Monitoring and Research on Wading Birds in the Water Conservation Areas of the Everglades: The 1996 Nesting season

Peter C. Frederick

Johanna Salatas

James Surdick

Department of Wildlife Ecology and Conservation

P.O. Box 110430

University of Florida

Gainesville, Florida 32611-0430

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Executive Summary

This project was initiated to continue monitoring reproductive responses of wading birds in the central Everglades, and to investigate two areas of research considered key to understanding and managing wading birds: nestling energetics, and factors affecting food availability. This report summarizes the first of two years of work.

Between January and July of 1996, we surveyed WCAs 2 and 3 for wading bird nesting via systematic aerial and ground surveys. Between January and late June of 1996, nest initiations by ciconiiform wading birds (not including Cattle Egrets, Anhingas or Double-crested Cormorants) totalled 6,214 attempts in WCAs 2 and 3, 3,363 in Loxahatchee National Wildlife Refuge, 1,396 in mainland Everglades National Park, 1,403 in Florida Bay, and 1,650 in Big Cypress National Preserve. The total for the Everglades region was 14,026 (again, not including Cattle Egrets, Anhingas or cormorants). These totals in the Everglades proper are less than 40% of "banner" years of 1992 and 1975, and are not exceptional in the context of the past ten years.

The 1996 season was characterized as being a high water year following three high water years. Most compartments showed stages well above normal for most of the nesting season. The winter and spring had little rain, and generally clement weather, leading to an uninterrupted and very rapid recession of surface waters from November - April. Both early and late recession rates were the fastest on record for WCA 3. 1996 constituted a good test of the effect of rapid surface drying on nesting effort, in the context of preceding wet conditions, and clement weather. The nesting response was unexceptional numbers, with increases in the proportions of Cattle Egrets (Bubulcus ibis), Great Egrets (Ardea albus), Wood Storks (Mycteria americana) and Little Blue Herons (Egretta caerulea), and decreases in proportion of White Ibises (Eudocimus albus), by comparison with 1986 - 1989, a period of neither drought nor flood. Nesting in the Everglades was concentrated within the Water Conservation Areas (80 - 95%, depending on where borders are drawn). These features were (with the exception of increasing Wood Storks), characteristic of the entire 1993 - 1996 period of high water.

The high water of the 1993 - 1996 period has also delivered considerably more surface water to the estuarine areas of the Everglades, and may constitute a test of the coastal degradation hypothesis. The latter predicts that nesting in the coastal zone should increase as

the area is rewatered, at least compared with the highly drained and salinized condition of the past 15 years. Although Wood Storks have increased slightly in the coastal regions of Everglades National Park, there is no obvious increase in nesting, and no evidence of a geographical shift of nesting from inland locations towards the coast. However, considerable uncertainty exists as to the timing of this prediction relative to rewatering.

In order to document the levels of energy required for successful nesting, we measured food intake of 39 Snowy Egret and Little Blue Heron nestlings from 5 - 22 d of age in the Hidden, Gator Baby, and Heron Alley colonies, using the labeled water technique. We found no evidence for an effect of geographic location of colony on food intake, nor of species on food intake and growth rate. Lumping across colonies and species, and controlling for the effect of nestling age and colony, we found a significant positive effect of food amount on chick mass. Analyses by species which controlled for age, colony, and hatch order also suggested that food amount consumed had an effect on chick mass. These results imply that food amount consumed has a strong residual effect upon chick mass even when the effects of species, hatch order, colony and age have been controlled for.

To identify environmental and biotic variables affecting wading bird foraging success, we observed at total of 817 foraging wading birds (292 Great Egrets, 151White Ibises, 213 Snowy Egrets, and 161Wood Storks) for a total of 4,633 minutes at an array of sites that were also being quantitatively sampled for prey fishes and macroinvertebrates. At each site and specifically for each observation we collected data on environmental variables that might affect foraging success. The analyses are to date incomplete because we have not yet received the prey database, and because our sample size of sites (and consequently range of environmental characteristics) remains too small for multivariate analaysis. However, univariate correlations between species-specific capture rates and environmental variables suggests significant negative relationships between between foraging success and water depth, water temperature, and vegetation density for most species. No significant relatonships were discovered between foraging success and sun angle, time of day, soil type and color, and air temperature.

For the second field season, we plan to continue monitoring wading birds using established techniques, and to expand both research efforts. The energetics work will focus in 1997 on identifying the levels of food at which chicks begin to experience substandard health and survival, and to examine the effect of total nest energy and brood size. The work on identifying factors affecting foraging success will expand to more sites as they attract birds, and will include monitoring of dissolved oxygen, begin supplemental samplings of prey at foraging sites, and examine the effect of environmental variables on choice of site as well as on foraging success.

Acknowledgements

We wish to thank Jeffrey Burm for his help as our field technician in 1996 - we valued his expertise, good humor, and companionship deeply. We also thank Chris Schadt, Aimee Weber, and Lenny Santisteban for helping cheerfully in the field under trying conditions, with little compensation other than the experience. Their help came at a critical time in the development of the research, and we thank them for their good humor and forbearance. Frank Burnett helped us with statistical analysis, and we thank him particularly for his help on short notice. This project was funded by the Jacksonville office of the U.S. Army Corps of Engineers.

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INTRODUCTION

This study was initiated in January of 1996 with three goals in mind - continued monitoring of nesting populations of wading birds in the Water Conservation Areas of the Everglades, and the pursuit of two directed research questions - measurement of reproductive energetics of nestling wading birds, and identification of factors affecting prey availability for adult wading birds. These three goals have immediate value to the larger goal of restoring wading bird populations to the Everglades. Continued monitoring of wading bird populations is essential, as a tool for measuring the effect of different water management strategies, as a method for better understanding the ecology of this group of birds, and as a way to detect changes that may be due to novel influences that are unrelated to water management (eg, exotic fish dynamics, contaminants, etc). The research on energetics is aimed at measuring the levels of food necessary for the production of young wading birds, and at understanding the effects of food amount on growth, health and survival of young. This work is aimed at helping to refine and direct modeling of wading bird reproductive responses, a process that has repeatedly identified nestling energetics as a critical area for research. The identification of environmental factors affecting prey availability to foraging wading birds is mandated both by the desire to better manage the marsh surface directly for wading bird foraging, and by the conjunction of a complementary project which will measure forage fish densities throughout much of the Everglades. These three subjects are linked to a much broader effort to understand and restore wading bird populations in the Everglades ecosystem. Since these three tasks represent essentially separate studies, they are treated in this report as chapters, each with their own introductions and justification. However, a review of the history of wading bird populations, and the probable causes of breeding population decline are common to all three, and should be presented at the outset.

The Everglades of southern Florida has historically supported very large populations of wading birds (herons, egrets, ibises, storks and spoonbills, order Ciconiiformes), numbering in the hundreds of thousands of pairs in some years (Robertson and Kushlan 1974, Ogden 1994). While there was typically large variability in numbers nesting from year to year during the pre-drainage period, a core population of at least one hundred thousand pairs seems to have been typical of the Everglades ecosystem in many years from 1930-1948 (Kushlan et al. 1984, Ogden 1994). Since that time, nesting wading bird populations have declined to less than 5% of their former numbers (Figure 1.1), nesting success of storks has been drastically reduced, the timing of nesting by storks has been shifted by as much as two or three months into the spring, and the location of most nesting has shifted from the estuarine areas of Everglades National Park to Water Conservation Areas (WCAs) one and three (Frederick and Collopy 1988, Bancroft 1989, Frederick and Spalding 1994, Ogden 1994).

These dramatic changes in breeding dynamics and numbers have been accompanied by an intensive period of manmade hydrological changes (Gunderson and Loftus 1993, Light and Dineen 1994). In the space of approximately 30 years, large portions of the freshwater marsh were diked and impounded, the majority of the northern freshwater marshes were drained and agriculturalized, and surface water flows came directly under the control of human management. This resulted in an outright loss of 30% of the marsh surface to other land uses (Browder 1978), a drastic cutoff of freshwater flows to the formerly productive estuarine zone of Everglades National Park (Walters et al. 1992), and the loss of the majority of short-hydroperiod marshes in the system (Fleming et al. 1994, Ogden 1994).

Why have wading birds declined?

The record of population monitoring is both lengthy and rich, and has been summarized in detail by Kushlan et al. (1984), and Ogden (1978, 1994). These summaries show that many of the heron and egret species went through a severe decline during the plume-hunting period from 1875 to 1910, after which many populations (Reddish Egret Egretta rufescens excepted) rebounded quite rapidly by the 1930's. An obvious conclusion is that once constraints on reproduction are removed, many of the species have the potential to increase rapidly and, in a healthy Everglades environment, could presumably be sustained in large numbers.

During the 1930's and 1940's, the emerging picture is one of high variability in annual nesting numbers, but a population of at least 100,000 pairs (all species combined) that bred with some regularity (Kushlan et al. 1984, Ogden 1978, 1994). The largest colonies were located in the mangrove zone along the coast of what is now Everglades National Park. In addition, substantial summer breeding by several species, and large summer roosting

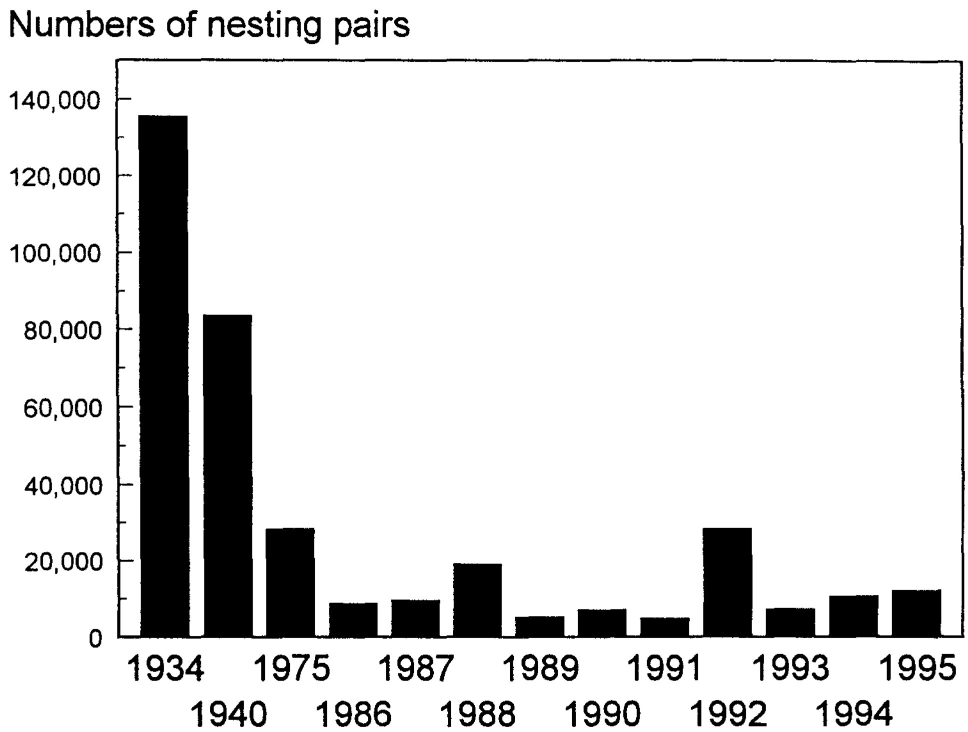


Figure 1.1. Numbers of nesting pairs of all species of wading birds in the Everglades, 1934 - 1995. Summarized from data in Kushlan and White (1977), Ogden (1978), Kushlan et al. (1984), Frederick and Collopy (1988), Bancroft (1989), Ogden (1994), and from unpublished records of the National Audubon Society.

populations of White Ibises (Eudocimus albus) were a regular feature of this period. Another consistent feature was that Wood Storks (Mycteria americana) were typically recorded initiating breeding during the late fall (November - December). Careful analysis of breeding and hydrological records during this period suggests that larger aggregations bred in wetter years, and that the size and success of breeding had only a weak association with the rapidity of drying of the interior marsh surface (Ogden 1994). In fact, the impression Ogden gives is that breeding occurred not so much under different conditions than at present, as under a much wider range of conditions.

The period of the 1950's and early 1960's was one of very sporadic and often incomplete surveys. At some point during this period, Wood Storks began to decline (there is some disagreement as to the timing, see Ogden 1994), and White Ibises began showing up in South Carolina and Georgia in more than token numbers (Frederick et al. 1995), and in central Florida in several very large colonies. By the late 1970's, colonies of White Ibises in the Carolinas had grown to over 50,000 birds annually, Central Florida ibis colonies were in the hundreds of thousands of birds, and Wood Storks had increased breeding numbers and numbers of colonies in north Florida, and expanded their breeding range into Georgia and South Carolina. These movements are most parsimoniously interpreted as an exodus of southern Florida breeding populations, (or at some point, the progeny of the southern Florida aggregations), in part in response to environmental degradation, rather than solely because the northern sites offered superior nesting opportunities (Walters et al. 1992).

By the late 1970's within the Everglades, the timing of Wood Stork breeding had also clearly shifted from starting in November and December to starting in February and March, and colonies of Wood Storks in Everglades National Park began to have very poor breeding success as a result (Ogden 1994). A dramatic change in nesting location within the Everglades was also obvious - the large mixed-species nesting colonies on the coast of Everglades National Park had shifted to the interior freshwater Everglades, and the size of colonies had generally decreased. Finally, the period of the late 1960's and 1970's showed a strong and previously unrecorded relationship between nesting numbers of Wood Storks and White Ibises, and speed of drying of the marsh surface (Kushlan et al. 1975, Frederick and Collopy 1989a). Studies during the 1980's also revealed frequent interruptions in nesting during wet springs, and during any reversals in the drying trend (Frederick and Collopy 1989a, Ogden 1994).

The reasons for these dramatic changes in wading bird distributions, timing of reproduction, and breeding numbers seem directly related to changes in amount of available foraging habitat, agricultural displacement, and marsh surface hydrology and water management, all of which have affected both the robustness of prey populations, and the ability of the birds to capture prey. The rough coincidence of massive structural changes to surface water flows in the Everglades during the 1960's, with declines in nesting, changes in timing of nesting, changes in nesting responses to hydrological variables, and movements of birds into other nesting regions certainly suggests a relationship.

During the late 1970's and throughout the 1980's, considerable research was devoted to understanding the causes of poor wading bird reproduction. Much of this work has been summarized in Davis and Ogden (1994), and the salient points are listed here:

1. Wading bird reproduction is strongly dependent upon the availability of food. Powell (1983) found that clutch size and productivity of Florida Bay Great White Herons (Ardea herodias) could be increased by food supplementation, and Frohring (unpublished Everglades National Park Research Center report) found that prey densities in close proximity to colonies was the environmental factor most strongly correlated with growth rate and productivity of young. Hafner et al. (1992) found that increases in productivity of Little Egrets (Egretta garzetta) were associated with increased food delivery rates. Hoyer and Canfield (1990) found that the number of wading bird species on Florida lakes was positively influenced by eutrophic status and attendant high secondary productivity. In the central Everglades, the timing and nature of nesting abandonments in the Everglades are consistent with interruptions in the availability of food through increases in water depth, dispersal of prey, increased rainfall, and low temperatures (Frederick and Spalding 1994, Frederick and Loftus 1993). Conversely, there is direct or indirect evidence that predation, human disturbance, and lack of colony substrate have a minor influence on breeding in the Everglades (Frederick and Collopy 1989b, Frederick and Spalding 1994). This evidence taken together suggests strongly that nesting is driven almost directly by food supply, and that problems with nesting can be traced to inadequacies or interruptions in food availability.

2. Wading bird foraging and nesting was often centered in coastal regions during the past. Of all the ecosystem habitat types, wading bird prey were probably most consistently available in the mangrove interface during the pre-drainage period, offering pre-breeding foraging habitat and feeding alternatives during periods of high freshwater levels that the deeper parts of interior marshes could not. This notion is supported by the few notes on the historical pattern of feeding in the ecosystem (Kushlan et al. 1984, Ogden 1994, W. B. Robertson pers. comm.), recorded densities of fishes (Loftus et al. 1986), modeling of predrainage interior marsh water depths (Walters et al. 1992) and by investigation of the foraging behavior of birds breeding on the coast (Bancroft et al. 1990, 1994).

3. The productivity of the estuarine zone has been severely compromised by a lack of freshwater flows (see review by McIvor et al. 1994). Modeling of surface water dynamics by two different groups of investigators has shown that historic flows to the estuary were vastly larger than at present (Walters et al. 1992, Fennema et al. 1994). Declines in sport fisheries, commercial shrimp fisheries, and a number of biological measures of Florida Bay hypersalinity, provide further evidence that the productivity of the estuarine zone has been severely compromised by the lack of fresh water (Browder 1985, Tilmant 1989, Rutherford et al. 1989, Bowman et al. 1989, Smith et al. 1991).

4. Within limits, productivity of small "bird forage" fishes in the freshwater marshes is related to hydroperiod (Loftus et al. 1986, Loftus et al. 1992, Loftus and Eklund 1994). Shortened hydroperiods over much of the southern Everglades may well have reduced the productivity of the prey that wading birds feed upon, particularly in the interface between freshwater marsh and mangroves, where the large historical colonies were located. The presence of dikes is also hypothesized to impair the ability of prey fishes to travel in the freshwater parts of the Everglades, and so may obstruct recolonization between compartments, particularly from areas of long hydroperiod to those of short hydroperiod.

5. Short hydroperiod freshwater marshes were also critical pre- and early breeding

season foraging habitat for wading birds (Kushlan 1974, Kushlan et al. 1984, Ogden 1994, Fleming et al. 1994). These high elevation marshes probably once offered wading birds feeding opportunities during high rainfall years, as well as during reversals in drying trend. The lack of early and pre-breeding feeding habitat is consistent both with the dramatically later breeding of Wood Storks, the early departure of the majority of the wintering population in most years, and the extreme sensitivity of the current breeding efforts to minor changes in drying trend.

6. A combination of man-made ecological events have led to instability in the production and availability of wading bird food. This hypothesis suggests that the cumulative effect of many man-induced changes has been responsible for a lack of productivity in the Everglades marsh, and eventually, for the decline of wading birds. The impoundment of much of the marsh into deeper pools, the tremendous reduction in area and hydrological isolation of short hydroperiod marshes, the shortened hydroperiod of lower Shark River Slough, and the degradation of the coastal estuary, seem to have sharply reduced the conditions under which robust and continuous wading bird feeding (apparently necessary for reproduction), can occur. Such feeding opportunities now seem limited to the impounded freshwater sections of the Everglades, during years of rapid surface water drying in which there are both few increases in water level, and infrequent or weak periods of cold (Bancroft et al. 1994, Frederick and Collopy 1989a, Frederick and Loftus 1993, Ogden 1994).

These conclusions have provided a new focus for restoration policy (Walters et al. 1992, Davis and Ogden 1994, Anonymous 1993), which now includes recommendations for increases in short hydroperiod habitat, increased flows to the estuary, greater hydrological connection among compartments, and restoration of long hydroperiods to northern Shark Slough as explicit components.

Chapter 1. Monitoring of breeding populations of wading birds in the Water Conservation Areas of the Everglades.

The argument for monitoring wading birds:

The results outlined in the introduction demonstrate that breeding wading birds respond dramatically to hydrological change and are valuable as a monitoring tool, but that such trends must often be monitored for a period of decades before they make sense.

In addition, even a cursory reading of the literature reveals that monitoring nearly always yields an unexpected understanding of reproductive biology, and biological relationships, which then become the foundation upon which biological understanding and ecosystem management can be built. Yet these fortuitous findings are never the stated goal of the monitoring projects. For instance, monitoring of wading bird breeding populations in the 1930's was aimed simply at documenting those areas that should be protected, yet this work became one of the invaluable keys to understanding the ecological dynamics of breeding in the pre-drainage Everglades. Collected in the first two decades of this century, the full value of those data were only realized in the last two decades of the century. Similarly, the monitoring of wading bird reactions to a modified water delivery plan (Frederick and Collopy 1988) resulted in the surprising conclusion that predation was a negligible factor in wading bird reproductive success (Frederick and Collopy 1989b), and yielded detailed information on the relationship between hydrology and breeding success (Frederick and Collopy 1989a).
There are other reasons for concentrating considerable effort on the monitoring and restoration of breeding wading birds. Since these species are at or near the top of the food chain, they can act as indicators of the health and diversity of the aquatic food web, and of contaminants in the ecosystem (Custer and Osborn 1977). The large between-species differences in foraging ecology also ensure that a wide range of responses to any environmental change will be evident in the breeding dynamics of the group of species.

The Everglades is unique in having an exceptionally long history of information on populations of wading birds (nearly 100 years for some types of information). This has allowed insight into the population dynamics during the pre-drainage system, which is central to understanding current ecosystem responses, and to divining a path for restoration (Ogden 1994). Given the relatively large numbers of wading birds in the ecosystem, their unique ability to sample conditions over large areas, and the relative ease of censusing many of the more conspicuous species, wading birds are a relatively cheap and efficient way to monitor ecological change in the wetlands in the enormous south Florida landscape. Thus wading birds are both a goal for restoration in and of themselves, and a cheap and efficient tool for long and short-term monitoring of restoration efforts.

The value of continuing any monitoring program also grows considerably with the length of time since inception. This is particularly true of the Everglades wading bird information. The record of nesting populations is now almost 100 years old. Detailed records of nesting effort in relation to hydrology and weather are now almost 30 years old. And systematic documentation of breeding effort and marsh use in the WCAs is now 9 years old.

A systematic program of documenting breeding numbers of wading birds throughout most of the central and southern Everglades is now in its 10th year. This work has been carried out cooperatively, with Everglades National Park, the National Audubon Society, the Florida Game and Freshwater Fish Commission, Loxahatchee National Wildlife Refuge, and the National Oceanic and Atmospheric Administration all contributing to coverage of this area.

In this chapter, we report on nesting in the Water Conservation Areas of the Everglades during the period January through June of 1996.

