantitatively. At two clay settling ponds, where large aggregations of herons (>100) were foraging, a few 5 second sweeps of a dip net into the ponds captured over 100 small (2 to 5 cm) mosquito fish (Gambusia affinis) illustrating the presence and high abundance of these prey. Double-crested Cormorants, another picivorous waterbird, consumed high numbers of small fish (e.g. mosquito fish and shad (Dorosoma spp., etc.), and small invertebrates from clay settling ponds in Florida phosphate mines (O'Meara et al. 1982), including the specific mines Snowy Egrets foraged at in this study. Mosquito fish are common and important prey for Snowy Egrets foraging in freshwater environments in Florida (Jenni 1969, Bancroft et al. 1988).

The temporal shift in habitat use to greater use of the phosphate mines and lesser use of temporary wetlands as the nesting season progressed may be influenced by the complete loss of surface water at some temporary wetlands towards the end of the dry season. The phosphate mines are similar to permanent natural feeding sites as they remain inundated with water throughout the breeding season. When the rainy season begins in mid-June water levels rise rapidly, likely dispersing remaining, or re-colonized prey. Temporal shifts in use of broad habitat types and individual foraging sites have been attributed to changes in prey density and availability (Hafner and Britton 1983, Hafner et al. 1986a). Although other permanent sites (e.g. Lake Hancock and other lakes in the area) did not show increased use by tagged birds with the progression of the season, the number of unmarked wading birds foraging at Lake Hancock became significantly greater as the water level fell (see Chapter II).

Alternatively, the phosphate mines may be experiencing a temporal difference in heron use for reasons other than increases in prey density, or the drying-out of temporary wetlands. Herons might also change use of foraging habitats as their chicks grew and required different prey sizes (Moser 1986) or nutritional content.

Areas associated with the circulatory system of the mining process were used with greater frequency and had significantly larger foraging aggregations than the isolated (mined-out) sites. This differential use also was documented at north Florida phosphate mines (Maehr and Marion 1981). Maehr and Marion (1981) attributed the characteristic steep slopes and narrow littoral zones of mined-out areas as hindering wading bird use of these areas.

At the mined-out areas, herons either grouped at shallow sandbars and mudflats or were spaced out singly along the shoreline edge. Recently reclaimed sites had minimal vegetation associated with them, whereas, some of the circulatory sites were covered by emergent plants such as cattails or floating mats of water hyacinth (Eichhornnia crassipes). At the circulatory sites, herons foraged either in areas of dense vegetation which gave them access to prey in deep water areas or herons foraged aerially in deep open water. This suggests the prey may have been more accessible and in greater quantity at the circulatory sites. Circulatory sites are used as a source for stocking fish into nearby reclaimed mined-out areas (Fin and Feather Club 1989), indicating their potential large fish populations. Additionally, water hyacinth mats in a nutrient-rich environment support abundant populations of aquatic invertebrates (reviewed in Haag et al. 1987).

Whereas the phosphate mines were generally located farther from the Lake Hancock breeding areas than natural foraging sites, the distances flown fall within published foraging ranges for Snowy Egrets breeding elsewhere (Custer and Osborn 1978, Bancroft et al. 1988, Frederick and Collopy 1988). Therefore, these longer flights may not reflect a substantially greater energetic cost for the birds.

The other artificial habitats (Wastewater treatment ponds and the roadside ditch) mimicked temporary wetlands by becoming very shallow and occasionally drying out as Florida's dry season progressed. At the orange juice and the sewage treatment Wastewater facilities, radio-tagged birds foraged at the overflow ponds that frequently dry out. The egrets were likely attracted to these sites, just as they are to temporary natural sites, for their availability of concentrated prey (Kushlan 1976b). Sewage ponds support large numbers of aquatic invertebrates (Swanson 1977, Belanger and Couture 1988).

The quantity and biomass of prey at the artificial wetlands is likely influenced by two major factors. The re-circulation areas at the phosphate mines have high levels of phosphorus (total P range: 0.26-2.25 mg/l) and nitrogen (tkn range: 0.7-8.13 mg/l) (IMC 1989), contributing to the high biological productivity of these systems. The Wastewater treatment ponds also have high levels of these nutrients (City of Lakeland, Unpubl. data), although data are not available for the adjacent overflow ponds specifically.