METHODS

Study Area: This report documents nesting by ciconiiform birds in Water Conservation Areas 1 (Loxahatchee National Wildlife Refuge), 2, and 3, as well as in colonies in Northeast Shark Slough (NESS) region of Everglades National Park (see Figure 1.2). In this report, we have used hydrological information from the gauging stations shown in Figure 1.2, and weather information from the station at the Tamiami Trail Ranger Station. Summaries of nesting effort include information from Everglades National Park (courtesy of S. Bass and Joan Browder), Loxahatchee National Wildlife Refuge (courtesy S. Jewell and xxxx), and Big Cypress National Preserve (courtesy Deborah Janzen).

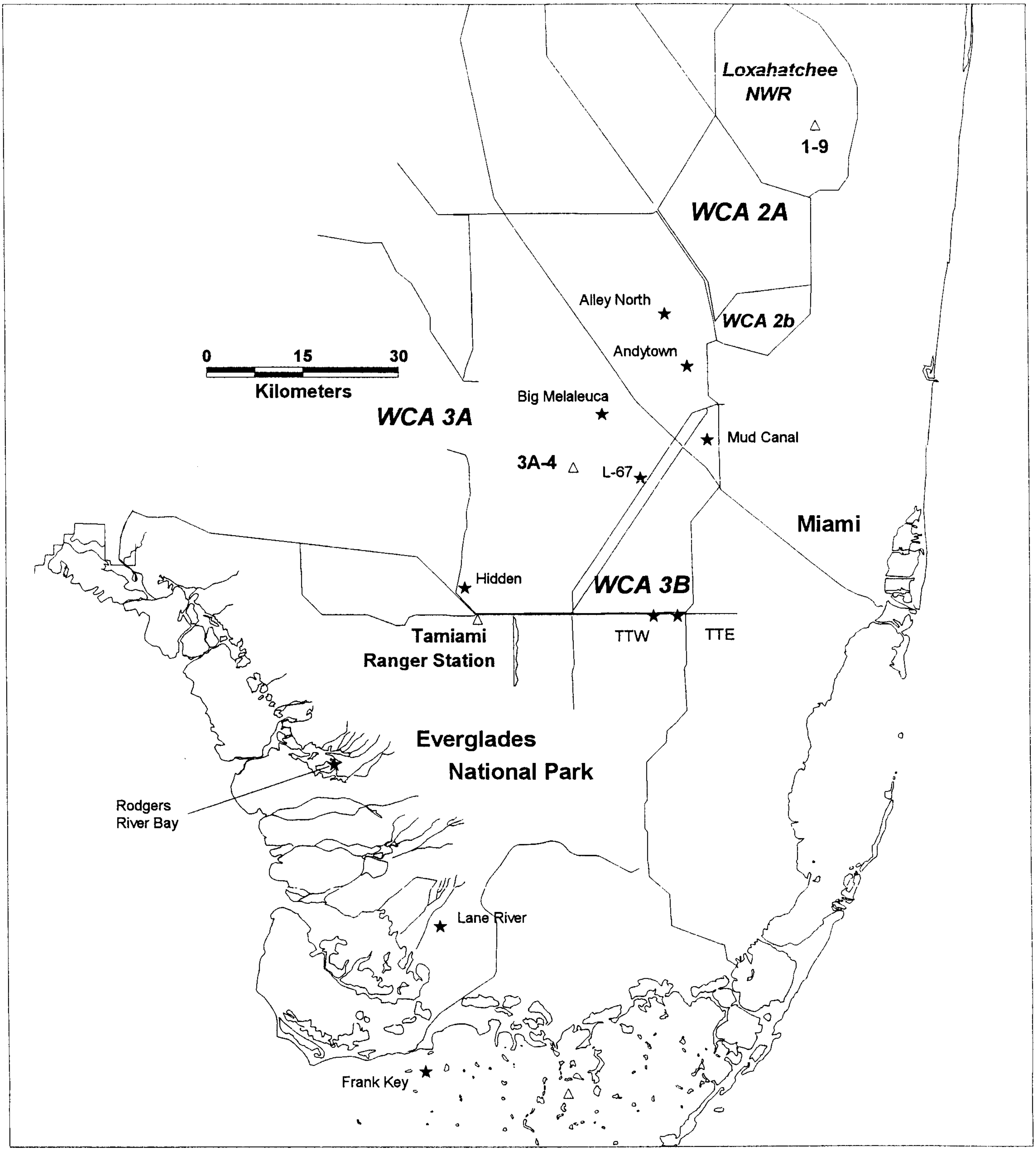


Figure1.2. Map of the study area in south Florida, showing boundaries of Water Conservation Areas 1, 2, and 3, Everglades National Park, and the locations of water gaging and weather stations and large colonies mentioned in this study.

Aerial Survey Flights: Monthly systematic breeding colony survey flights were completed on or about the middle of each month from February through June of 1996. These flights were designed to detect colonies (> 10 nests) of breeding wading birds, and are quite distinct in purpose and methodology from the SRF surveys performed since 1985 by NPS, National Audubon Society (NAS) and the Florida Game and Freshwater Fish Commission (FGFC). The SRFs are designed to estimate the numbers of wading birds feeding on the marsh, and do so by counting birds in strips of quantifiable area at low altitude. The resulting densities are then extrapolated to come up with an estimate of birds for the entire area of interest. Methodology for the breeding survey flights was developed in 1986 (Frederick and Collopy 1988) and has been used consistently since by NAS, ENP, and University of Florida researchers in the WCAs in every breeding season since 1986.

Breeding colony surveys covered 100% of the marsh surface, were flown at 250-300m altitude, at 160 km/hr airspeed in a single-engine, high winged aircraft (Cessna 172s were used in this study and have been used almost exclusively in past surveys), with one observer on each side of the aircraft (total crew of three, including pilot). Transects were flown in east-west directions, and spaced approximately 2.4 km apart. This transect spacing was determined empirically by flying past known colony locations at various distances, and determining a minimum detection distance under a variety of visibility conditions (Frederick and Collopy 1988). The 2.4 km spacing allowed for considerable overlap of the detection distance on adjacent transects. Transect spacing was occasionally decreased in poor visibility conditions, such as haze, smoke or glare on one or both sides of the aircraft; since 100% coverage is achieved under any conditions, this variable spacing is not considered an inconsistency in methodology.

Colonies were circled when located, and a position noted when the aircraft was directly over the north end of the colony island. Positions while flying were noted using an aviation-grade Global Positioning System (GPS). Colony locations are likely to be accurate to 300 meters (combined maximum estimated error in positioning the aircraft over the colony, plus error in triangulation due to unpredictable, intentional degradation of GPS satellite signals for military purposes). For large colonies (> 100 nests), numbers of nests were repeatedly counted initially from an altitude of 300 m, followed by one or two counts at low altitude (90 - 100 m). A final count was derived from averaging successive, silent counts by each observer; the averaged counts from the two observers typically differed by less than 10%.

Aerial counts were considered accurate only for Great Egrets (Ardea albus), White Ibises, Wood Storks, Snowy Egrets (Egretta thula), and Cattle Egrets (Bubulcus ibis) (Frederick et al. in press). While the presence of Tricolored Herons (Egretta tricolor), Little Blue Herons (E. caerulea), Great Blue Herons (Ardea herodias), and Glossy Ibises (Plegadis falcinellus) was frequently detected by aerial surveys, aerial nest counts were considered unreliable due to the dark plumage and more cryptic, sub-canopy nesting habits of many of these species. For this reason, each colony was also visited on the ground at least once during the period from April 8 through July 15, and nests were counted in each. We relied upon systematic airboat surveys to locate colonies containing only dark plumaged species. The combination of aerial and ground surveys has been proven to be far more efficient in both detection and counting of nesting birds in the Everglades (Frederick et al. in press).

Colonies of Little Blue Herons are often detectable from the air after eggs hatched, because the young have white plumage. Comparison of aerial counts with complete ground surveys has in the past shown that 100% of the Little Blue Heron colonies containing over 100 nests were detected, and 90% of those containing at least 50 nests were detected (Frederick and Collopy 1988). Little Blue Heron colonies would therefore be undetectable from the air only if they failed prior to the hatching of young.

Surveys of Loxahatchee National Wildlife Refuge (NWR) were performed largely by Su Jewell and co-workers at Loxahatchee NWR, using similar methodology for both air and ground surveys. Aerial surveys of Everglades National Park were performed by Oron Bass and Laurie Oberhofer of the South Florida Research Center (ENP), and included ground visits to some but not all of the colonies located. Aerial counts are also now available for Florida Bay, derived from a series of monthly helicopter surveys performed by Oron Bass and Joan Browder. Big Cypress National Preserve initiated their first breeding wading bird surveys this year, performed by Deborah Janzen.

Airboat Surveys: All colonies were visited at least once by airboat during the nesting season.

Species composition, nesting numbers and stage, and location were noted on each visit; at large colonies, estimation of nesting phenology within the colony, and species composition were enhanced through the use of a 7.9 meter collapsible aluminum tower, erected in the airboat near the edge of the colony.

Systematic boat surveys were undertaken in order to locate smaller colonies of dark-colored species, isolated nests and colonies of Great Blue Herons and Anhingas (Anhinga anhinga), between late April and late June. Airboat surveys were accomplished in all of northeast Shark Slough, WCA 2A, 3A, 3B, and Loxahatchee NWR. Most of WCA 2B was surveyed by airboat, except for much of the northern and northeastern part, which is a melaleuca (Melaleuca quinquenerva) forest. Airboat surveys were made systematic with the use of the GPS unit, and the entire area was searched in north-south strips 0.3 km wide; all willow (Salix caroliniana) and bay heads were approached to within 20 m in order to flush incubating birds. Searches in WCA 2A were conducted for the most part by Dave Anderson of the Florida Game and Fresh Water Fish Commission. Searches in all areas were enhanced by reports from the SRF surveys, and Rob Bennett's Snail Kite project. In addition, all previously occupied colonies discovered since 1986 were visited at least once by airboat to determine occupancy.

Timing and success of nesting

In this project, we made no attempt to systematically record nesting success via repeated nest visits, as had been done in many earlier years (Frederick 1995). This was based on the finding that nesting success on the scale of the Everglades ecosystem is dependent on multiple factors, and is only weakly linked to numbers of nesting attempts. In addition, various nesting success measures have not been correlated with each other, even within years. Finally, the the numbers of nesting pairs have been found to be a more consistent predictor of ecosystem productivity than have any other measure of nest success. For these reasons, numbers of nest initiations has been deemed a more efficient and cost effective way of monitoring nesting in the Everglades (Frederick 1995). Nonetheless, our systematic aerial and ground surveys allow us to monitor a gross level of nesting success - whether or not colonies have substantial (>50%) abandonment after initiating.

Food Habits: We collected regurgitated food samples opportunistically from young herons and ibises during our visits to colonies (see chapter 2), and during visits that were specifically designed for collecting regurgitant at colonies we did not go into regularly. These samples were collected only from chicks that regurgitated spontaneously as we approached, or which regurgitated while we were handling them for other reasons. Marked regurgitant samples were stored individually in plastic bags and frozen for later analysis.

Food samples were analyzed at the end of the nesting season. All intact fishes were dissected and examined for presence of the nematode parasite Eustrongylides ignotus and other parasites for which the fish or wading bird could serve as host. For all samples, individual prey items were identified, weighed to the nearest 0.1 gm and measured to the nearest mm (total length). For crayfish, shrimps and insects, body parts usually break off rapidly after ingestion, and we weighed the accumulated total of parts together. Food items were usually readily identifiable for herons, egrets and Wood Storks. White Ibises, however, feed their young a highly masticated and partly digested mass. Prey items are much more difficult to distinguish and measure in White Ibis samples, and require a somewhat different analysis. We dispersed each bolus in a pan with 2 cm of water in order to separate food particles, pick out any identifiable food items, and estimate the approximate volumetric proportions of fish, shrimp, crayfish, and insects in the sample as a whole. This is facilitated to some extent by the fact that crustacean parts turn red or pink in digestive juices. We suspect that soft-bodied invertebrates such as polychaete worms would have been underestimated in our samplings because they are digested more quickly and have no hard-body markers to distinguish their presence.

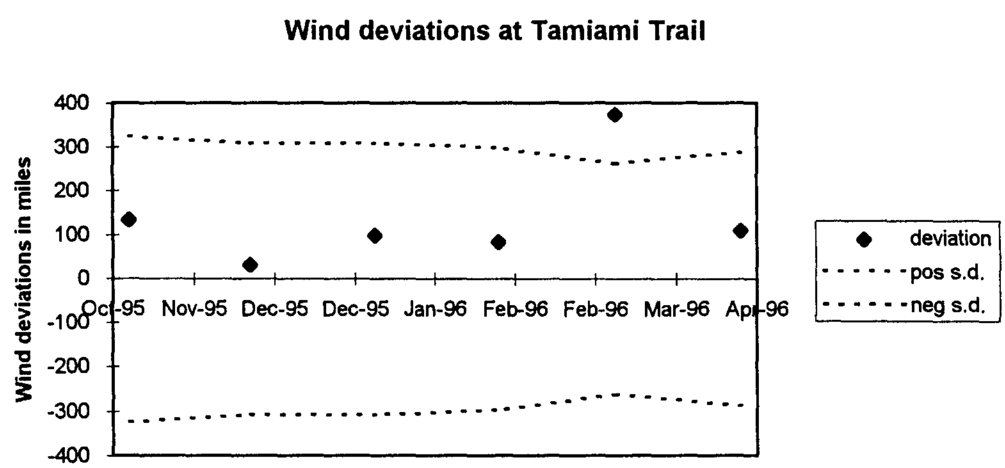
RESULTS

Weather and hydrology during the breeding season

The 1996 breeding season can be characterized as having considerably higher water in most areas during the breeding season and in the months leading up to the breeding season, having no real extremes of weather, and having exceptionally fast surface water drying rates.

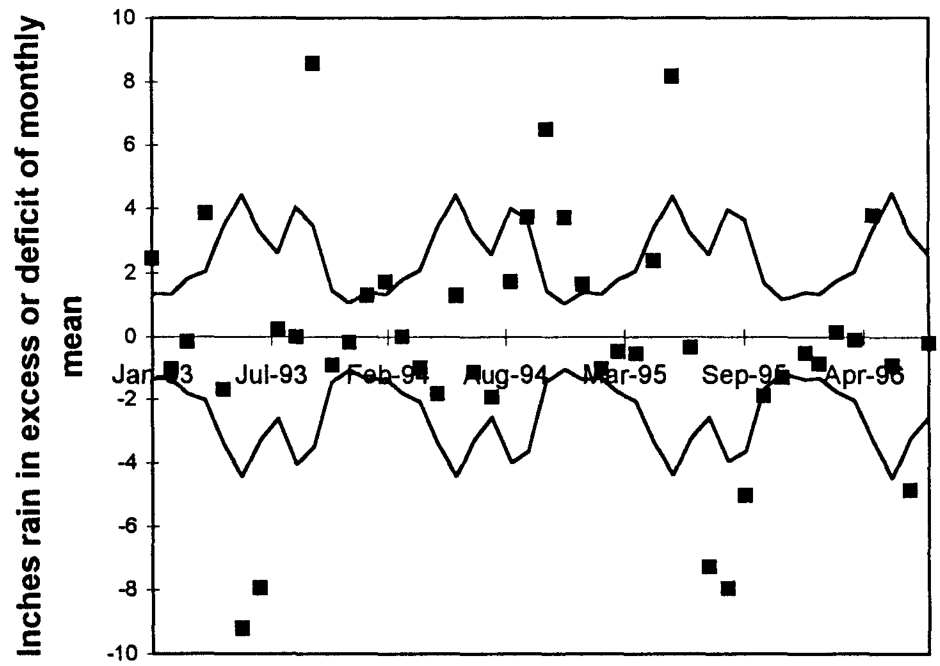
Wind: Totalized wind at the Tamiami Trail Ranger Station showed no strong deviations from monthly means, with the exception of March 1996, which showed very windy conditions (Figure 1.3). During March, wind was considerably in excess of one standard deviation above the mean.

Figure 1.3. Deviations in monthly totalized wind at Tamiami Trail during the prenesting and nesting season.



Rainfall: Rainfall was generally at or below monthly means during the months preceding and during the breeding season (Figure 1.4). Exceptions were April 1996, which showed over 1 standard deviation above the normal rainfall for the month, and August and September of 1995, which showed more than 1 standard deviation below the mean for those months.

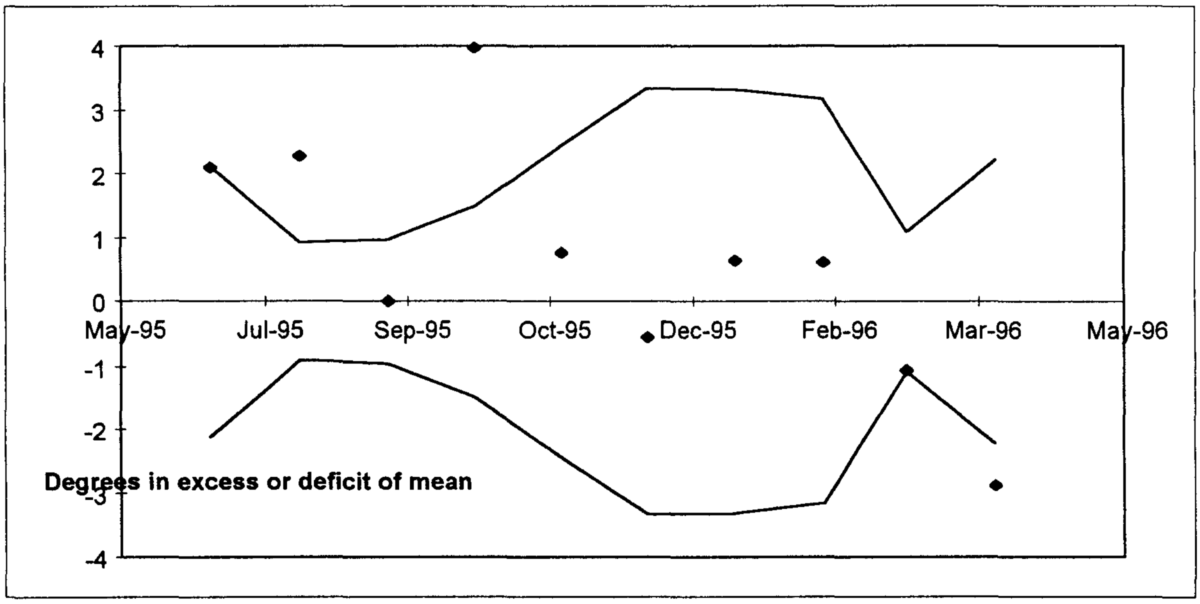
Figure 1.4. Rainfall deviations at Tamiami Trail Ranger Station from January of 1993 through the period of study. Monthly deviations (squares) in excess or deficit of the long term mean (shown as the horizontal line) are shown in relation to one standard deviation above and below the monthly mean (fluctuating lines).



Temperatures: No real temperature extremes were encountered during the nesting season, or during the months leading up to the nesting season (Figure 1.5).

Hydrology: In general, the period of study occurred during a lengthy period of high water in the central Everglades (Figures 1.6-1.8). Stages in WCAs 1, 2, and 3 all began the season (November 1995) at or above 1 standard deviation above the mean monthly maximums. In the case of WCA 3, these extremely high stages continued throughout the nesting season (Figure 1.8). For all three pools, the 1996 season continued a period of very high water that arguably began as early as late 1992.

Figure 1.5. Mean monthly air temperature deviations at the Tamiami Trail Ranger Station, May 1995 - May 1996, expressed as deviations from the period-of-record averages. The horizontal line indicates the mean, and the fluctuating lines indicate one standard deviation above or below the mean for reference.



These wet conditions in 1996 were not abetted by particularly high rainfall during the months preceding the breeding season, nor during the breeding season. As a result, very rapid surface water recession (=drying rate) was recorded in most areas, and particularly in WCA 3 (Figure 1.9, 1.10, Table 1.1). At the 3-4 gage, drying rates during both the early (November through January) and late (January through March) periods were the fastest ever recorded for that station, and were well in excess of the 2 mm/d thought to be necessary to stimulate nesting (Figures 1.9 - 1.10). At the 2A1-7 gage in WCA 2, the early drying rate was very nearly the fastest on record, though this rate slowed considerably during the February - April period. In Loxahatchee NWR, recession rates were not particularly fast, exceeding the values of only 25% of the years on record for the early drying rate, and showing the slowest late drying rate on record.

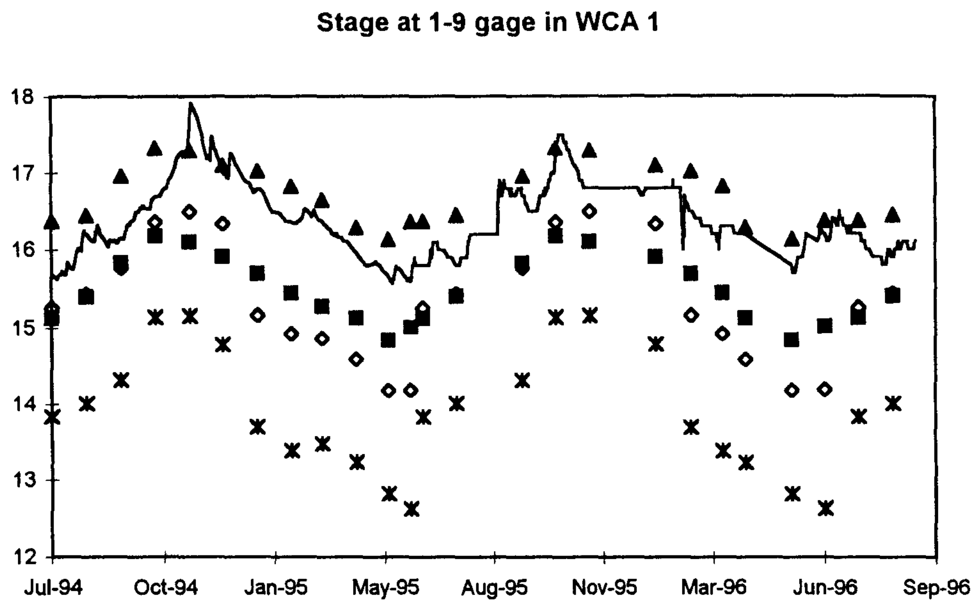


Figure 1.6. Stage at the 1-9 gage in Loxahatchee National Wildlife Refuge from July 1994 through the period of study, in feet msl. Daily stage is shown as a thin line, monthly mean maximums for the period of record are shown as solid diamonds, and monthy mean minimums are shown as triangles. One standard deviation above the mean maximums and below the mean minimums are shown as solid triangles and x's for reference.

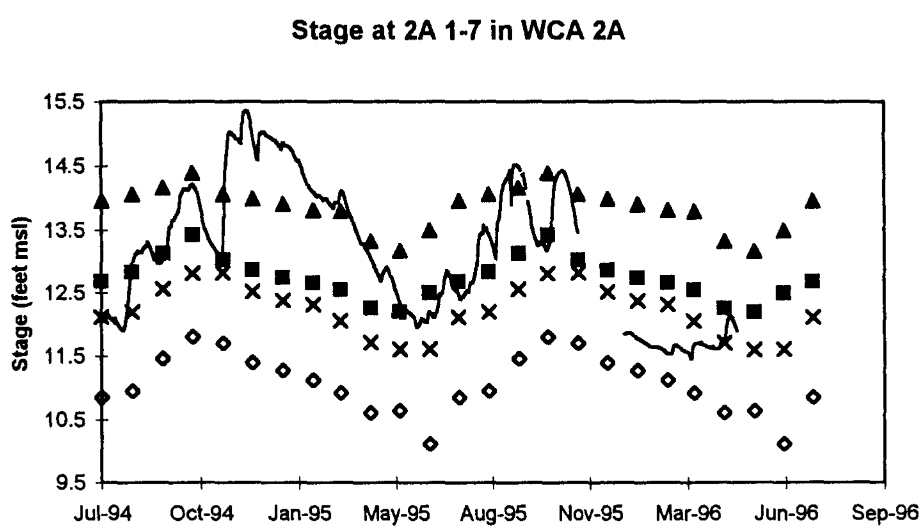


Figure 1.7. Stage at the 2A 1-7 gage in WCA 2A from July 1994 through the period of study, in feet msl. Daily stage is shown as a thin line, monthly mean maximums for the period of record are shown as solid squares, and monthy mean minimums are shown as x's. One standard deviation above the mean maximums and below the mean minimums are shown as solid triangles and open diamonds, respectively, for reference.

Stage at 3-4 in WCA 3A

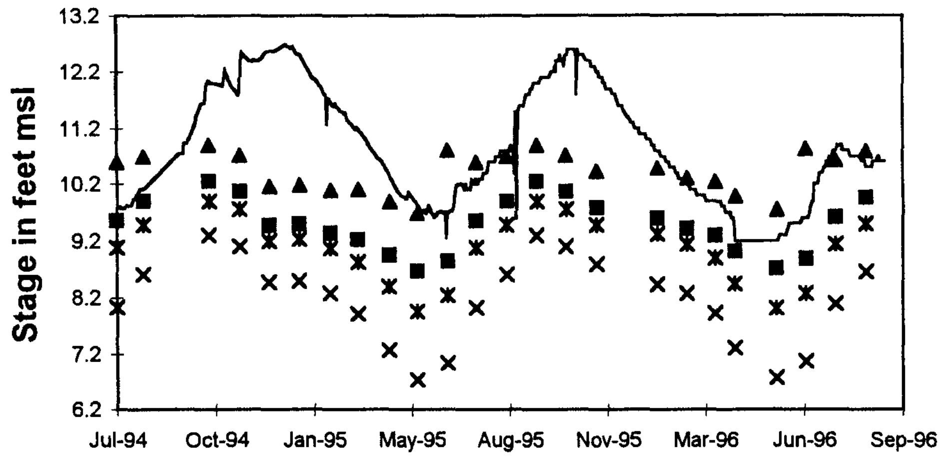


Figure 1.7. Stage at the 3A-4 gage in WCA 3A from July 1994 through the period of study, in feet msl. Daily stage is shown as a thin line, monthly mean maximums for the period of record are shown as solid squares, and monthy mean minimums are shown as x's. One standard deviation above the mean maximums and below the mean minimums are shown as solid triangles and open diamonds, respectively.

Numbers of nesting birds

Between January and late June of 1996, nest initiations by ciconiiform wading birds (not including Cattle Egrets, Anhingas or Double-crested Cormorants) totalled 6,214 attempts in WCAs 2 and 3, 3,363 in Loxahatchee NWR, 1,396 in mainland Everglades National Park, 1,403 in Florida Bay, and 1,650 in Big Cypress National Preserve (Table 1.2). The total for the Everglades region was 14,026 (again, not including Cattle Egrets, Anhingas or cormorants). Geographic distribution of nesting is shown in Figures 1.11 - 1.13, and breakdowns of colonies by species are shown in Table 1.3.

Ground and aerial surveys were interrupted to some degree by the Valu-Jet crash, which created a 10-mile diameter no-fly, no entry zone in the middle of the study area in WCA 3A and 3B. This occurred during May, the peak of our ground surveys, and we suspect that numbers of Great Blue Herons, Anhingas, and Little Blue Herons were underestimates because of this constraint. The entire eastern section of WCA 3B, for instane, was not surveyed on the ground because of the no-entry zone. It is unlikely that total numbers were affected by more than 10%, however.

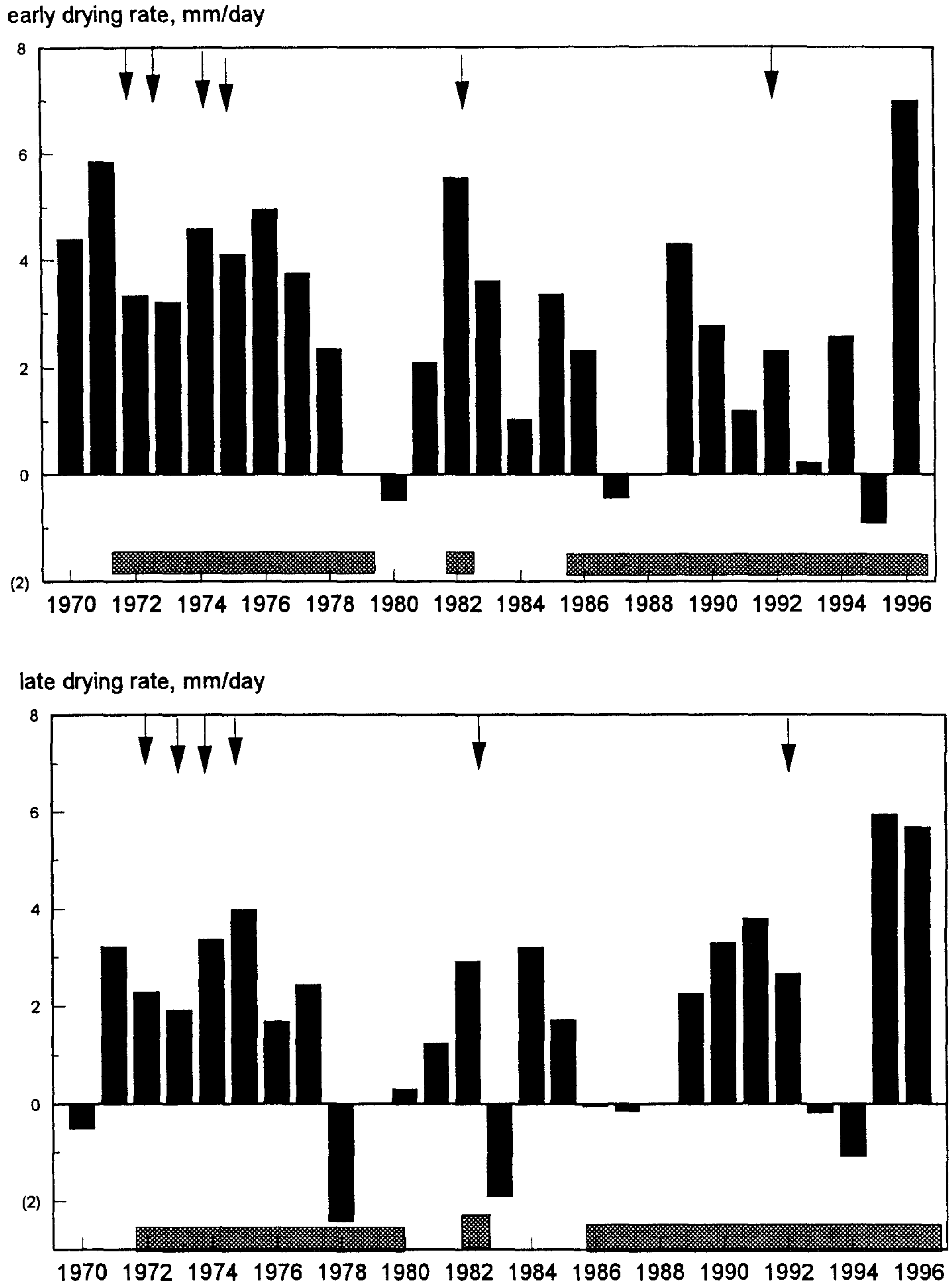


Figure 1.9 (top) and 1.10 (bottom). Rates of surface water recession at 3-4 gauge in central WCA 3 during the early (top) and late (bottom) months of nest initiation. Drying rates are calculated from highest stage in November to highest in January (early) and highest in January to highest in March (late). Patterned strips mark years in which nesting effort was monitored, and arrows designate years of substantial nesting effort.

Table 1.1. Water level recession rates in mm/day in the Water Conservation Areas of the Everglades, with comparisons of the year in question with period-of-record statistics at each station. Negative values indicate rising water, positive values indicate falling water. Percent exceedance is the percent of years in the record in which the measurement is less than that of the focal year.

Year	Station	Early Dry	Late Dry	% Exceedance Early Drying Rate*	% Exceedance Late Drying Rate*	% Exceedance Both Early and Late Drying Rate*
1996	3-4	6.99	5.68	100	100	100
1996	1-9	0.14	0.383	25.0	3.5	0.0
1996	2A 1-7	11.50	0.646	96.9	34.4	34.4
1995	3-4	-0.90	5.95	0.0	100.0	0.0
1995	1-9	0.97	0.21	32.1	10.7	3.6
1995	2A 1-7	0.55	3.50	28.1	87.5	29.0
1994	3-4	2.56	-1.08	58.6	6.9	3.6
1994	1-9	1.49	0.42	21.8	9.3	3.1
1994	2A 1-7	3.32	-4.67	90.0	3.3	3.3
1993	3-4	0.22	-0.40	10.0	10.0	3.3
1993	1-9	-0.33	3.91	14.8	7.8	0.0
1993	2A 1-7	-1.45	0.22	12.9	29.0	3.2
1992	3-4	2.29	2.63	24	38	14
1992	1-9	2.01	1.47	46	54	21
1992	2A 1-7	3.16	2.09	82.1	53.5	44.4

It should be remembered that 1996 is the first year for which we have counts for Big Cypress, and the first year in many for which we have counts for Florida Bay. A more useful total therefore, is the total of the Water Conservation Areas, and mainland Everglades National Park (10,973 nests). Either of these totals is considerably less than the 100,000 pairs thought to have regularly nested in the Everglades region during the predrainage period (Figure 1.14). The total from the WCAs plus mainland Everglades National Park is also less than 40% of the recent highs of 1992 and 1975. In short, 1996 could in no way be construed to be a "banner year".

Ogden et al. (in prep) have proposed that wading bird nesting be used as a measure of ecological restoration of the Everglades. Specifically, they suggest that timing, location, and numbers of nesting pairs be evaluated relative to targets for restoration. For size of the

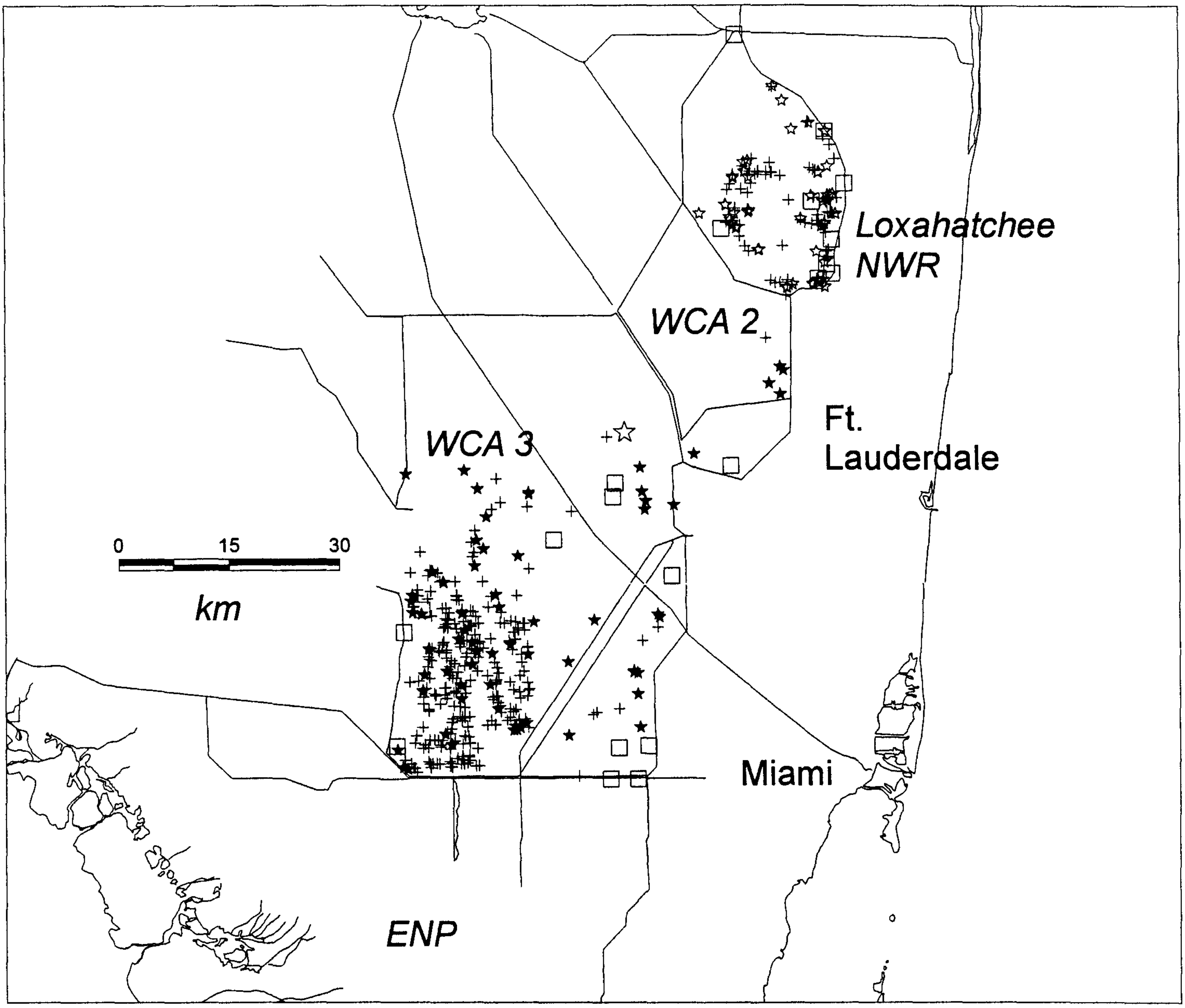


Figure 1.11. Map of the central Everglades showing the locations of colonies of wading birds between January and May of 1996. Squares represent colonies of over 100 pairs, stars represent colonies of 10 - 100 pairs, and crosses 2 - 9 pairs.

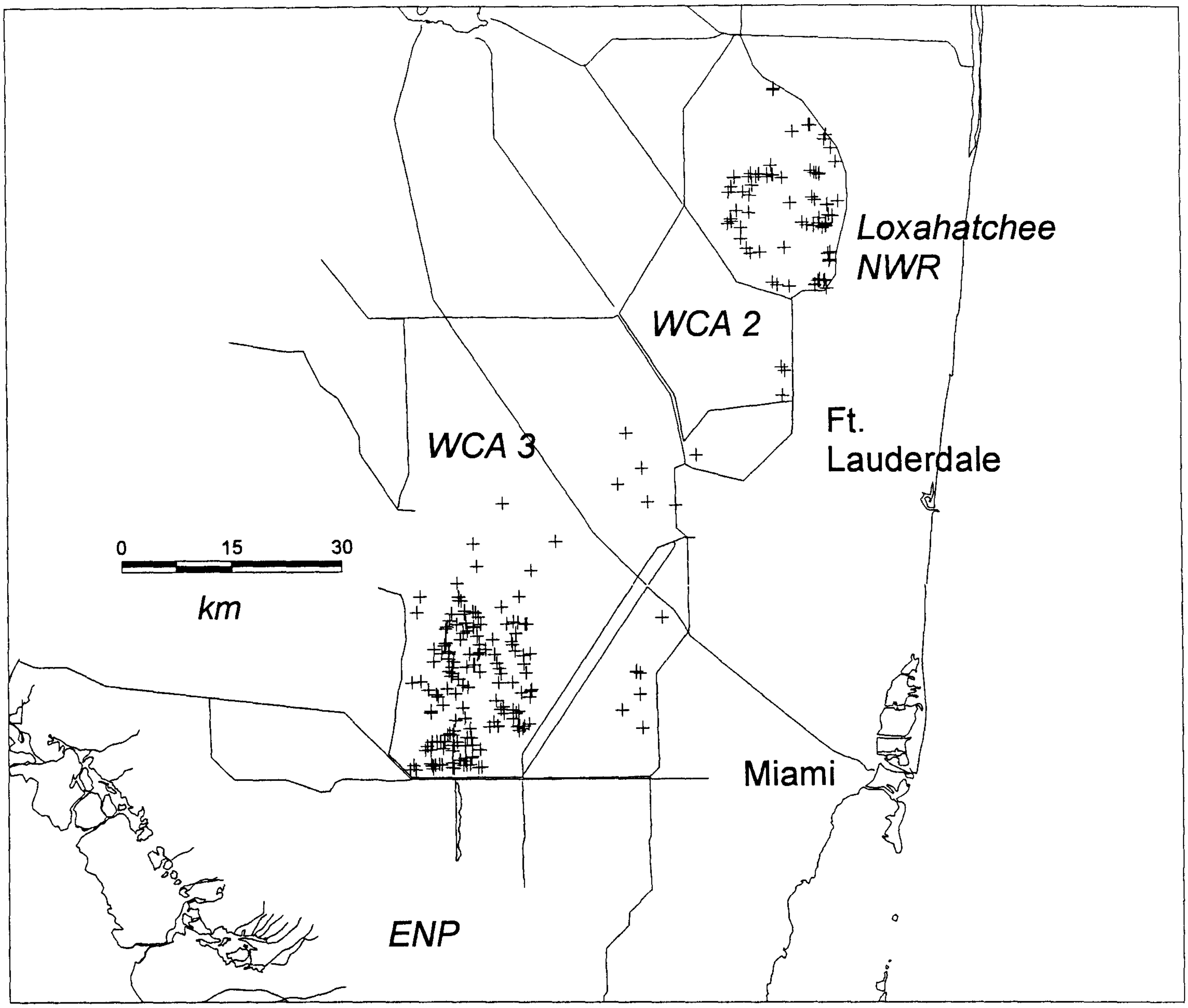


Figure 1.12. Map of the central Everglades showing the locations of all colonies and solitary nests of Anhingas located in the study area in January - June 1996. Note that Loxahatchee NWR was not surveyed for Anhingas..

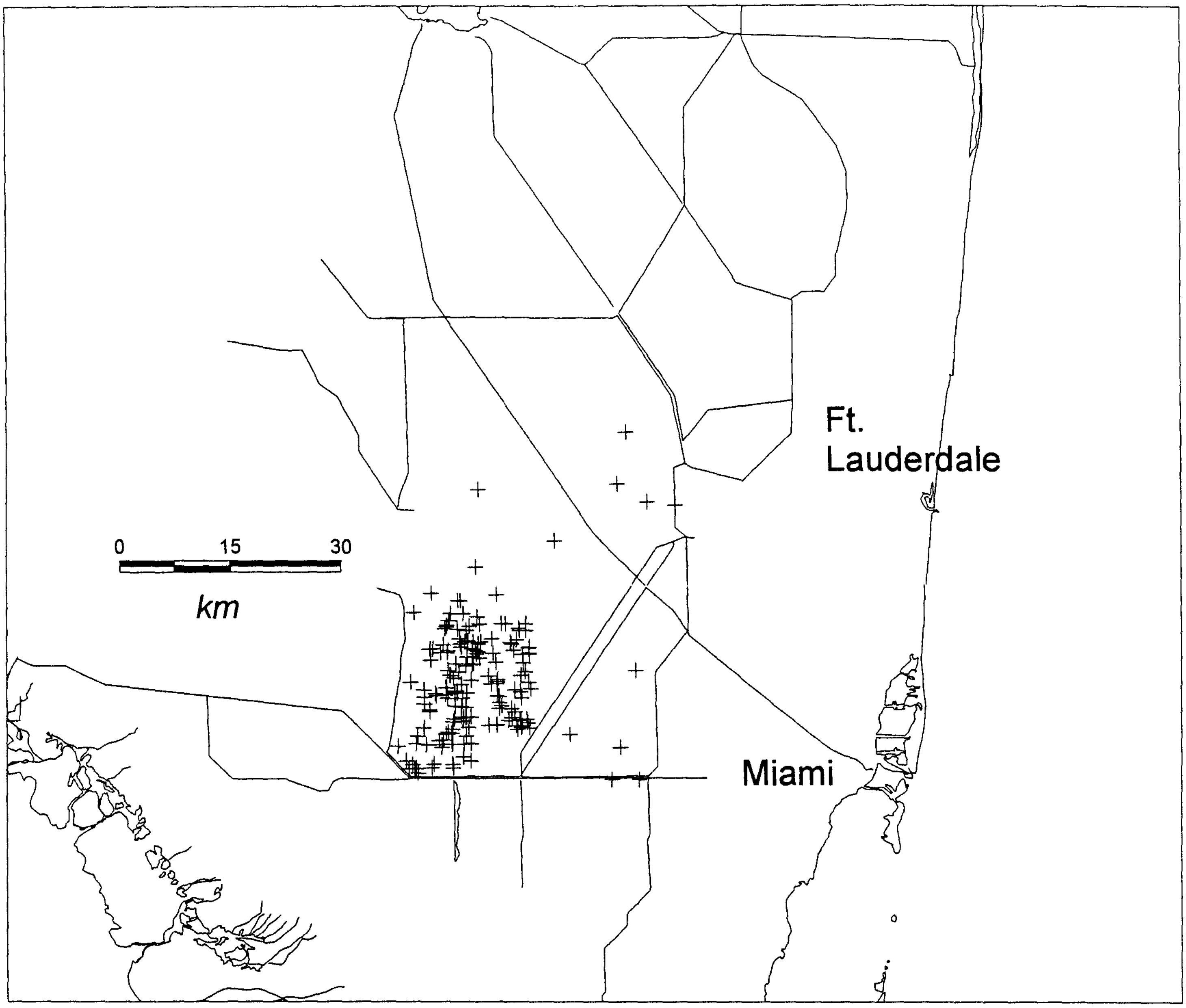


Figure 1.13. Map of the central Everglades showing the locations of all colonies and solitary nests of Anhingas located in the study area in January - June 1996. Note that Loxahatchee NWR was not surveyed for Anhingas..

breeding population, they recommend targets of 4,000 breeding pairs for Great Egrets, 10 - 20,000 pairs for Egretta herons (Snowy Egrets and Tricolored Herons), 10 - 25,000 pairs for Ibises, and 1,500 - 2,500 pairs for Wood Storks. Using a three-year running mean (1994 - 1996), the target for Great Egrets appears to have been met (4,043 pairs), and the targets are quite far from being met for Egretta herons (1,508 pairs, less than 15% of the target), White Ibises (2,172 pairs, less than 20% of target), and Wood Storks (395 pairs, less than 27% of target).