Additionally, and maybe more importantly, these areas are essentially new systems with colonizing fish and invertebrate populations increasing rapidly in quantity and biomass. Bass in clay settling ponds and mined-out areas have growth rates two times greater than many natural lakes in Florida (F. Langford, pers. comm). The re-circulation areas have water constantly flowing among the ponds whereas the mined-out sites are isolated from other wetlands, thus limiting recruitment of fishes.

Many , if not all, of the "natural" areas also were influenced by human activities including the addition of nutrients resulting in artificially high levels of productivity. For example, Lake Hancock was the most frequently used permanent site by radio-tagged Snowy Egrets. Both the lake and the phosphate mines have high nitrogen and phosphorus values (IMC 1989, PCWRD 1990). Both the mines and the lake (FGFWFC 1986) have large populations of the exotic Nile perch (Tilapia spp.) which thrive in such highly nutrient-enriched environments.

Artificial sites are not always an adequate substitute for natural wetlands as foraging habitat for wading birds. In Oklahoma during the post-breeding season, wading birds avoided human-created farm ponds and other reservoirs especially those with a mud substrate and lacking submergent and emergent vegetation (Heitmeyer 1986). A comparison of use of anthropogenic ponds by breeding waterfowl found dabbling duck broods were more common on sewage ponds than on any other human-made pond (Belanger and Couture 1988). This was attributed to the exceptionally high biological productivity of the sewage ponds. Apparently, nutrient-enriched artificial sites within a disturbed landscape are being selected by dabbling ducks.

Whereas my data suggest artificial sites appear to play an important role in providing foraging habitat for Snowy Egrets in the Lake Hancock vicinity, there are reasons for concern. Current reclamation regulations and practices often result in clay settling ponds and mined-out lands being replaced with pastures or other less-productive wildlife habitats (Schnoes and Humphrey 1987). Over the long-term, if Snowy Egrets become dependant on phosphate mines, when phosphate extraction ends in central Florida, their populations may not be sustained through time. Their status as a Species of Special Concern may be further jeopardized. Compared to natural foraging areas, some artificial areas also may have greater risks associated with heavy metal contamination (Scanlon 1979) or parasite infection such as Eustronguilides spp. (M. Spalding, pers. comm.). In some cases, the creation of artificial sites is at the expense or destruction of natural habitats, further exacerbating the choice of sites for Snowy Egrets.

Snowy Egrets breeding at Lake Hancock colonies appear to have acclimated to a severely altered natural landscape by foraging in artificial areas. Snowy Egrets, being pre-adapted as a fish-consumer species that forages in wetlands, are able to exploit these newly created niches. Although phosphate mines are atypical foraging habitat, they provide insight into the plasticity and underlying requirements of foraging area preferences of Snowy Egrets. The current use of artificial sites is likely due both to their temporal and spatial availability and their apparently high biological productivity.

CHAPTER IV

CONCLUSION AND SYNTHESIS

Use of a hypereutrophic lake and phosphate mines by wading birds for foraging dispels some of the popular conceptions about their habitat requirements. Both areas are non-pristine, deep-water systems. Both are highly eutrophic systems with high levels of nitrogen and phosphorus and relatively poor water clarity (IMC 1989, PCWRD 1990).

In both situations, aerial foraging, an unusual and energetically expensive foraging behavior, was frequent. The birds also foraged in atypical vegetative habitat (e.g. cattails), probably because the vegetation allowed them access to deep water areas. Additionally, large numbers of two primarily fish-eating species, Snowy and Great egrets, foraged both at the phosphate mines and at Lake Hancock, whereas most other wading bird species did not. What these two altered habitats appear to have in common is an abundance of fish. It is likely that the large fish populations are a direct result of the high levels of nutrients.

What is unknown is the specific level of productivity that allows some wading bird species to exploit these non-traditional foraging areas, as well as the relevance of other factors. Radio-tagged Snowy Egrets nesting at Lake Hancock did not forage at adjacent lakes in the Winter Haven region, although these lakes were located the same distance from the colonies as the phosphate mines (see Figure 3.1). This may be due to the greater productivity of Lake Hancock and the phosphate mines, which have two times greater chlorophyll-a concentrations than nearby lakes (Zellars-Williams, Inc. 1987). Chlorophyll-a is a measure of biological productivity and can be a good predictor of fish populations (Jones and Hoyer 1982).