The 1996 season continued some trends in species composition changes that seem to follow the pattern found in high water years from 1993 - 1995 (Figure 1.15). The period of comparison is 1986 - 1989, a period of neither high nor particularly low water, which included normal cycles of wet and dry. By comparison, numbers of nesting White Ibises were down by 50%, and Great Egrets, Little Blue Herons, and Cattle Egrets were up by over 150%. A feature not noted in other wet years was the increase in Wood Storks, also by over 150%. Another continuing trend was the fact that Roseate Spoonbills (Ajaia ajaja) nested once again at the Alley North colony during the middle of the season. This continues an unbroken span of nesting by a handful of birds in this colony since 1992 (Frederick and Towles 1995).

The proportion of wading birds nesting in the mainland Everglades ecosystem that are found in the Water Conservation Areas also remains quite high (Figures 1.11 and 1.16). This conclusion rests to some extent on whether or not the two Tamiami colonies are counted as within or outside of Everglades National Park (ENP), but even if they are counted as within ENP, fully 83% of the population still remains within the WCAs. Ogden et al.'s restoration goal of moving nesting from the inland areas to the coast therefore shows little or no sign of progressing in recent years, or in 1996 specifically. In general, the geographic distribution of nesting in 1996 was quite similar to each of the years 1993 - 1995, with large colonies located mostly on the periphery of the deeper water areas, with immediate access to shorter hydroperiod marshes. No evidence can be discerned of a move from inland areas to the coastal region.

Table 1.2. Numbers of nesting pairs of wading birds in the Everglades region during spring and early summer, 1996. Note that colony totals do not include numbers of Anhingas, Double-crested Cormorants, or Cattle Egrets.

Region**	GE*	SE	WI	WS	GBH	ANH	LBH	TC	DCCO	BCNH	GI	CE	RS	total
WCA 2 and 3	2,686	554	1,013	225	253	989	678	749	8	22	19	100	15	**6,214**
Loxahatchee NWR	814	26	807	0	117		1,372	197	0	30	0	2,253	0	**3,363**
Everglades National Park	896	100	5	395								1,200		**1,396**
Florida Bay	333		315		573			102					80	**1,403**
Big Cypress	400		1,250											**1,650**
Total nesting pairs	**5,129**	**680**	**3,390**	**620**	**943**	**989**	**2,050**	**1,048**	**8**	**52**	**19**	**3,553**	**95**	**14,026**

* GE = Great Egret, SE = Snowy Egret, WI = White Ibis, WS = Wood Stork, GH = Great Blue Heron, ANH = Anhinga, LBH = Little Blue Heron, TC = Tricolored Heron,
DCCO = Double-crested Cormorant, BCNH = Black-crowned Night Heron, GI = Glossy Ibis, CE = Cattle Egret, RS = Roseate Spoonbill.

** Data are from this report and from the 1996 Late-season wading bird nesting report, South Florida Water Management District, West Palm Beach, Fl.

Table 1.3. Colony locations and numbers of nesting pairs of wading birds in WCAs 1, 2 and 3 during spring and early summer

COLONY	Decimal degreees Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	DCCO	BCNH	GI	CE	RS	Total
Alley North	26.18917	80.52583	650	200	1,000		20	75	50	100		6	10		15	2,126
Hidden	25.79883	80.84300	240	200			0	53	2	150						645
Tamiami West	25.75867	80.54600	215			125		15								355
Crossover Colon	25.94000	80.83250	168			100										268
Big Meleleuca	26.05483	80.62550	100	8			1	50	18	22		3	9			211
Mud Canal	26.01000	80.46083	90	20										100		210
Heron Alley	25.79755	80.53462		53				6	81	60						200
	26.10833	80.54167	170													170
2b-20	26.14628	80.37925	34	6					20	50				50		160
3b Mud Canal E	25.79978	80.49400	128						10							138
Cypress City	26.12500	80.53833	109				1	20								130
Tamiami East	25.75862	80.50843	50	15				48								113
	25.96732	80.80763							62	45						107
l67	25.95667	80.56833	98													98
	25.92030	80.79888						20	60	15						95
Gator Baby	25.96333	80.80833		30					28	37						95
Andytown	26.10333	80.49667	13	13			5	26	6	4						67
2agfc	26.25017	80.32667							30	30						60
Holiday Park N	26.09900	80.45783	30	7	13		1	1								52
Lumpy	25.95400	80.65300	51													51
	26.01583	80.79407							50							50
	26.01605	80.79440							43	5						48
2?	26.14083	80.74933	47													47
	25.92012	80.79847						2	37	5						44
	25.96517	80.82070						1	25	18						44
3b-4	25.81375	80.60450	39					2								41

WCA 3 Colonies	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
	26.13667	80.83000	40													40
	26.01543	80.79312							37	2						39
	26.11500	80.50167	38													38
	25.77310	80.83415							30	5						35
JW2	26.11833	80.73167	32					2								34
JW2	26.08450	80.71917	33													33
2agfc	26.23667	80.31050	2				30									32
	25.82323	80.67160					1	30								31
	25.82043	80.67688					1	28								29
	25.86882	80.80650							5	24						29
	25.86980	80.80697						1	16	12						29
	25.92625	80.68632					1	28								29
	25.93305	80.75817					1	27			1					29
	26.00253	80.77800							10	17						27
	26.09333	80.49833	26													26
LBH near Hidden	25.79500	80.84167							20	5						25
	26.00233	80.77832		1					5	18						24
	25.88897	80.80435								23						23
	25.98630	80.82077							11	10	1					22
3bGFC	25.89300	80.51433	20				2									22
2agfc	26.27050	80.31167					2					20				22
	25.80190	80.76760					1	20								21
	25.91700	80.73200					2	18								20
	26.14500	80.50488	19				1									20
3bgfc	25.82400	80.50483	15				5									20
2agfc	26.26600	80.30717	10				10									20
	25.91417	80.66093						18								18
	25.96022	80.47828	17				1									18
	26.00257	80.77888							14	3		1				18

WCA 3 Colonies	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
	26.03528	80.67490							14	4						18
	25.82000	80.68100	16	1												17
	25.85910	80.75345						17								17
	25.89167	80.50833	16				1									17
	25.90170	80.73863					2	15								17
	26.05467	80.73285	1						3	13						17
	25.82482	80.67927	6				1	9								16
3A unknown 12	26.11167	80.66000	16													16
	25.82915	80.66345					2	12								14
	25.98778	80.70667						2	8	3						13
	26.16167	80.43000	12				1									13
3b gfc	25.86583	80.50833	10				3									13
	25.87683	80.75517					1	10	1							12
	25.87730	80.71423						12								12
	25.92873	80.73927						12								12
	25.84710	80.70307					1	10								11
	25.89343	80.77365					2	9								11
3b-44	25.89415	80.51325	9				1	1								11
	25.96433	80.75270					1	10								11
	26.02263	80.73482					1	7	2	1						11
	25.77110	80.82750					1	9								10
	25.81447	80.77562					2	8								10
	25.91507	80.71138					2	8								10
	25.94352	80.74902					1	4			5					10
	25.96400	80.48033	10													10
Unnamed	25.97225	80.70107	9				1									10
	25.97900	80.82237							1	9						10
	26.04345	80.72250							5	5						10
Unnamed	26.11415	80.65933	10													10

WCA 3 Colonies	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
	25.80083	80.80377					1	8								9
	25.83593	80.74257						9								9
3b-10	25.84212	80.56500	9													9
	25.93282	80.71372					2	7								9
	26.00237	80.76223					5		4							9
	26.09285	80.71135							6	3						9
	25.83318	80.76500					1	7								8
3b 37	25.84633	80.53300	6				2									8
	25.90668	80.79785						2	1	5						8
	25.96500	80.69833	8													8
	25.81658	80.77277					1	6								7
	25.82322	80.74543					1	6								7
3b-11	25.83932	80.57027	7													7
	25.84892	80.75522					1	6								7
	25.89248	80.66690					1	6								7
	25.91528	80.77463					2	5								7
	25.92623	80.73217					1	6								7
	26.13000	80.70483							7							7
	25.82650	80.67667	2				4									6
	25.83130	80.67407						6								6
	25.84300	80.79867					2	3		1						6
	25.86558	80.74840						6								6
	25.87683	80.75533					1	4	1							6
	25.88738	80.71768						6								6
	25.91563	80.66135					3	3								6
	25.92068	80.79467					1	5								6
	25.95175	80.66642					2	4								6
	25.77153	80.81997					3	2								5
	25.80163	80.76907					1	4								5

WCA 3 Colonies	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
	25.83537	80.74915						5								5
	25.84502	80.79902					1	4								5
	25.84752	80.74900						5								5
	25.85052	80.69913					3	2								5
	25.88753	80.77008					2	3								5
	25.88792	80.77105					1	4								5
	25.91410	80.73428					2	3								5
	25.91572	80.78357					1	4								5
	25.91827	80.77372					1	2		2						5
	25.92247	80.75532						4	1							5
	25.92872	80.68775						5								5
	25.93180	80.67905						5								5
	25.94318	80.66648						5								5
	25.95172	80.69410					2	3								5
	25.97200	80.81857								5						5
	25.77673	80.82253					1	3								4
	25.77733	80.79300					1	3								4
	25.79813	80.78232					2	2								4
	25.80240	80.74237					1	3								4
	25.80663	80.77992					1	3								4
	25.82258	80.80712						4								4
	25.82622	80.70647					1	3								4
	25.84162	80.69863					3		1							4
	25.84237	80.68143					2	2								4
	25.84517	80.79867					3	1								4
	25.85793	80.70940					4									4
	25.86558	80.74820						4								4
	25.87123	80.80202					1			3						4
	25.91472	80.74590					4									4

WCA 3 Colonies	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
	25.92650	80.75665						2	2							4
	25.95213	80.69962						4								4
	25.95542	80.77287					1	3								4
	25.95958	80.79432							1	3						4
	25.95997	80.73345					1	1	2							4
	25.96543	80.73737					1			3						4
	25.97008	80.77448								2		2				4
	25.98003	80.75643					1	3								4
	26.03835	80.73587								4						4
	26.09000	80.60000	4													4
1?	26.18193	80.54960	4													4
	25.77235	80.79635					2	1								3
	25.77937	80.79900					3									3
	25.79547	80.76947					2					1				3
	25.80202	80.75243					1	2								3
	25.81503	80.76885					1	2								3
	25.82042	80.76755					1	2								3
	25.82592	80.71755					1	2								3
	25.82615	80.66975					3									3
	25.83092	80.75313						3								3
	25.83348	80.66445						3								3
	25.83497	80.74895						3								3
	25.83527	80.68557					2	1								3
	25.83612	80.75233					1	2								3
	25.84663	80.68535					1	2								3
	25.85227	80.80647						3								3
	25.85942	80.77390						2				1				3
	25.86507	80.79107					1	2								3
	25.86773	80.67360					1	2								3

WCA 3 Colonies	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
	25.88460	80.76620						3								3
	25.89908	80.74928					1	2								3
	25.91347	80.67028					1	2								3
	25.91907	80.68273					1	2								3
	25.92167	80.66213						3								3
	25.94567	80.67545						3								3
	25.94788	80.77585					1	2								3
	25.95130	80.73032					2	1								3
	25.96415	80.77007					1	2								3
	25.96563	80.81727					1			2						3
	25.98535	80.81470								2		1				3
	26.00982	80.79950								3						3
Unnamed A	26.09565	80.66193	3													3
	25.43250	80.67438						2								2
Frog City N	25.76167	80.59000	2													2
	25.77167	80.81725						2								2
	25.77973	80.76977					2									2
	25.78618	80.75193						1	1							2
	25.80075	80.78265						2								2
	25.80298	80.74245						2								2
	25.80602	80.76303					2									2
	25.80652	80.78593					1	1								2
	25.82567	80.70700					1	1								2
	25.83168	80.68962						2								2
	25.83285	80.67358						2								2
	25.83605	80.75555						2								2
	25.84270	80.79880					1	1								2
	25.85398	80.70192						2								2
	25.86207	80.70330						2								2

WCA 3 Colonies	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
	25.86357	80.77652						2								2
	25.87180	80.65888					1	1								2
	25.87213	80.77680					1	1								2
	25.87263	80.77543						1				1				2
	25.87712	80.70602						2								2
	25.87925	80.82485					1	1								2
	25.87945	80.66150						2								2
	25.87968	80.70597					2	0								2
	25.88748	80.67242						2								2
	25.90352	80.66975					1	1								2
	25.90377	80.70805					1	1								2
	25.90595	80.76728					2									2
	25.90933	80.72997						2								2
	25.92105	80.72368					1		1							2
	25.92280	80.66128						2								2
	25.92517	80.78030					1	1								2
	25.92790	80.77873					1		1							2
	25.93000	80.50167	2													2
	25.93035	80.68788					2									2
	25.93707	80.73538					2									2
	25.94557	80.77778					1	1								2
	25.95017	80.77538						2								2
	25.95083	80.72972					1	1								2
	25.95468	80.68457					2									2
	25.95580	80.77195						2								2
	25.95700	80.77535										2				2
	25.97047	80.81928								2						2
	25.98058	80.76035					1	1								2
	25.98528	80.81283					1			1						2

WCA 3 Colonies	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
	25.98537	80.75985					2									2
	26.01350	80.78568							1	1						2
	26.01650	80.79710								2						2
	26.01830	80.65993					2									2
	26.03895	80.80992								2						2
	26.06613	80.73537							2							2
	25.76627	80.81472						1								1
	25.77265	80.76633						1								1
	25.77325	80.76755					1									1
	25.77360	80.76933					1									1
	25.77408	80.73348					1									1
	25.77458	80.72950					1									1
	25.77600	80.79600					1									1
	25.77668	80.79765					1									1
	25.77690	80.74988					1									1
	25.77690	80.75448					1									1
	25.77693	80.78418					1									1
	25.77723	80.76738						1								1
	25.77770	80.78755					1									1
	25.77783	80.74483					1									1
	25.78107	80.74218						1								1
	25.78125	80.83148						1								1
	25.78212	80.75160					1									1
	25.78365	80.75920					1									1
	25.78593	80.74268					1									1
	25.78613	80.75245					1									1
	25.78613	80.75300						1								1
	25.78743	80.74325					1									1
	25.78785	80.74278					1									1

WCA 3 Colonies	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
	25.79580	80.80682					1									1
	25.79632	80.73180					1									1
	25.79683	80.79973					1									1
	25.80250	80.81783						1								1
	25.80632	80.79770					1									1
	25.80708	80.79093					1									1
	25.81115	80.74395					1									1
	25.81175	80.74903						1								1
	25.81197	80.74938					1									1
	25.81205	80.81538						1								1
	25.82250	80.66025						1								1
	25.82505	80.67137						1								1
	25.82922	80.76690						1								1
	25.83148	80.71217					1									1
	25.84530	80.67777					1									1
	25.84955	80.76345						1								1
	25.85192	80.78232					1									1
	25.86017	80.67158						1								1
	25.86058	80.80640						1								1
	25.86130	80.71080														1
	25.86262	80.70590						1								1
	25.86265	80.78937						1								1
	25.86275	80.66165					1									1
	25.86283	80.78887					1									1
	25.86602	80.76065						1								1
	25.86613	80.76413					1									1
	25.86625	80.76448						1								1
	25.86827	80.76132						1								1
	25.86937	80.66060					1									1

WCA 3 Colonies	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
	25.87020	80.68095						1								1
	25.87400	80.74790					1									1
	25.87973	80.68612					1									1
	25.88073	80.81262					1									1
	25.88202	80.74185						1								1
	25.88262	80.70462						1								1
	25.88427	80.79745										1				1
	25.88448	80.76060					1									1
	25.89073	80.70213					1									1
	25.89147	80.75865						1								1
	25.89182	80.76862					1									1
	25.89280	80.73138					1									1
	25.89742	80.70435					1									1
	25.89782	80.79997								1						1
	25.89878	80.76938					1									1
	25.90103	80.74110						1								1
	25.90192	80.76315						1								1
	25.90208	80.74012					1									1
	25.90223	80.74002						1								1
	25.90580	80.79443					1									1
	25.90882	80.77363					1									1
	25.90998	80.79885								1						1
	25.91020	80.74692						1								1
	25.91773	80.78508										1				1
	25.91877	80.73545						1								1
	25.92047	80.73983						1								1
	25.92853	80.77820					1									1
	25.92887	80.72887						1								1
	25.92937	80.75110						1								1

WCA 3 Colonies	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
	25.93033	80.74632						1								1
	25.94043	80.68120					1									1
	25.94072	80.75465					1									1
	25.94320	80.67447						1								1
	25.94462	80.76103						1								1
	25.94580	80.77247										1				1
	25.94667	80.48000	1													1
	25.94723	80.74040					1									1
	25.94820	80.74218							1							1
	25.94863	80.74008					1									1
	25.94865	80.74425						1								1
	25.95088	80.76322					1									1
	25.95163	80.66808					1									1
	25.95313	80.75073					1									1
	25.95328	80.67852					1									1
	25.96042	80.74715								1						1
	25.96663	80.74113					1									1
	25.96810	80.75213					1									1
	25.96952	80.77922								1						1
	25.97170	80.71628								1						1
	25.98088	80.79977								1						1
	25.98480	80.71238								1						1
	25.98502	80.75967					1									1
	25.98582	80.67600					1									1
	25.98997	80.79633						1								1
	25.99225	80.81293								1						1
	26.00228	80.78282										1				1
	26.00242	80.72462														1
	26.01347	80.82338									1					1

WCA 3 Colonies	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
	26.03307	80.73808							1							1
	26.05140	80.73983					1									1
	26.10100	80.69928					1									1
	26.30500	80.33000	1													1
WCA 2 and 3			2,686	554	1,013	225	253	989	678	749	8	22	19	100	15	6,214

Loxahatchee colonies 1996

COLONY	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
	Decimal degreees															
96142	26.425833	80.240833		1	800				85	15						901
96152	26.678333	80.372333												750		750
96102	26.439167	80.392167	310							2				200		512
96155	26.383167	80.240167												450		450
96135	26.395167	80.247333							75	15				100		190
96154	26.494667	80.223333							1	2				180		183
96131	26.377500	80.259167	3				1			2				155		161
96149	26.473000	80.267833							65	8				70		143
96057	26.559500	80.250000	4	8			1		65	4				30		112
96059	26.560833	80.249333		6					60	6				20		92
96096	26.460333	80.354833	45						39	1						85
96129	26.376500	80.259667					1							70		71
96127	26.372500	80.265833					1							70		71
96150	26.480667	80.268500	3				1		60	4				1		69
96066	26.562833	80.295000					1		60	5						66
96038	26.458333	80.241500	65				1									66
96029	26.458000	80.235167							40	2				23		65
96093	26.458833	80.374333	10						50	1						61
96068	26.616667	80.320667	2				1		55	2						60
96076	26.481333	80.242333								8				50		58
96104	26.444167	80.377833	21						37							58
96075	26.481000	80.246167		8	5				5	6				30		54
96073	26.509000	80.259500	20				2			4		27				53
96091	26.469000	80.385667							50	1						51
96146	26.452500	80.283167	2						45	2						49
96106	26.442167	80.372167							45	4						49
96087	26.504667	80.375333	1				2		43	1						47
96147	26.517000	80.246667		3					40	4						47
96079	26.511167	80.360500	1						45	1						47
96085	26.504167	80.354500	6						40							46
96107	26.441000	80.372000							45							45
96067	26.598500	80.307833			2				40	2						44
96077	26.482667	80.238833							36	4						40

COLONY	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
96126	26.371000	80.265667	15				1							20		36
96095	26.462333	80.354167	1						33	2						36
96098	26.451000	80.380000	33				1									34
96049	26.443333	80.254667	12				1		15	4		1				33
96097	26.461667	80.354167	10						15	6						31
96153	26.459000	80.422000	11											15		26
96125	26.370833	80.293667	1						23	1						25
96103	26.447333	80.376667							25							25
96099	26.454167	80.380167	22				2									24
96082	26.524333	80.355167							22	1						23
96061	26.570833	80.271500	21				1									22
96080	26.511833	80.359833							15	6						21
96156	26.368000	80.250000	13				7									20
96032	26.473833	80.251833							1	19						20
96088	26.502500	80.375500							18	2						20
96058	26.559833	80.249000	10							4				6		20
96060	26.560333	80.249000	20													20
96074	26.509833	80.258500	12				5			2						19
96035	26.446000	80.250833	16				3									19
96112	26.413333	80.341333					1		14	4						19
96092	26.469667	80.386000							18	1						19
96081	26.522333	80.360833							18							18
96113	26.414500	80.339667	3						11	3						17
96128	26.375167	80.259000												13		13
96123	26.366500	80.301667							2	10						12
96030	26.475000	80.246000								11						11
96122	26.367833	80.301833							1	10						11
96157	26.411667	80.261667	11													11
96036	26.447000	80.250667	9				1									10
96136	26.398000	80.250667	10													10
96117	26.372500	80.310500	8						1							9
96083	26.525667	80.349667	1						7	1						9
96100	26.448500	80.384500	6				2									8
96069	26.614833	80.321500					1		5	2						8
96040	26.458167	80.242833	7													7
96044	26.458833	80.239833	7													7

COLONY	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
96101	26.446500	80.385500	7													7
96158	26.357000	80.303000	7													7
96026	26.542500	80.243333					5									5
96143	26.445167	80.267167	3				2									5
96054	26.444000	80.258667	5													5
96051	26.444500	80.257500	4									1				5
96159	26.462167	80.372333	5													5
96070	26.514167	80.270333					4									4
96094	26.462500	80.355500	3				1									4
96120	26.375833	80.300500	4													4
96078	26.448833	80.260500					3									3
96003	26.459667	80.246000					3									3
96064	26.571333	80.272833	2				1									3
96065	26.570667	80.272333	3													3
96062	26.572167	80.272833	3													3
96045	26.458333	80.238833	3													3
96072	26.511000	80.262500					2									2
96130	26.376667	80.261000					2									2
96121	26.369833	80.301000					2									2
96001	26.403500	80.245667					2									2
96005	26.471667	80.248167					2									2
96018	26.509333	80.341667					2									2
96022	26.510000	80.341000					2									2
96041	26.459833	80.242500	2													2
96050	26.443833	80.254000	1									1				2
96137	26.400333	80.250500	2													2
96027	26.474167	80.244500								2						2
96124	26.369167	80.294667	1						1							2
96034	26.445500	80.249500					1									1
96144	26.446667	80.276500					1									1
96046	26.449333	80.249667					1									1
96145	26.450000	80.282833					1									1
96028	26.476500	80.233333					1									1
96063	26.571000	80.273667					1									1
96151	26.477500	80.265167					1									1
96086	26.495667	80.351333					1									1

COLONY	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
96114	26.418000	80.307000					1									1
96108	26.443167	80.365833					1									1
96071	26.511667	80.265333					1									1
96056	26.553167	80.251667					1									1
96148	26.456000	80.259500					1									1
96031	26.472167	80.248000					1									1
96133	26.376667	80.253500					1									1
96134	26.378167	80.251667					1									1
96132	26.379500	80.259500					1									1
96140	26.411167	80.247833					1									1
96141	26.412833	80.245000					1									1
96115	26.374833	80.324000					1									1
96111	26.412000	80.354000					1									1
96109	26.430000	80.367000					1									1
96116	26.371500	80.317500					1									1
96110	26.418167	80.358667					1									1
96090	26.487167	80.383667					1									1
96089	26.494167	80.379500					1									1
96002	26.401667	80.246500					1									1
96004	26.464667	80.372333					1									1
96006	26.472833	80.247833					1									1
96007	26.474333	80.298833					1									1
96008	26.483333	80.354833					1									1
96009	26.487667	80.363667					1									1
96010	26.504667	80.309833					1									1
96011	26.506000	80.330500					1									1
96012	26.506000	80.375500					1									1
96013	26.506167	80.355333					1									1
96014	26.506333	80.345333					1									1
96015	26.508167	80.322500					1									1
96016	26.508667	80.324000					1									1
96017	26.509000	80.323333					1									1
96019	26.509333	80.341833					1									1
96020	26.509500	80.330000					1									1
96021	26.509500	80.341333					1									1
96023	26.510167	80.352167					1									1

COLONY	Latitude	Longitud	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
96024	26.520667	80.325333					1									1
96025	26.525000	80.236667					1									1
96039	26.458333	80.242500	1													1
96048	26.443000	80.255333	1													1
96043	26.459000	80.240167	1													1
96138	26.399833	80.250500	1													1
96139	26.404333	80.248667	1													1
96037	26.434167	80.248667	1													1
96042	26.459500	80.241333	1													1
96084	26.517000	80.362167							1							1

COLONY	GE	SE	WI	WS	GBH	ANH	LBH	TC	CC	BCNH	GI	CE	RS	Total
Total, Loxahatchee National Wildlife Refuge	814	26	807	0	117	0	1372	197	0	30	0	2253	0	5616

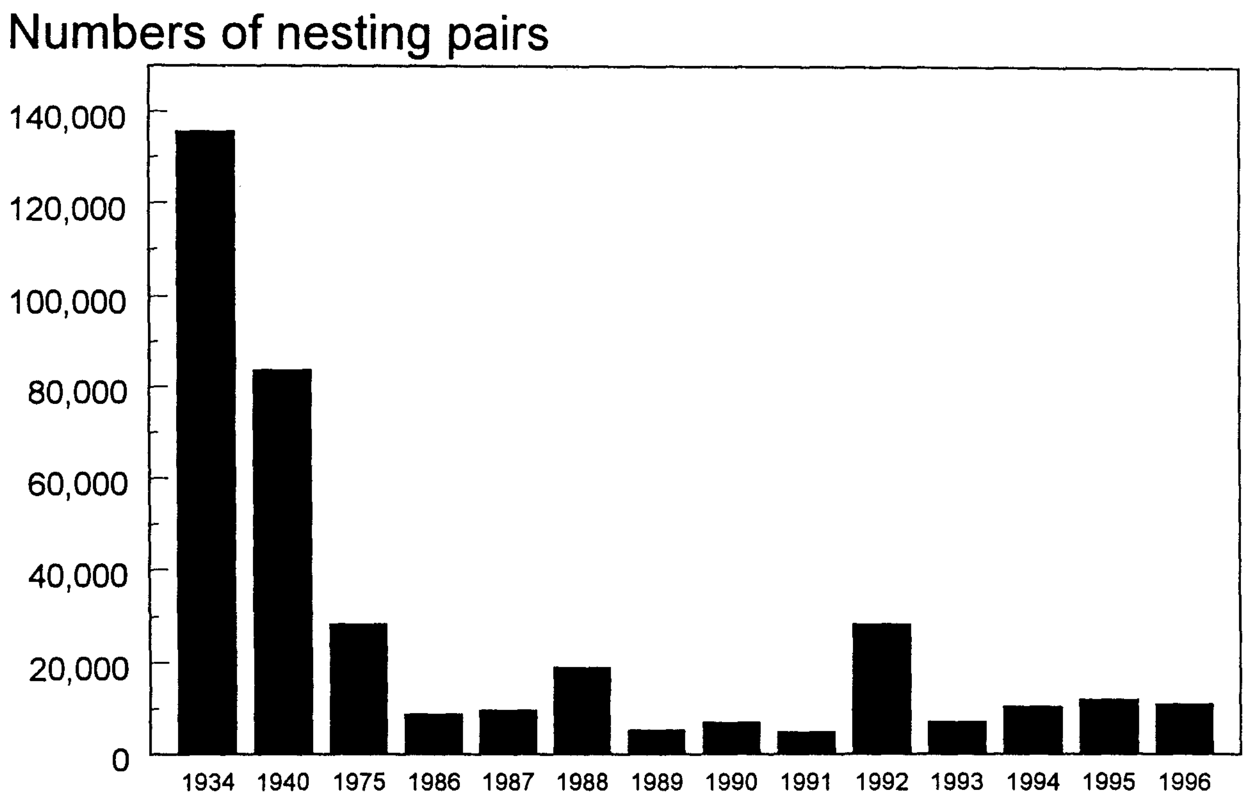


Figure 1.14. Numbers of nesting pairs of all species of wading birds in the Everglades, 1934 - 1995. Summarized from data in Kushlan and White (1977), Ogden (1978), Kushlan et al. (1984), Frederick and Collopy (1988), Bancroft (1989), Ogden (1994), and from unpublished records of the National Audubon Society.

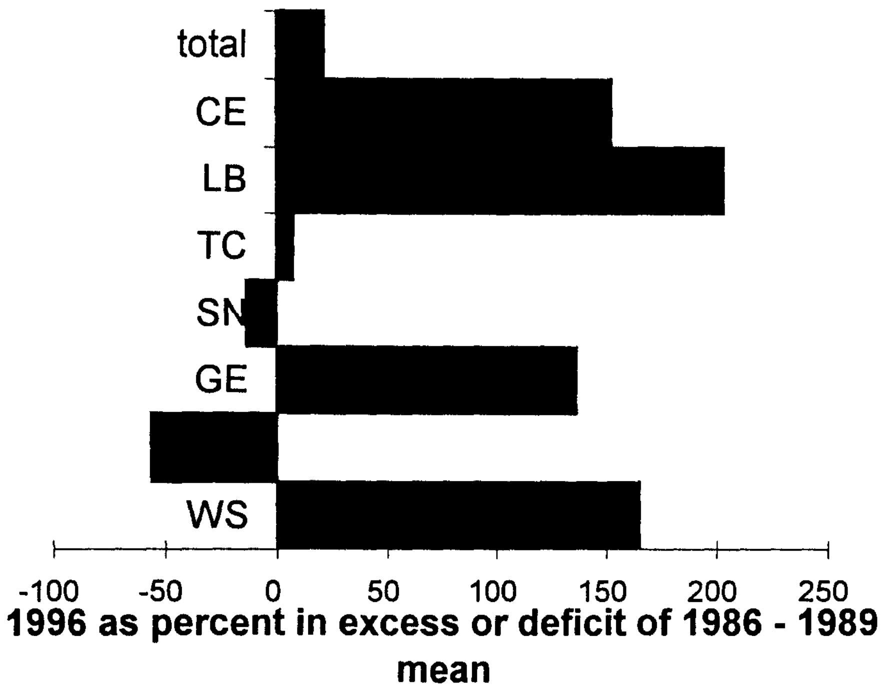


Figure 1.15. Wading bird nesting numbers by species in 1996, represented as the percent increase or decrease relative to the 1986 - 1989 mean. The 1986 - 1989 period was chosen for comparison as a time of neither high nor low water conditons during the recent period.

Figure 1.16. Proportion of nesting in the mainland Everglades (WCAs 1, 2, and 3, and mainland Everglades National Park) that is located in the WCAs, 1986 through the present.

Timing and success of nesting

In this project, we made no attempt to systematically record nesting success via repeated nest visits, as had been done in many earlier years (Frederick 1995). However, the aerial and ground surveys allow us to detect large-scale abandonments (>50% of nests) in colonies that are checked on a monthly basis. In 1996, we found almost complete abandonment of Wood Storks at the Crossover colony, and partial abandonment of Snowy Egrets at the Gator Baby colony. At the Tamiami West colony, large flying Wood Stork young were noted by the time of the onset of rains in late May and early June, suggesting that this nesting event was largely successful. At the Alley North colony, we noted one abandonment event involving White Ibises in early April, but the majority of birds appeared to have re-nested; a minimum of 1,000 nests fledged young. Other than these, nesting was generally successful throughout the season, and the aerial surveys suggested that large numbers of nestlings were fledged in most colonies.

The timing of nesting was somewhat early. Wood Storks began in late January at the Crossover Colony - while this is not early by the standards of the 1930's - 1960's, it is earlier than most years during the past 10. White Ibises began nesting in the Alley North colony in late February, which is earlier than the more frequent April and often May initiations typical of the past 10 years.

Food habits

We collected a total of 66 boluses from nestling wading birds in 1996, 13 from Tricolored Herons (Hidden colony), 24 from Snowy Egrets (Hidden and Heron Alley colonies), and 29 from Great Egrets (Hidden and JW1 colonies) (see Tables 1.4 - 1.6).

At the Hidden colony in 1996, Tricolored Herons were feeding their young an almost entirely piscivorous diet, with over 40% of the diet being made up of killifishes of the genus Fundulus (F. chrysotus and f. confluentis, see Figure 1.17, Table 1.5). Other small fishes such as flagfish (Jordanella floridae) and Sailfin Mollies (Poecilia lattipinna). The species composition and strongly piscine diet agree well with other studies in the Everglades (Frederick 1995, Sepulveda et al. 1995, Bancroft and Jewell 1987).

By comparison, Snowy Egrets were feeding their chicks a much more varied diet at the

Table 1.4. Results of analysis of 13 boluses of food regurgitated by Tricolored Heron nestlings in Hidden colony in 1996. Total mass of boluses was 225 g, total food items was 336.

		Number of items	**Proportion of boluses**	**Proportion of total biomass**	**Proportion of otal prey item**	**Mean total length**	**s.d.**	**Mean mass**	**s.d.**
Vertebrata:	Fundulus chrysotus	59	0.368	0.257	0.176	40.17	15.11	0.98	0.70
Osteichthys:	Fundulus confluentu	47	0.500	0.147	0.140	29.53	19.07	0.70	0.47
	Poecilia lattipinna	55	0.571	0.121	0.164	29.95	11.14	0.50	0.33
	Jordanella floridae	43	0.353	0.111	0.128	31.28	8.67	0.58	0.31
	Lucania goodei	63	0.333	0.040	0.188	23.76	4.58	0.14	0.08
	Gambusia holbrooki	42	0.615	0.027	0.125	24.07	6.97	0.14	0.08
	Lepomis punctatus	2	0.091	0.016	0.006	25.30	27.86	1.80	0.42
	Lepomis Sp.	1	0.050	0.002	0.003	30.00	-1.00	0.40	0.00
	Cyprinodon variegat	6	0.067	0.007	0.018	25.67	1.21	0.25	0.05
	Unknown fish	13	0.238	0.045	0.039				
Invertebrata:									
Crustacea:	Shrimp	2	0.080	0.002	0.006	30.00	0.00	0.20	0.00
Insecta:	Odanata	2	0.087	0.002	0.006	0.00	0.00	0.25	0.07
	vegetation	1	0.042	0.001	0.003				

Table 1.5. Results of analysis of 23 boluses regurgitated by Snowy Egret nestlings at Hidden (22 boluses) and Heron Alley (1 bolus) colonies in 1996. Total mass of boluses was 296 g, total prey items was 599.

	Prey species	Number of items	Proportion of boluses	Proportion of biomass	Proportion of Prey items	Mean total length	s.d.	Mean mass	s.d.
Vertebrata:									
Osteichthys:	Jordanella floridae	137	0.583	0.167	0.229	27.07	7.66	0.36	0.20
	Fundulus chrysotus	50	0.458	0.114	0.083	34.38	15.41	0.67	0.52
	Poecilia lattipinna	76	0.625	0.107	0.127	23.39	0.42	0.42	0.42
	Unknown fish	32	0.417	0.073	0.053				
	Fundulus confluentu	27	0.542	0.059	0.045	39.19	11.59	0.65	0.44
	Gambusia holbrooki	89	0.500	0.044	0.149	22.03	8.63	0.15	0.23
	Lucania goodei	115	0.542	0.043	0.192	21.29	7.94	0.11	0.06
	Lepomis Sp.	1	0.042	0.010	0.002	0.00	0.00	3.00	0.00
	Heterandia formosa	16	0.417	0.002	0.027	15.38	2.36	0.04	0.13
	Lepomis punctatus	2	0.042	0.020	0.003	60.50	0.71	2.90	0.42
Invertebrata:									
Crustcea:	Paleomenetes palud	44	0.500	0.017	0.073	16.11	10.58	0.11	0.10
	Procambarus alleni	1	0.042	0.004	0.002	42.00	0.00	1.10	0.00
Insecta:	Insecta	10.000	0.333	0.004	0.017				
	Odanata	6	0.208	0.004	0.010	2.67	6.53	0.18	0.10
	Orthoptera	1	0.042	0.000	0.002	0.00	0.00	0.10	0.00
	Diptera	2	0.042	0.000	0.003	0.00	0.00	0.00	0.00
	Belastomatidae	1	0.042	0.000	0.002				

Table 1.6. Results of analysis of 29 boluses regurgitated by Great Egret nestlings at Hidden (19 boluses) and JW1 (10 boluses) colonies in 1996. Total mass of boluses was 785 g, 70 total prey items.

	Prey species	Total items	Proportion of boluses	Proportion total biomass	Proportion of all prey items	Mean total length	s.d.	Mean mass	s.d.
Vertebrata:									
Osteichthys	Lepomis punctatus	22	0.579	0.314	0.314	38.45	39.75	11.19	0.54
	Lepomis Sp.	15	0.368	0.093	0.214	32.87	39.55	9.81	14.33
	Fundulus confluentu	1	0.053	0.001	0.014	43.00	0.00	0.80	0.00
	Jordanella floridae	2	0.105	0.001	0.029	15.00	21.21	0.30	0.00
	unknown fish	27	0.737	0.497	0.386				
Invertebrata:									
Crustacea:	Paleomenetes palud	1	0.053	0.000	0.014	18.00	0.00	0.10	0.00
Insecta:	Odanata	1	0.053	0.000	0.014	0.00	0.00	0.20	0.00
	vegetation	1	0.053	0.003	0.014				

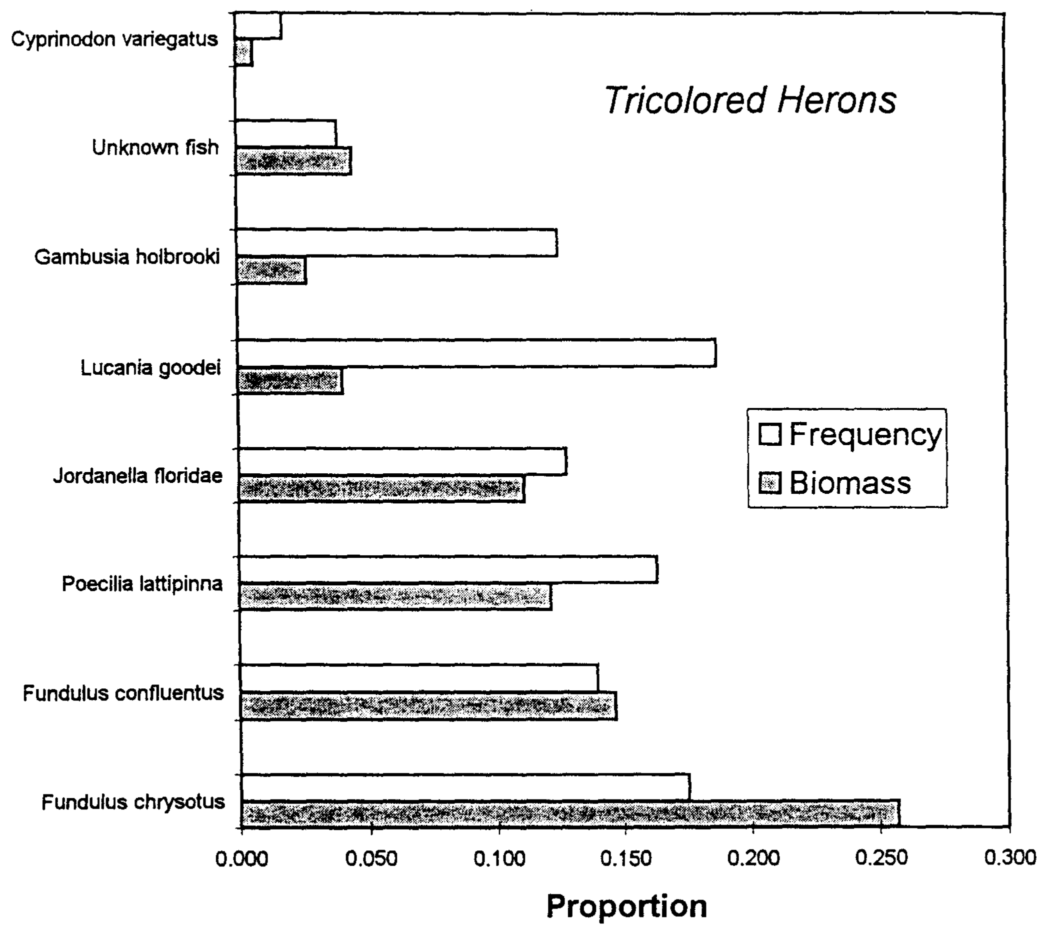
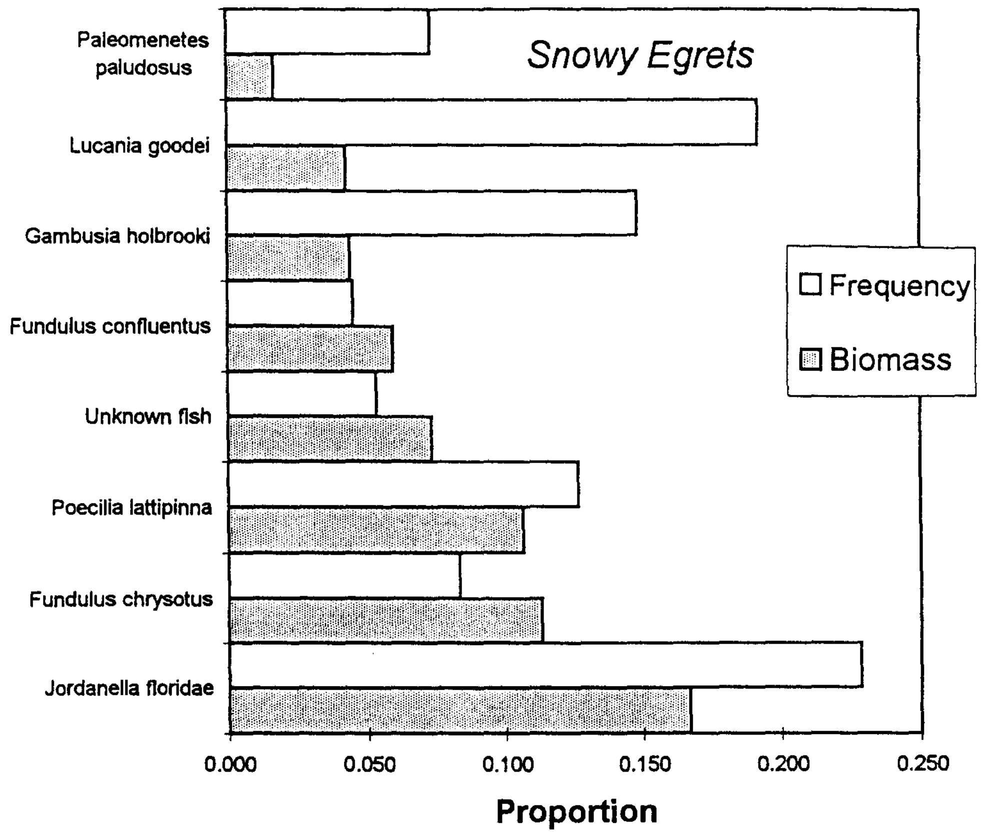
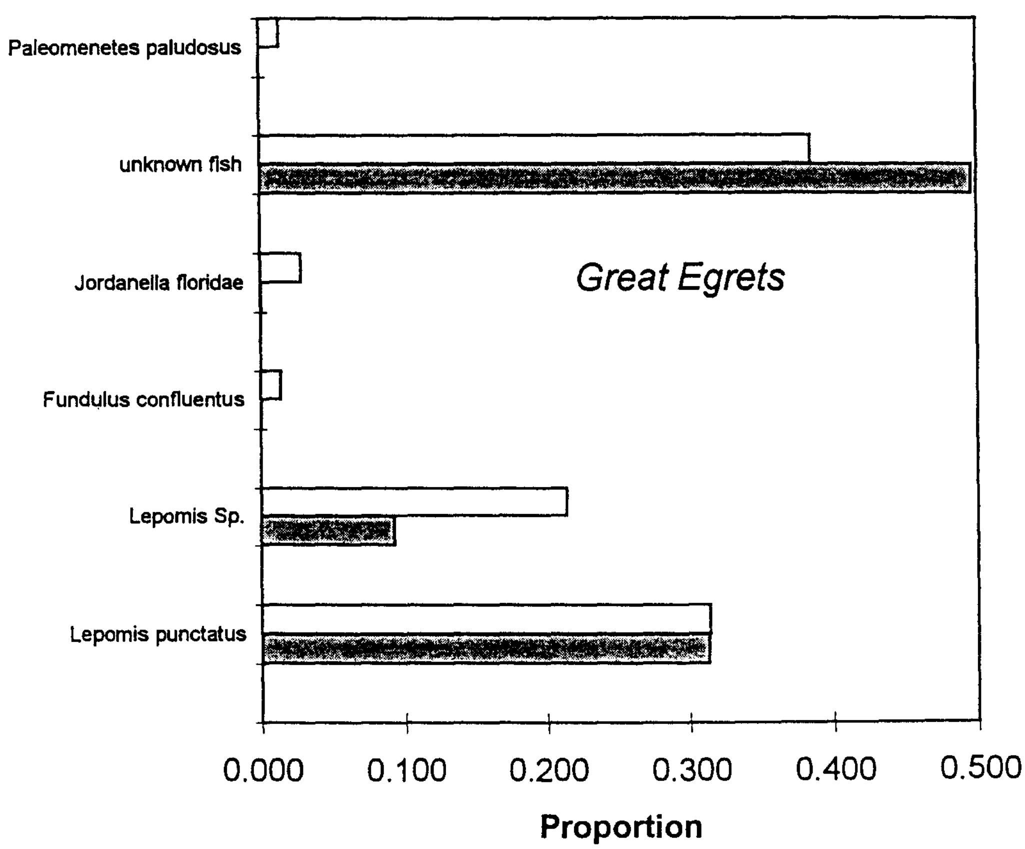