Additionally, the busy recreational and residential setting of Winter Haven's lakes contrasts with the relatively disturbance-free Lake Hancock. The phosphate mines are closed to public access and also are relatively disturbance-free. The status of the phosphate mines appeared to influence the egrets as well; non-active phosphate mines located a few kilometers north of Lake Hancock were rarely used by radio-tagged egrets.

My results suggest artificial sites, particularly active phosphate mines, can support large numbers of wading birds. Whereas the mines may appear to be very productive and attractive, we need to consider their long-term sustainability and the health of the wading bird populations using them. Large numbers of wading birds nest and forage at the mines, but the nesting or foraging success of these birds remains undocumented. Further, the creation of new clay settling ponds and other artificial sites often relies on the destruction of natural habitats, including wetlands. Most artificially created wetlands will persist only as long as they are useful to humans, as exemplified by the filling in of clay settling ponds to create pastures and other less-productive wildlife habitats (Schnoes and Humphrey 1987). Overall, artificial sites may temporarily support an already declining population and mask our strong need to protect natural foraging habitat.

The 2 previous chapters (Chapter II and III) illustrate an example of an unusual foraging situation that has developed in response to strong human influences. I believe the conservation of wading bird populations is largely dependent on our understanding of their foraging habitat requirements and on the use of this information to construct conservation strategies. The results of this study demonstrate the importance of understanding the function of altered and artificially nutrient-enriched wetlands as alternatives to lost natural wetlands in a growth state such as Florida.

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APPENDIX
LAKE HANCOCK SURVEY DATA

Table A.1. Number of wading birds observed foraging at Lake Hancock and lake level by date, 1988.

Date	GBH	GE	LBH	SE	WI	BCN	WS	TRI	GRB	SWH	SDH	UNI	GI	TOT	LL (m MSL)
20 Mar	137	76	34	49	27	23	29	3	0	0	0	6	0	384	ND
28 Mar	106	82	16	51	5	10	8	2	1	0	0	15	1	297	29.809
5 Apr	137	80	10	18	13	17	5	4	1	4	0	3	0	292	29.840
13 Apr	159	51	16	14	13	17	0	4	3	2	0	4	0	283	ND
5 May	146	100	22	135	15	6	0	13	4	1	0	10	0	452	29.764
12 May	150	69	22	48	6	5	0	7	5	2	0	4	0	318	29.742
20 May	151	78	21	47	13	2	0	3	3	0	0	1	0	319	29.718
27 May	136	238	30	164	13	4	1	6	3	2	0	0	0	597	29.718
3 Jun	144	159	26	82	22	3	0	5	6	0	1	1	1	450	29.672
10 Jun	154	97	24	67	18	6	0	6	5	0	0	3	1	381	29.611
17 Jun	135	121	24	89	21	3	0	5	5	5	0	0	2	410	29.611
25 Jun	136	234	44	134	39	13	42	11	8	48	1	0	4	714	29.642
2 Jul	150	246	30	133	12	13	127	7	6	28	0	0	2	754	29.672
8 Jul	185	115	35	74	11	32	30	12	6	7	1	1	7	516	29.642
15 Jul	159	132	27	94	20	34	77	8	6	11	1	2	0	571	29.688
27 Jul	102	299	18	155	3	9	240	12	5	24	0	6	0	873	29.764
2 Aug	113	188	11	81	4	6	63	2	10	7	0	2	0	487	29.901
12 Aug	90	131	21	67	6	40	95	6	4	2	4	1	0	467	29.825
18 Aug	160	205	20	96	12	52	27	9	9	13	1	1	0	605	29.886
4 Sep	155	137	19	67	1	18	2	13	18	0	1	2	0	433	29.840
18 Sep	125	59	7	48	1	11	1	4	16	0	1	0	0	273	30.114

GBH=Great Blue Heron, GE=Great Egret, LBH=Little Blue Heron, SE=Snowy Egret, WI=White Ibis, BCN= Black-crowned Night-heron, WS=Wood Stork, TRI=Tricolored Heron, GRB=Green-backed Heron, SWH=Unidentified Small White Heron, SDH= Unidentified Small Dark Heron, UNI=Unidentified, GI=Glossy Ibis, RS=Roseate Spoonbill, YCN=Yellow-crowned Night-heron, TOT=Total number of wading birds observed on survey, LL=Lake level.

Table A.2. Number of wading birds observed foraging at Lake Hancock by date, 1989.