Figure 1. 17. Analysis of food items found in boluses regurgitated by Tricolored Heron nestlings from Hidden Colony in 1996, shown as percent of total biomass, and as percent of total numbers of prey items (frequency).



Figures 1.18 (above) and 1.19 (below). Analysis of food items found in boluses regurgitated by Snowy Egret nestlings in Hidden and Heron Alley colonies (Figure 1.18) and Great Egret nestlings in Hidden and JW1 colonies (Figure 1.19) in 1996, shown as percent of total biomass, and as percent of total numbers of prey items (frequency).



same colony (Figure 1.18, Table 1.5). For example, 70% of the biomass of the diet is made up of over ten species for Snowies, whereas 5 species accounted for the same proportion of Tricolored Heron diets. Small fishes dominated the diet of Snowy Egrets, such as Flagfish, Sailfin Mollies, and Mosquitofish (Gambusia holbrooki). Snowies did include some insects and crustaceans in their diet (3%), but the diet was dominated by fishes.

Great Egrets concentrated on much larger fishes, and on sunfishes (Figure 1.19, Table 1.6). A large proportion of the boluses (50% of biomass) was not identifiable to species, but consisted of large-bodied fishes. Sunfishes dominated the identifiable portion of the diet, and all of those identifiable to species were Spotted Sunfishes (Lepomis punctatus). The diet was entirely fish at both Hidden and JW1 colonies. By comparison with other studies, Great Egrets in 1996 ate a greater proportion of Spotted Sunfishes, and ate far fewer exotic fishes. Although exotic cichlids and Pike Killifish (Bellenesox belizanus) have made up nearly 30% of the biomass in some years, we found no exotics in the diet in 1996. The high proportion of Spotted Sunfish in the diet and the lack of exotics may indicate that the Great Egrets were obtaining prey from wet prairie habitat, well away from canals where exotic fishes may be more prevalent.

DISCUSSION

The 1996 season was unique in having extremely high stages in most compartments during the early breeding season, in combination with extremely rapid and uninterrupted surface water recession. The recession also began early in the season, in November, rather than in January or February. Finally, there were no periods of severe cold to delay the onset of nesting, or to interrupt nesting once it began.

Thus 1996 represents an interesting natural test of the drydown hypothesis. The drydown hypothesis holds that wading bird nesting numbers and nesting success are strongly dependent upon the rate at which surface waters recede, and in so doing, exposing and concentrating prey animals (Kushlan et al. 1975). Although a surface water drying trend has always been part of the nesting season in the Everglades, there is question as to how necessary drying is to productive foraging. Though nesting effort by Wood Storks and White Ibises have been associated with strength of drying trend in the Everglades (Kushlan 1975, Kahl 1964, Frederick and Collopy 1989a), this relationship only seems to be true of the post-WCA period (Ogden 1994). Similarly, the very strong drying trends associated with the 1989 - 1991 protracted drought did not produce abnormally large numbers of nests. The latter may not have been a good test of the hypothesis, however, because during the drought years, stages were low and virtually no surface water was available by the middle of the nesting season. In contrast, the 1992 season began with high stages and had strong drying throughout the nesting season. However, the 1992 season was special in that it came on the heels of a prolonged drought, suggesting that the lengthy drying followed by rewetting catalyzed the ecosystem for a burst of secondary productivity, either through reliberation of nutrients, or by killing off the large predatory fishes.

The 1996 sequence of events is quite different, coming on the heels of a prolonged period of very high water and exceptionally long hydroperiods. In 1996, the effect of an extremely rapid drying rate was unconfounded by preceding drought effects, effects of severe weather or temperature, or by low stages. In WCA 3A, the drying rates were the fastest so far recorded for ***both*** early and late periods.

The result was might be called an unexceptional nesting season, in which the numbers of nesting pairs was similar to the previous three very wet years. The only evidence that this combination of environmental characteristics was stimulating to nesting was that a somewhat larger number of Wood Storks attempted to nest than usual. The fact that nesting was largely successful is of interest, but not directly attributable to drying rates, because the weather was perhaps abnormally clement during much of the season.

Taken in combination with the preceding three high water seasons, the 1996 season suggests that drying rate by itself is a poor predictor of nesting effort in the Everglades. This by default lends credence to the idea that the strong 1992 nesting event was stimulated by something other than (or at least in addition to), drying rate, probably the preceding drought. The wading bird nesting responses seen in 1996 were also generally consistent with the other three high water years (1993 - 1995). These years seem to have consistently stimulated between 10 and 14,000 pairs of wading birds to nest, with steadily increasing numbers of Great Egrets, Little Blue Herons, and Cattle Egrets, and decreasing numbers of White Ibises. In 1993 - 1995, aggregated foraging was rare, and most foraging concentrated on the periphery of the WCAs, usually in much shorter hydroperiod marshes. Colonies have been located within the deeper water of the WCAs, but the larger and more successful colonies have been located near the edges, close to the shorter hydroperiod areas.

These high water years are also of interest because they constitute an ongoing test of the coastal degradation hypothesis. This hypothesis suggests that the ability of the coastal and estuarine areas of the Everglades to produce secondary productivity has been destroyed through the severe reduction in freshwater flows to the area as a result of water management during the past 50 years (McIvor et al. 1994, Ogden et al. 1994). This hypothesis predicts that re-watering of the coastal region should result in growth of the size of coastal colonies, if not restoration of abandoned ones. We have now experienced four straight years of incrreased flows to the coastal area through naturally heavier than normal rainfall. So far, no dramatic increases have been noted in the coastal zone, though the number of storks nesting at Rodgers River Bay and Paurotis Pond colonies have increased somewhat. A large uncertainty in this hypothesis is the lag time between rewatering and response of both prey organisms, and wading birds. It is possible that rewatering must also be accompanied by some form of disturbance such as periodic droughts in order to catalyze a surge of secondary productivity.

Chapter 2:
Energetic Requirements of Nestling Wading Birds

INTRODUCTION

The hydrological modifications due to flood protection during the 20th century have substantially altered the hydrology of the Everglades ecosystem (Maltby and Dugan 1994), resulting in a conspicuous decline in the numbers of wading birds (Ogden 1994, Davis and Ogden 1994). Since the 1940's, the number of nesting attempts of all species combined has decreased by over 90%, specifically involving Wood Storks *(Mycteria americana)*, White Ibis (*Eudocimus albus*), and Snowy Egrets (*Egretta thula*) (Ogden 1994, Frederick and Spalding 1994). Although the altered landscape of the Everglades still provides foraging habitat for large numbers of non-breeding wading birds (Bancroft et al. 1994), the decline in the number of breeding birds has frequently been cited as an indicator of the degradation of the ecosystem (Ogden 1994). The restoration of productive wading bird populations in the Everglades may translate into successful restoration of the entire ecosystem.

Availability of food may be the single most important factor limiting the distribution and nesting success of wading birds, especially in the relatively oligotrophic Everglades ecosystem (Frederick and Spalding 1994). For instance, Powell (1983) demonstrated that food-supplemented great white herons (*Ardea herodias*) laid significantly larger clutches and raised more young than did unsupplemented pairs in Florida Bay. Because the growth and brood size of some young ciconiiform birds are thought to be highly dependent upon amounts of food delivered to the nest during the early period of rapid growth (Werschkul 1979, Powell 1983), The relationship between food intake, weight gain and survival of wild nestlings may therefore elucidate the nutritional requirements for nestling survivorship and the effect of suboptimal energy provisionings on productivity and later growth and survival. Correlating food availability with nutritional requirements will provide information about the constraints on adult reproduction and colony formation. As a result, this study aims to accumulate information on the energetics of nestling and juvenile wading birds in the Southern Florida Everglades environment, and to investigate the relationship between food and chick quantity and quality.

Modeling projects that incorporate the simulation of ecological processes, and the organisms involved, may help to explore and direct certain aspects of the restoration effort. History, plasticity of species characteristics, species interactions, and modifications of the environment through abiotic and biotic processes are integral pieces of knowledge that lend to ecological theory (DeAngelis and White 1994). Frederick and Powell (1994) demonstrated the importance of wading birds as vectors of nutrient flow in the Everglades; and this serves as an example of how wading birds modify their own environment. However, accurate information concerning energy and food consumed by nestling wading birds was a missing link in the model, as well as in other models that are based largely on energetics. For example, other modeling attempts of wading bird dynamics in the Everglades exist in the literature (Fleming et al. 1994), but threshold levels of food required by nestlings, as well as the effect of food intake on growth rates at different ages and stages of the nestling phase could enhance the accuracy of the modeling projects considerably. Specific recommendations for restoration and improved management remain hampered by inadequate information, especially concerning the ecology of food organisms (Robertson and Frederick 1994).

Energetics of wading bird nesting have been poorly documented simply because the logistics of measuring energy consumed have been insurmountable, and only sporadically investigated using captive animals. Frederick and Powell (1994) claim that energy consumption by young could lead to overestimation of food consumption and excretion by young of up to 80%. A technique now exists for accurately measuring food consumption in nestling wading birds. The labeled water technique (Lifson and McClintock 1966, Nagy 1983 & 1980) is extremely useful for measuring prey intake. Chicks are injected in the field with a small amount of radioactively labeled water, specifically tritium (H3O), which is concentrated in the bird's blood stream. As the chicks are fed, the tritiated water is diluted by the water in the food. By extracting blood samples initially after injection and comparing the concentrations to those taken a few days later, the degree of dilution can be accurately converted to a water turnover rate. Because the water content of prey items in the Everglades is well known (Kushlan et al. 1989), and the other sources of water (metabolic water, water vapor) and sinks (excretion and respriation) are easily calculated, water turnover can be used to estimate prey consumption with a relatively small error of 5-9% (Nagy 1983). This was successfully accomplished with Great Egret nestlings during the 1994-5 breeding seasons (Sepulveda et al. 1995).

Our primary focus in this work is to relate food intake in wild nestlings to their growth and survival and brood size. In so doing, we hope to 1) supply basic ecological information to modeling efforts such as ATLSS, 2) be able to make refined statements about the levels of energy required for nesting in several species and 3) evaluate the effect of food supply on productivity, condition and survival of nestling wading birds. .

METHODS

Study Sites and Birds

During the 1996 breeding season, data were collected from three sites in Water Conservation Areas 3A and 3B named Hidden Colony, Gator Baby Colony and Heron Alley (see Table 1.3 for coordinates). Snowy Egrets were the primary target of the study, although, we inadvertently treated and measured food intake in Little Blue Heron nestlings at the 3B Mud Canal because they are indistinguishable from Snowy Egret chicks until 3 weeks of age. We visited the colonies every five days, at which time nests were identified. We recorded the number of eggs present, weighed chicks to the nearest gram using 50, 100 or 300 gram Pesola scales (depending on size), measured culmen length to the nearest mm, and color-banded or inconspicuously marked the nestlings.

Labeled Water

Food intake was measured using the labeled water technique. In order to minimize heat stress on the chicks, the procedure was carried out between 0630 and 0800 h. After weighing chicks and measuring culmen length, all chicks were injected with tritated water at a rate of 1 milliCurie (mCi) tritiated water/kg body weight into the thigh muscle mass using a 1 ml insulin syringe. Each bird was then returned to the nest for 1 hour to allow equilibration of the isotopes in the body fluids (Williams and Nagy 1984). Blood samples (between 0.15 and 0.30 ml) were drawn from the jugular vein, placed in sterile vacutainers, and transferred to 75 mm heparinized capillary tubes a few hours later. The tubes were flame-sealed with a miniature butane torch and refrigerated. Five days later, we returned to the colony and drew final blood samples. If we felt the birds would be easy enough to catch 5 days later, we performed the entire procedure again, starting with a new injection.

Blood samples were distilled to obtain pure water by vacuum distillation. The capillary tube containing the blood sample was cracked and heated under vacuum (pressure=, causing the water contained in the sample to vaporize. The vapor was then condensed into an ampule that was immersed in a cold trap filled with liquid nitrogen. The ampule containing the frozen water was flame-sealed under vacuum and removed from the vacuum manifold.

After distillation, 10 ul of the the tritiated water was pipetted into three separate scintillation vials, . Scinitillation cocktail was added to each vial and the triplicate sets of vials were assayed for tritium activity with a liquid scintillation counter. I calculated water turnover using the following equation from Nagy (1983):

Water Efflux = ((2000*(BWf-Bwi)*LN((CPMi*Bwi)/(BWf*CPMf)))/((Mi+Mf)*LN(BWf/Bwi)*t))

Water Influx = Efflux+((2000*(BWf-Bwi))/(t*(Mi+Mf)))

where

Bwi =initial body water of chick (ml)
BWf =final body water of chick (ml)
CPMi =initial counts per minute of tritium injected into the chick
CPMf =final counts per minute of tritium injectedinto the chick
Mi =inital mass of chick (g)
Mf =final mass of chick (g) and the ratios.

Water turnover was then converted to food intake using the following equation (Dunn 1975):

Food Intake (g/d) = (Influx/0.87)*(((0.001*Mi)+(0.001*Mf))/2).

We assumed that 70% of chick bodies was water .

RESULTS

We analyzed a total of 78 blood samples, representing food intake during 39 five-day intervals. The results of the blood samples are derived from 37 of the chicks. Two Little Blue Heron chicks from the Heron Alley Colony provided blood samples for two five-day intervals. The total number of samples were taken from a 72 chicks between 5 and 22 days of age. We did not have accurate ages for all chicks, however, there was a strong correlation between weight and age (Pearson Correlation, R=.84, p=.0001) and therefore we inputed age values based on the weight measurements we collected. We also found that culmen growth was highly correlated with age (Pearson Correlation, R=.91, p=.0001), and weight (Pearson Correlation, R=.83, p=.0001). The relationship between age and weight is as follows: [age=1.943+.0635*weight].

To test for the effect of colony location on food intake we performed an ANCOVA, adjusting for age. In this analysis we pooled the samples from all three colonies, combining the data from both Snowy Egret and Little Blue Heron chicks. The analysis showed no statistical evidence that colony location affected food intake (F=2.88, p=.0697). There was, however, a strong association between food intake and age (F=19.29, p=.0001). The relationship between age and food intake is as follows: [food intake=15.53+4.99*age].

We analyzed the data to determine if food intake affects mass of chick. This analysis also tested if colony affected weight gain. Again, we pooled the samples from all three colonies for this analysis. The results showed no statistically significant effect of colony by food intake interaction (ANOVA, F=.46, p=.6372), nor for colony effect (ANOVA, F=.1.3, p=.2873). The analysis did show a significant association between food intake and weight gain (p=.0006). The estimated regression equation is as follows:

Figure 2.1. The weight and age of Snowy Egret chicks are highly correlated (R=.84, p=.0001).

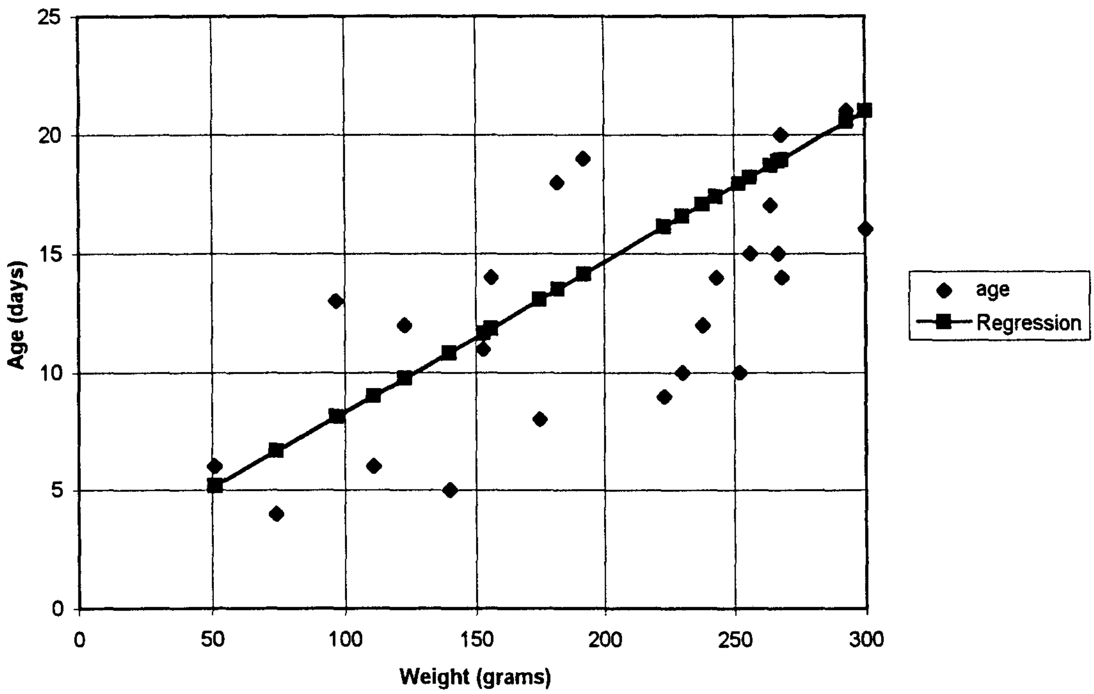


Figure 2.2. In different colonies (see legend), Snowy Egret nestlings receive more food from parents as they age (R-Square=.37, p=.0001). There was no significant effect of colonies on the food intake of chicks (p=.0697).