Date	GBH	GE	LBH	SE	WI	BCN	WS	TRI	GRB	SWH	SDH	UNI	GI	RS	YCN	TOT
21 Feb	159	109	27	84	13	28	31	1	8	1	2	0	0	0	0	463
27 Feb	157	105	18	27	24	47	36	2	8	1	2	3	0	0	0	430
11 Mar	158	80	30	36	18	56	5	3	12	1	2	1	0	0	0	403
21 Mar	154	52	9	41	11	20	8	3	2	2	2	1	0	0	0	305
29 Mar	142	82	21	48	2	24	10	5	5	0	2	0	0	0	0	341
5 Apr	207	123	9	46	10	33	3	10	4	0	5	0	0	0	0	450
14 Apr	169	128	7	54	3	29	1	6	8	2	0	0	0	0	0	407
22 Apr	185	126	8	34	14	20	2	6	5	0	2	0	0	0	0	402
30 Apr	184	195	8	74	9	18	2	10	2	0	1	0	0	0	0	503
8 May	205	103	10	25	6	36	0	1	3	1	0	0	0	0	0	390
15 May	188	154	22	87	14	11	0	6	17	0	0	0	0	0	0	499
22 May	181	127	13	38	12	15	0	1	13	1	0	2	0	0	0	403
29 May	169	109	11	55	9	12	0	3	17	0	2	6	0	0	0	393
5 Jun	160	149	17	85	16	16	0	5	10	3	1	0	0	0	1	463
12 Jun	139	340	19	224	92	32	8	13	11	24	0	0	0	0	1	903
19 Jun	151	316	33	148	42	14	5	7	9	25	1	14	11	0	1	777
26 Jun	174	194	24	105	17	34	4	13	14	20	1	0	0	0	0	600
3 Jul	206	266	22	154	13	59	24	11	15	35	3	0	0	0	0	808
10 Jul	192	332	19	124	20	21	73	14	6	23	0	1	0	5	0	830
17 Jul	176	253	21	167	31	8	36	8	10	27	0	0	0	3	0	740
24 Jul	148	127	22	98	4	13	16	13	5	14	1	0	0	2	0	463
31 Jul	185	267	22	140	1	35	0	7	1	8	1	0	0	0	0	667
17 Aug	164	176	18	58	0	3	0	10	11	13	1	0	6	0	0	460
1 Sep	143	170	15	80	1	10	0	11	5	2	0	0	13	0	0	450
24 Sep	93	63	5	35	4	5	5	5	1	0	0	0	0	0	0	216

GBH=Great Blue Heron, GE=Great Egret, LBH=Little Blue Heron, SE=Snowy Egret, WI=White Ibis, BCN= Black-crowned Night-heron, WS=Wood Stork, TRI=Tricolored Heron, GRB=Green-backed Heron, SWH=Unidentified Small White Heron, SDH= Unidentified Small Dark Heron, UNI=Unidentified, GI=Glossy Ibis, RS=Roseate Spoonbill, YCN=Yellow-crowned Night-heron, TOT=Total number of wading birds observed on survey.

Table A.3. Water parameters measured at Lake Hancock by date, 1989.

Date	Lake Level (m MSL)	Mean Water Temp. (C)	Mean Dissolved Oxygen (mg/l)	Mean Secchi Depth (cm)
21 Feb	29.800	ND	ND	ND
27 Feb	29.800	ND	ND	ND
11 Mar	29.840	ND	ND	ND
21 Mar	29.779	ND	ND	ND
29 Mar	29.779	ND	ND	ND
5 Apr	29.779	ND	ND	ND
14 Apr	29.748	22.0	ND	20.0
22 Apr	29.790	21.6	6.44	19.8
30 Apr	29.760	25.4	1.70	22.0
8 May	29.748	22.4	3.23	14.6
15 May	29.688	24.8	3.51	16.9
22 May	29.645	27.3	2.73	18.3
29 May	29.602	27.3	2.14	17.5
5 Jun	29.535	27.3	1.02	17.8
12 Jun	29.535	27.8	0.46	13.4
19 Jun	29.486	27.4	0.93	11.7
26 Jun	29.550	28.0	2.85	13.0
3 Jul	29.590	27.9	0.36	11.1
10 Jul	29.566	27.9	1.57	11.9
17 Jul	29.578	28.9	1.56	11.5
24 Jul	29.642	26.7	0.76	10.8
31 Jul	29.620	27.9	0.33	10.8
17 Aug	29.638	27.5	1.29	11.8
1 Sep	29.669	29.7	0.81	15.1
24 Sep	29.864	ND	ND	ND

RECOMMENDATIONS[1]

1. A study should be conducted to evaluate the regional and statewide significance of Lake Hancock to wading birds for its value as nesting and foraging habitat.