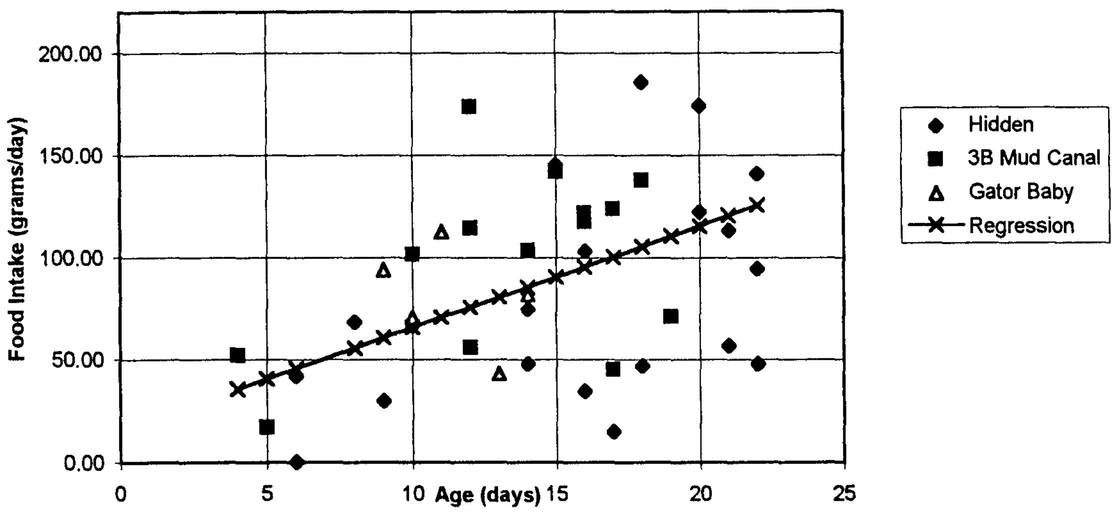
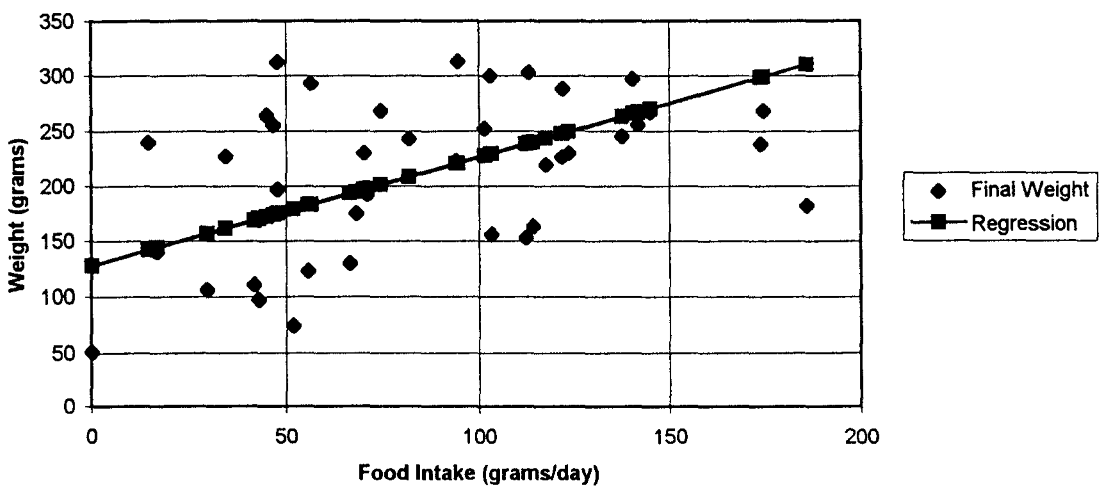


Figure 2.3. As Snowy Egret chicks intake more food, their weight increases (R-Square=.54, p=.0006).



[weight gain=127.91+.98*food intake}. Thus food intake appears to influence weight gain positively when the effects of colony are factored out.

We also performed separate analyses by species. We performed an ANCOVA and controlled for age, colony and hatch order for the Gator Baby and Hidden colonies which consisted only of Snowy Egret in order to further determine if food intake affects weight gain. The analysis showed that there was no effect of food intake on weight gain ($F=3.93$, $p=.0621$). However, the results of the analysis, controlled for age and status for Little Blue Heron chicks at the Heron Alley colonies implied that food intake affects weight gain ($F=8.80$, $p=.0158$) independently of age and hatch order. .

Field notes suggest that chicks died more frequently during the early parts of June than during other, earlier stages of the breeding season. In early June, two of the experimental Little Blue Heron chicks died at the Heron Alley Colony, 15 Snowy Egret chicks from the Gator Baby Colony died, and five chicks from the Hidden Colony died. However, during the earlier parts of the breeding season, only one chick (from a clutch of four) died and 1 chick from the Hidden Colony died. We had difficulty documenting food intake in these dying chicks because they were too young to sample at the time. However, on the five days prior to the death of a third-hatched chick from Hidden Colony, the oldest sibling received food at a rate of 68.12 grams/day and the second eldest sibling received food at a rate of 41.69 grams/day.

DISCUSSION

During 1996, we demonstrated that food intake can be measured in Egretta herons using the labeled water technique, and our data provide a first cut at understanding the levels of food necessary to maintain chicks of specific ages. We have also demonstrated that food amount delivered to chicks is not strongly influenced by geographic differences among colonies, at least during this year. In addition, food amount seems to strongly influence chick mass, independently of chick age or hatch order. This fact is the first real evidence from the field that food amount is critical to the residual mass and, by extension, the condition of ciconiiform chicks. We anticipate that these relationships will become better developed and will be more robustly tested as our sample sizes increase with re-runs.

Data on other species in the Everglades are also available, perhaps enough to begin modeling the energetics of wading bird reproduction. Sepulveda et al. (1995) measured food consumption of Great Egrets using a similar labeled water technique, and age-specific values are available from that study. The reproductive success of Great Blue Herons is thought to be limited by the parents' ability to gather food (Powell 1983) and Bennett et al. (1995) have published information on age-specific energy consumption of Great Blue Heron young. As the chicks grew, their total gross energy requirement and total energy requirement for maintenance, which may include accumulation of metabolically inactive tissues such as adipose, feathers and skeleton, increased to a maximum between 30 and 39 days of age and declined thereafter. Daily metabolizable energy intake did not vary significantly between males and females. Perhaps the most significant finding of this study suggested that parents must provide 6100 and 8100 Kj/day during the period of maximum energy intake to support a brood of three and four nestlings, respectively, in addition to providing for their own energy requirements. Other estimates of energetic consumption for Wood Storks (Kahl 1964) and White Ibises (Kushlan 1974) are also available.

The significance of our work has to do with the fact that it was carried out in a field situation. Most of the other estimates come from captive-reared chicks, or from estimates based purely on allometric extrapolations. The Bennett (1995) study was carried out on captive chicks that were fed until they reached satiation. For this reason, the results determine growth curves and energetic needs effectively, but they do not help to determine threshold levels of food intake. Our study, on the other hand, was conducted on free-ranging, wild nestlings that are subject to all the elements and receive actual parental feedings, and the labeled water method accurately reflects the parental food deliveries. Although we are constrained by the mobility of the chicks and our study cannot be carried out for an unlimited period of time, if Great Blue Heron growth curves are similar to those of other wading birds, the Bennett et al. (1995) study implies that we are collecting data during the times of maximum growth and energy needs of the chicks.

Our results from the 1996 breeding season are preliminary and will be subjected to further analyses. We intend to continue this research during the 1997 breeding season, and to investigate the effect of food supply on survival of chicks, condition of chicks, and brood size. The techniques involved with effectively handling and catching the birds once they are mobile, as well the analysis of the blood samples in the lab, have been refined in the past year, and are now fully operational. This will hopefully serve to improve the sample size, and hence accuracy of this data, so that it can become available for future modeling projects.

Chapter 3:
Environmental and Hydrological Factors
Affecting Wading Bird Foraging Success

Introduction

Wading bird breeding numbers in the Everglades have declined as much as 90% in the last 70 years (Bancroft 1989, Ogden 1994). There may be many factors contributing to the decline, but a lack of suitable foraging habitat may be an important proximal factor (Bancroft 1989, Frederick and Spalding 1994, Kushlan 1978, Ogden 1978, 1994).

In the Everglades, there are several lines of evidence linking foraging success with both the willingness to initiate breeding, and the success of breeding. First, the wading bird reproductive cycle is closely tied to the drying of surface water, which may serve to concentrate prey animals (Kushlan et al. 1975, Kushlan 1987, 1989, Frederick and Collopy 1989a). At the nest level Great White Herons with supplemented diets had larger clutches and brood sizes than non-supplemented herons (Powell 1983). Finally, when prey availability becomes reduced during the breeding season for any reason (increases in stage, cold temperatures, drought conditions) breeding by wading birds is interrupted (Frederick and Spalding 1994).

Quality of wading bird foraging habitat in the Everglades has probably been impacted by a number of mechanisms, most having to do with the distribution and timing of freshwater flows. Reduction in the quantity of foraging areas has been estimated to be as much as 1.2 million ha or 50% lost to drainage (Davis et al. 1994), and the process of draining shallow peripheral areas and diking the deeper parts has led to a significant reduction in the percentage of the marsh represented by short-hydroperiod wetlands (Fleming et al. 1994). These short hydroperiod wetlands are those hypothesized to be important for early nesting season foraging, and consequent stimulation of nesting. Estuarine productivity has also decreased, through a dramatic reduction in the flows of fresh water to the coastal areas of Everglades National Park (Walters et al. 1992, McIvor et al. 1994). In the freshwater marsh, there may also have been vegetative community shifts from the more productive wet prairie habitat to sawgrass dominated habitats (Davis et al. 1994). Finally, the overdrainage of many parts of Everglades National Park may have resulted in considerable reductions in the standing crop of those marshes, both through shortened hydroperiod (Loftus et al. 1994) and through the isolation of karst topography refugia from deeper water pools (Loftus et al. 1992).

The ability to mitigate these effects is of course hampered by the political and geographic realities of the current Everglades - flood protection is a must, urban water use and agricultural pollution are challenges that drastically limit the ability to manage water to restore the Everglades. There may also be direct tradeoffs inherent in different water management strategies. For instance, increasing water depth seems to be a necessary corrolary of increasing hydroperiod in the impounded sections of the Everglades. Although increasing hydroperiod to a point is associated with increased standing crop of prey organisms, it is unclear if the associated depths will limit the availability of those prey animals to wading birds. Similarly, there may be a tradeoff between the speed of surface water recession, and the ability of the marsh to produce high densities of prey animals - repeated rapid drying will probably produce short hydroperiod conditions, which may lead to poor production of prey animals. Further, there are probably strong effects of vegetative density, dissolved oxygen, and flow rates that affect the production and availability of prey. And these factors must somehow be separated from the effects of factors that are impossible to control, such as weather, soil type, time of day and season. Thus the ability to predict the conditions that will affect wading bird foraging is very poorly developed, but could have very strong implications for hydrological solutions to the restoration of Everglades wading birds.

This part of the study is aimed at understanding the hydroligical, environmental, and biotic conditions that affect wading bird foraging success, in an effort to achieve the ability to predict the effect of different hydrological manipulations and their implications for restoration. Although this study is timely in its own right, it recieves a great boost from a collaborative study of the dynamics of the prey animal community (small fishes and macroinvertebrates) that is concurrently being carried out by Joel Trexler and Frank Jordan of Florida International University and Jacksonville University, respectively.

Methods

Our main method of quantifying foraging behavior and success was to observe individual wading birds forage and relate foraging success with measurable physical and environmental variables. We chose to concentrate on Great Egrets, Snowy Egrets, White Ibises and Wood Storks. We selected these species because they represent a variety of wading bird sizes and foraging techniques (tactile, active, visual, sit and wait), representing a wide spectrum of the wading bird community. Another factor in choosing these species is that many of these species' (Snowy Egret, White Ibis and Wood Stork) breeding populations have shown the most dramatic declines in the last 60 years (Bancroft 1989, Ogden 1994).

We observed birds using telescopes (15x to 45x) often from a 4 meter collapsible tower mounted on an airboat. Observations from one site in Everglades National Park were conducted from a truck sitting on the Shark Valley Tram Road. Observations ranged from 1.5 to 15 minutes and were conducted from sunrise until noon, the period of most active foraging by wading birds (Kushlan 1978). Observations were terminated by: 1) predetermined time (5 or 15 minutes) 2) bird flies away 3) bird is lost from sight or 4) bird stops foraging. Predetermined times of 5 minutes were used for individuals in a flock and 15 minute observations were used for solitary birds. In part these times were chosen because of their practicality and the shorter observation time for individuals within a flock allowed us to observe a greater variety of birds. We attempted to observe only adult birds.

Our observations were conducted only at an array of sites being concurrently sampled for fishes and macroinvertebrates, in order to take advantage of the site-specific information on prey animal communities. The fish sampling sites (Figure 3.1) are areas where principle investigators Joel Trexler and Frank Jordan, are measuring fish and macroinvertebrate densities on a semimonthly basis (six sites in Everglades National Park and eleven sites in the Water Conservation Area 3). One square meter throw traps are

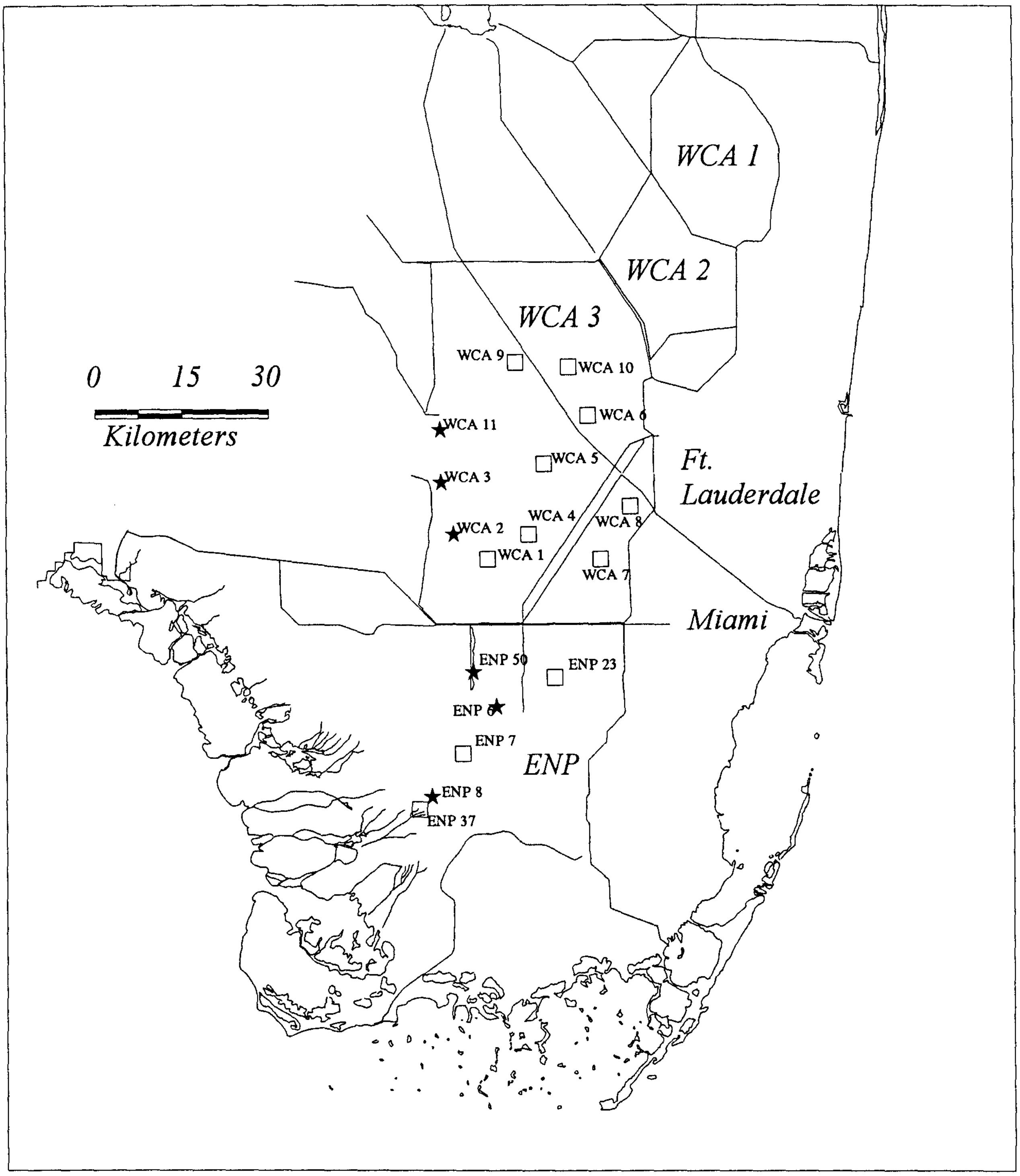


Figure 3.1. Map of the study area showing the locations of all fish sampling sites. Sites represented by stars were those at which we collected information on foraging behavior in 1996, and those that did not attract birds are shown as squares.

used to determine prey density in predominately wet prairie areas throughout the Everglades system. In the sawgrass and wet prairie dominated landscape of the Everglades system the wet prairie habitat was chosen because it tends to support the majority of the foraging wading birds and is often the area of highest prey production.

Fish and macroinvertebrate sampling was carried out at randomly selected sub-sites within each identified area. We sampled birds that were foraging at distances of no more than 400 meters from any sub-site.

In addition to the foraging behavior information we collected from each focal bird, we collected a wide range of environmental and site variables. Average depths were measured at all foraging sites by taking five measurements with a pole, mounted with metal spurs on the base to mimic the approximate area of a wading bird's foot, and weighted to 1,000 g (the approximate mass of an adult Great Egret or White Ibis). The pole was allowed to settle with no additional force applied, into the substrate.

In addition we collected other variables (see sample data sheet Figure 3.2):

1)The number of captures and their approximate prey sizes are recorded and an attempt is made to identify the prey. The number of strikes, probes, steps and other quantifiable behavioral traits are recorded.

2)A note is made for why the observation was terminated: time, flies off, out of sight, or disturbance.

3)Vegetation and physical features within 150 meters are recorded: sawgrass strand, willow head, tree island, road, etc.

4)Dominant vegetation at the foraging site is recorded (species composition and an estimate of density). A note is also made on the percentage of periphyton coverage.

5)Depth of water to the flocculent layer

6) Water temperature

7) Type of substrate (i.e. rock, peat, marl etc.) and its color.

Figure 3.2 Wading bird observation data sheets (following two pages).

Foraging Observation Sheet

OBS # __

Date ________ Species _____ Observer _____ Time Start:_____

Location description ____

Age _____ Sex ______ Breeding Color ____ Plumes_________

Solitary? Flock: Numbers of other birds within 50 meters:
GBH GLI SE GE WS WI TC LB RS Other sp.

Nearest neighbor at start: ________ meters away ________

Step = s **Strike** = str **Probe** = pr **Stir** = fs **Capture** = cap
Wing extended = wext **Aerial forage** = af **Foot drag** = fd **Lookup** = lu
Bill wipe = bw **Aggression towards** = at (species) **Focal bird displaced** = db (species)
Focal bird displaces: dis (species) **Prey dip** = pd **Head swing** = hs

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Observation terminated by: time ___ flies off __ out of sight ____ disturbance ___ other:

Total minutes observed (in minutes and tenths of minutes) __________

#steps______ strikes_____ probes _____ captures_______ AF ______ Stir ______
AT ____ FD _____

Notes on microhabitat used:

Wading Bird Foraging Site Descriptions

Date ________________ **OBS #**______

Location (description)____

Latitude___________________________ **Longitude**__________________

Bioregion: Cypress Slough/Tree island Rocky Glade Melaleucaland
Mangrove Urban Agricultural

Vegetation and physical features within 150 m:
Tree island Willow head airboat trail camp road pond canal other
wet prairie cattail stand sawgrass strand open water Cypress stand

Landscape feature in which the bird is standing: Wet prairie (size)
Sawgrass strand Cypress forest Cattail stand Pond (size) Canal edge
Airboat trail Other: (describe)

Vegetation at foraging site:
Dominant
- emergent (rough density)
- submergent
- trees/shrubs (bird must pass w/in 10 meters)

Periphyton: coverage %
100 75 60 50 40 30 20 10 <10
- solid mat
- floating clumps
- cigars on stems
- finely broken, on bottom
- little or none
- no white material

Edges followed:

Water:
Clarity: clear, slightly turbid, cloudy
Depth (cm): ___ ___ ___ ___ ___
Temp.

Substrate:
rock peat Color: dark
marl sand light
flock mottled

Weather: Wind direction: N NE E SE S SW W NW
Wind speed: none 0-5kts 5-10 10-15 15-20 20-25
Air Temp:______
Clouds: Clear 25% 50% 75% overcast thunderstorms other
Sun Angle (overhead is 90°, horizon is zero) _______

8) Estimated weather variables: wind direction, speed, cloud percentage, and sun angle.

9) Air temperature.

10) Size and species composition of the foraging flock.

11) Species and approximate distance to the closest bird at the start of the observation.

To determine the energetic content of food items, size estimations of prey were made along with an attempt to identify the prey species. Estimations of prey size were made by comparing the prey length to that of the birds culmen (e.g. Draulans 1987). An estimation of energetic gain using the calculated prey length to mass ratio and the caloric intake from each prey item can than be made using the estimates of Kushlan et al. (1986).

We examined univariate correlations (Pearson Correlation Coefficients) between species-specific capture rates, and environmental variables of interest, in order to assess the relative importance of those variables, and to reduce the number of variables to be used in a later multivariate analysis . In order to do this, we pooled all observations of each species across sites.

Results

In 1996 we completed over 900 observations of foraging wading birds for a total of 5,018 minutes (Tables 3.1 and 3.2). We observed Great Egrets (292 observations for 2,044 minutes), Snowy Egrets (213 observations for 1,064 minutes), Wood Storks (161 observations for 766 minutes) and White Ibis (151 observations for 759 minutes). Six of the 17 sites that we monitored sustained large flocks (>18 birds) at some point during the January - July period, some for a period of months, and some for as little as two weeks. We observed Great Egrets at five sites, Wood Storks at four, and Snowy Egrets and White Ibis were observed at only two sites.