2. Another facet of determining the regional/statewide significance should include analyzing data on colony distribution and abundance of wading bird colonies statewide to specifically determine if the distribution of Snowy Egret and Great Egret colonies are clumped near the phosphate mine regions of the state and if the number of breeding pairs is greater in these colonies than in other regions of the state. The original Florida Atlas of Breeding Sites for Herons and their Allies (Nesbitt et al. 1982) and the more recent survey data collected by the GFC's Nongame Program should be used in this analysis. This may illuminate if egrets are "seeking out" phosphate mines or if they are just using a habitat type that is more available.

3. Initiate studies of other lakes to determine habitats used, temporal use, and level of lake productivity important for foraging wading birds.

4. Threats to these foraging and nesting habitats should be identified.

5. Develop mitigation plans for any adverse impacts to these habitats.

6. Develop a management program to protect and maintain the important foraging and nesting habitats for wading birds in the region.

7. Restrict the development of Lake Hancock's shoreline and areas next to the wading bird colonies immediately adjacent to the lake (e.g. Sickle Colony, see Chapter II). The value of Lake Hancock as nesting habitat is independant of the lake's foraging value and these shoreline habitats and adjacent areas should be recognized and protected singularly.

8. Discourage recreational activities in proximity to nesting colonies, especially during the breeding season.

9. During the breeding season (January-July):

a) estimate the number of breeding pairs in each colony on and immediately adjacent to Lake Hancock annually or bi-annually; at a minimum, monitor nesting colonies annually for presence/absence and species composition; and

b) monitor and maintain the water depth under Lake Hancock colonies.

10. Determine the foraging areas important to White Ibises nesting at the Lake Hancock colonies.

11. Examine fish from Lake Hancock for possible parasites (e.g. Eustronguilides spp.) detrimental to wading birds.

12. Any Lake Hancock restoration plan should incorporate and consider the data in this report. Some general recommendations include:

a) Any draw-down of the lake should be conducted during the wading birds' non-breeding season (August-November);

b) Create a wider (e.g. shallower) littoral zone;

c) Monitor the fish population and the number of nesting and foraging wading birds at the lake after restoration; and

d) Protect off-lake foraging areas to offset any losses associated with the lake's restoration.

13. Wetlands within a minimum of 17 km should be considered potential foraging habitat for Snowy Egrets birds nesting in the Lake Hancock vicinity.

14. Incorporate a variety of wetland types within the potential foraging range of nesting colonies into statewide and local conservation plans. There was a great deal of variability among and within individuals, with some birds relying primarily on non-artificial sites. A greater diversity of wading birds used the natural areas. Both permanent and temporary natural areas were used by foraging wading birds and likely are differentially important according to annual surface water levels.

15. Protection of a large number of small, isolated wetlands, in proximity to each other and the nesting colony, will likely better ensure the continued use of these temporary sites throughout the breeding season.

16. Estimate the number of breeding pairs in colonies located at the phosphate mines every 3-5 years; monitor nesting colonies annually for presence or absence and species composition.

17. Future studies should describe and quantify the prey egrets are capturing at artificial sites and at Lake Hancock. In particular, regurgitant analysis of the food adults are bringing the chicks would be valuable.

18. Future studies should quantify the foraging and nesting success of individuals using artificial sites: if possible in conjunction with quantifying the success of using nearby natural areas.

19. Conduct systematic aerial surveys of the mines to determine the distribution and abundance of foraging wading birds. This will compliment and expand upon this study's findings by addressing the question of which specific areas are used versus those that are not used.

20. Future studies should examine the abundance, distribution, recruitment, and growth of prey in the various phosphate mine habitats (e.g. clay settling ponds vs. mined-out areas).

21. The reclamation of phosphate mine lands should consider:

a) Creating islands within deep water mined-out areas to provide nesting habitat for wading birds; and

b) Reclaiming some of the mined-out areas and clay settling ponds as temporary wetlands, and some as permanent wetlands with a wide, shallow littoral zone.

[1] Some of these recommendations are based on information from scientific literature and discussions with professional biologists familiar with wading birds. They have been incorporated here along with those that came directly from data collected during this study.