Table 3.1

Great Egret	Total	s.d.	site 3	s.d.	site 11	s.d.	site 50	s.d.	site E6	s.d.	site E8	s.d.
observations	292		65		138		16		48		24	
minutes	2044		627		825		111		245		231	
average depth	18.50	6.37	17.74	5.96	16.76	4.01	11.68	5.62	24.74	7.63	22.13	5.26
steps/minute	3.22	2.85	3.25	2.82	2.90	2.68	5.24	2.93	3.27	2.64	3.56	3.78
captures/minute	0.43	0.60	0.22	0.26	0.66	0.70	0.84	0.71	0.09	0.22	0.05	0.09
strikes/minute	0.35	0.47	0.21	0.23	0.53	0.57	0.46	0.46	0.09	0.15	0.13	0.19

Snowy Egret	Total	s.d.	site 11	s.d.	site 50	s.d.
observations	213		30		183	
minutes	1064		885		179	
average depth	13.81	4.78	14.93	4.08	7.17	2.80
steps/minute	8.47	7.61	7.30	5.93	15.63	11.86
captures/minute	1.02	1.21	0.90	0.97	1.74	2.04
strikes/minute	2.01	1.71	1.87	1.26	2.87	3.25
look ups/minute	0.28	0.36	0.24	0.32	0.55	0.49
foot stirs/min.	0.39	1.40	0.24	0.88	1.29	2.91

Table 3.1. Characteristics of behavioral observations on foraging wading birds in Conservaion Area 3 and Everglades National Park during 1996. (s.d. = standard deviation)

Table 3.2

White Ibis	Total	s.d.	site 11	s.d.	site 50	s.d.
observations	151		102		49	
minutes	759		522		237	
average depth	12.60	5.54	15.45	4.18	6.65	2.39
steps/minute	11.49	8.18	10.70	7.17	13.14	9.84
captures/minute	1.38	1.05	1.40	1.03	1.33	1.12
probes/minute	23.36	8.06	22.01	8.20	26.18	7.04
look ups/minute	1.95	3.41	2.06	3.72	1.73	2.65

Wood Stork	Total	s.d.	site 11	s.d.	site E6	s.d.	site 50	s.d.	site E8	s.d.
observations	161		6		124		26		5	
minutes	766		38		576		118		34	
average depth	24.26	6.94	14.40	5.44	26.76	5.12	14.60	4.62	24.16	2.60
steps/minute	18.45	6.26	18.09	9.75	17.90	5.59	19.86	7.94	25.02	4.61
captures/minute	0.19	0.37	1.20	1.17	0.11	0.16	0.38	0.42	0.23	0.20
probes/minute	13.70	4.72	11.60	4.09	14.17	4.94	12.26	3.72	11.98	2.06
look ups/minute	0.72	0.71	0.34	0.33	0.78	0.71	0.41	0.52	1.22	1.35
wing ext./minute	0.80	1.75	0.31	0.49	0.91	1.86	0.13	0.31	2.07	2.94
foot stirs/min.	5.99	5.70	9.37	5.12	3.05	4.54	10.18	4.44	*	*

Table 3.2 Characteristics of behavioral observations on foraging wading birds in Everglades National Park and Conservation Area 3 during 1996. (s.d. = standard deviation)

Our most observation-rich site (11), is located in Conservation Area 3A within the outflow of nutrient rich water from L-28 Interceptor Canal (Figure 1). This site consistently had foraging flocks of up to 694 birds, from February 22 until April 26 when all surface water had receded. At site 3 which is also in Conservation Area 3A we observed only Great Egrets in flocks of up to 18 birds, from February 26 until May 20. From March 26 until June 6 all four focal bird species were observed at site 50 in Everglades National Park, in flocks ranging from 2 to 377 birds. Two more sites, sites ENP 6 and ENP 8, also in Everglades National Park sustained flocks of Great Egrets and Wood Storks, ranging from a few individuals to approximately 150 birds.

Our most active site, site 11, was within the zone of transition between wet and dry areas of the marsh, during the entire length of our observations at this site. The transition zone presumably concentrates fish into shallow pools and are foraging areas for wading birds (DeAngelis 1994). Of the 2,100 observed captures by all four focal birds, 98% were prey items less than two centimeters. The second active site in Conservation Area 3A, site 3, is located in the gap region. This region is hydrologically complex, with high flow rates from the Big Cypress region, allowing for an extended transitional period during most seasons. It is used by wading birds over a wide range of water levels (Hoffman et al. 1994). Of the 130 observed captures at this site, 91% of the prey items were smaller than two centimeters. Site 50 in Everglades National park was also part of the transition zone from March 26 until June 6 when it was completely dry. During this time all four focal birds were observed in flocks ranging from 2 to 377 birds. Of the 715 captures observed at this site 92% were less than two centimeters.

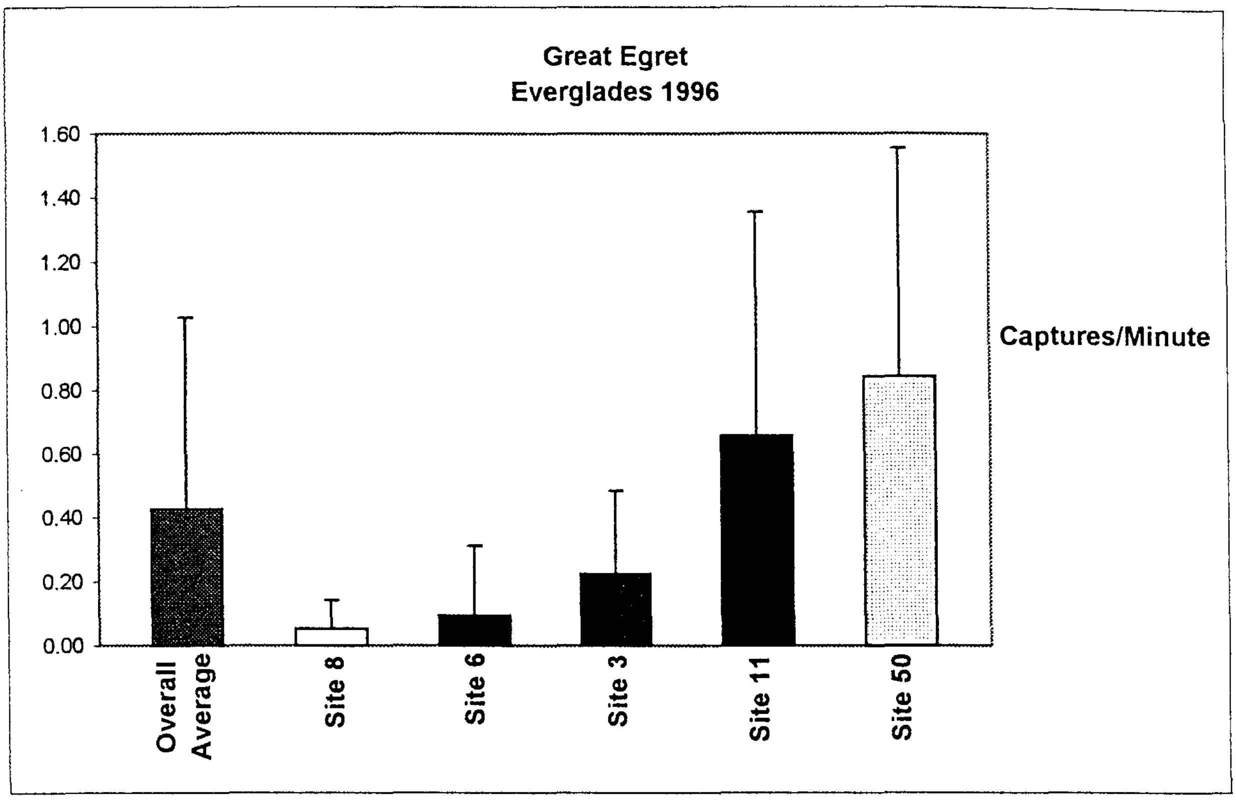
We had two active sites with longer hydroperiods in the park, sites ENP 6 and ENP 8. Of the 76 observed captures at site ENP 6 approximately 38% of the prey were smaller than two centimeters and 54% of the 22 captures observed at site ENP 8 were smaller than two centimeters. Only larger focal species were observed at these two sites. Sites 3, 11 and 50 were in the transition zone in 1996. Predominately small fish, smaller than 2 cm, are produced (Loftus and Eklund 1994) and captured at these sites. Areas with longer hydroperiods, sites ENP 6 and ENP 8, tend to produce larger fish.

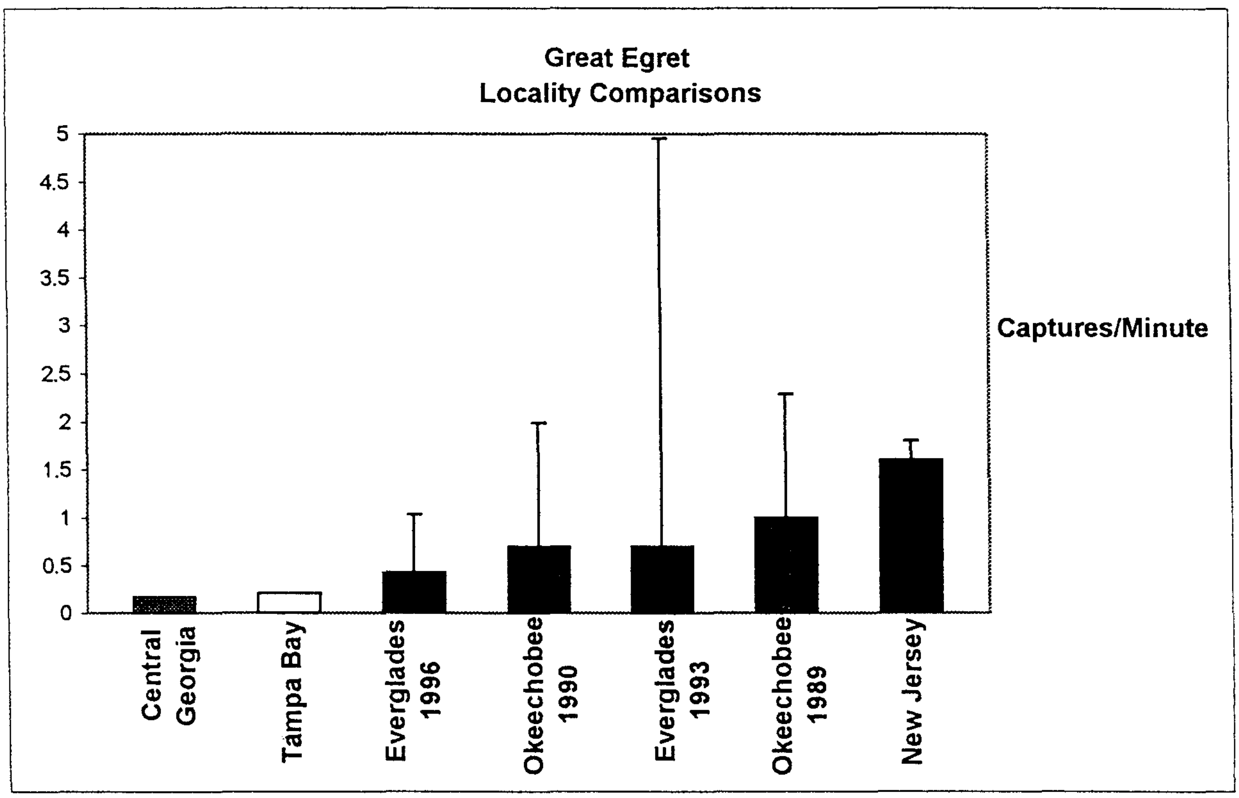
In early May, our airboat had a catastrophic breakdown, and was not back in service until July. This meant that our observations during that time were quite limited, and particularly during an interesting period, when water was falling fastest, and also rising during the onset of the rainy season. This was also a time of great wading bird activity as parental birds were making large numbers of foraging trips, and chicks were fledging from the colonies. In addition, this was a period when other sites that had no previous wading bird activity suddenly became productive.

We compared capture rates at our sites with published records from the Everglades and other areas in the United States (Figures 3.4, 3.6, 3.8,3.10) graphically showed some of the variability in capture rate among our sites in 1996 (Figures 3.3, 3.5, 3.7, 3.9). The between-site variability in capture rates was most evident for Great Egrets and Wood Storks (Figures 3.3 and 3.9). Across studies in different regions of the U.S., we found generally high variability in capture rates within studies, and considerable overlap of ranges between studies.

Correlation analysis Although we expect that our sample size (particularly of sites) is too small for a full analysis, we conducted univariate correlations to look for preliminary trends in the data, and in order to identify variables that seemed not to influence capture rates.. We compared capture rate to several habitat and environmenta variables (Table 3.3). We were unable to look at the effect of prey density or biomass, simply because Joel Trexler and his associates are currently compiling and analyzing those data.

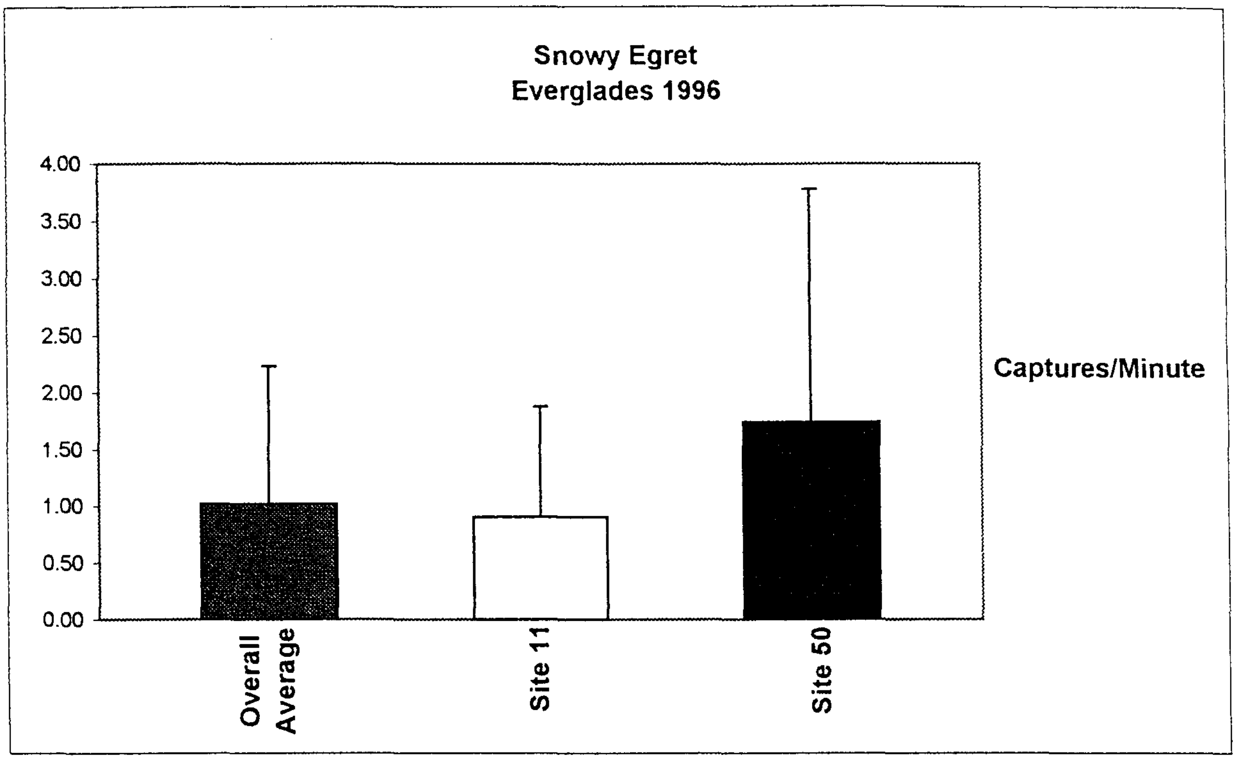
We performed these analyses using capture rates (captures/min) as the dependent variable. Although the real currency for wading birds is likely to be caloric return per minute, we did not feel confident enough so far in the accuracy of our prey size estimation to use this variable. We plan a study of the effects of observer variability, distance, prey species, prey size, bird species, and viewing angle, on the estimation of prey size in the coming year.

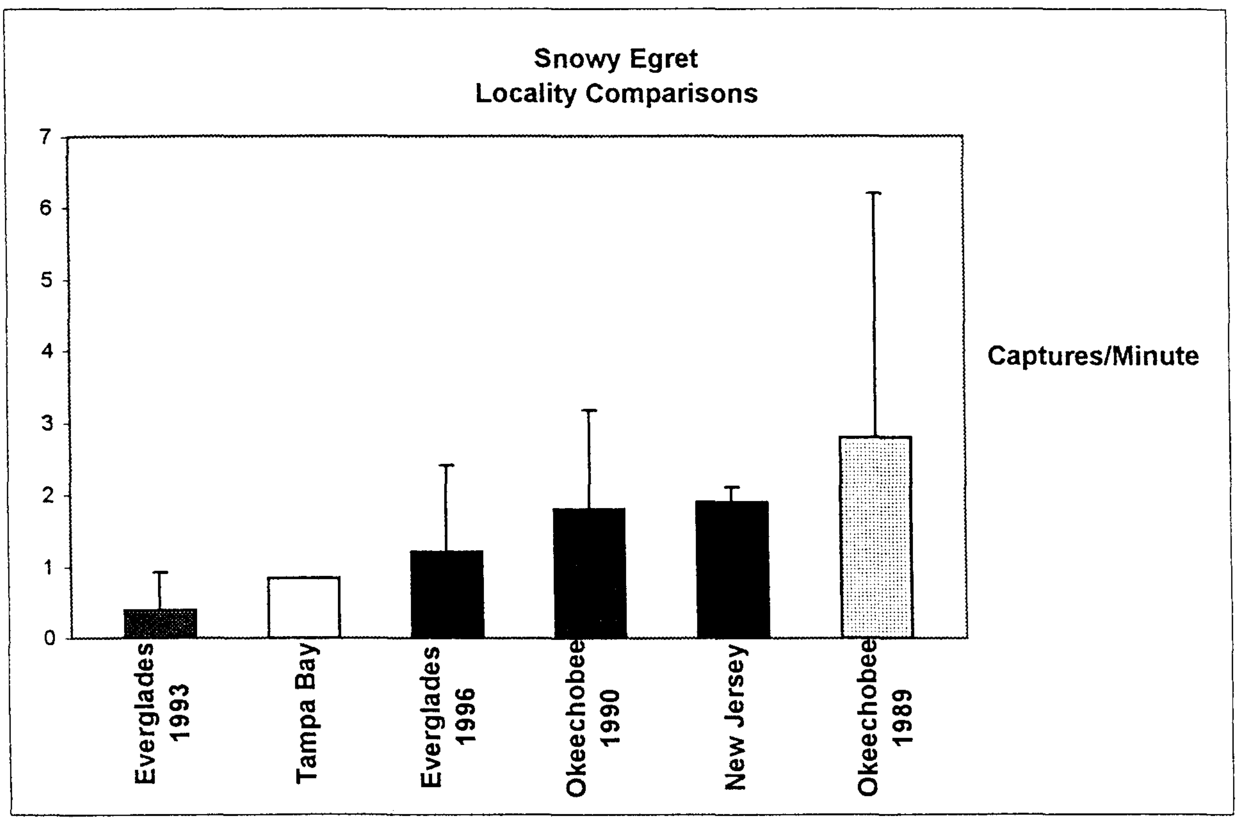




Figures 3.3 and 3.4. Average capture rates for Great Egrets sampled in 1996 in the Everglades (top) and comparisons with other published studies (bottom).

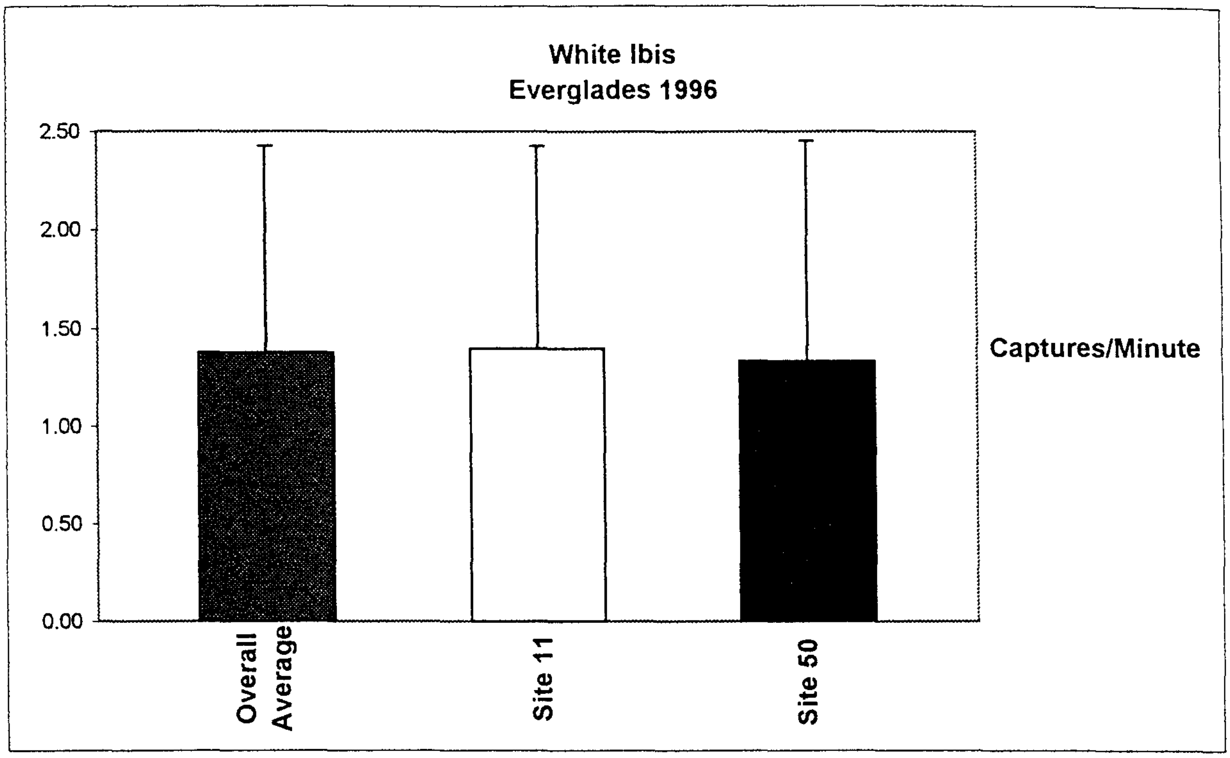
Figures 3.5 and 3.6

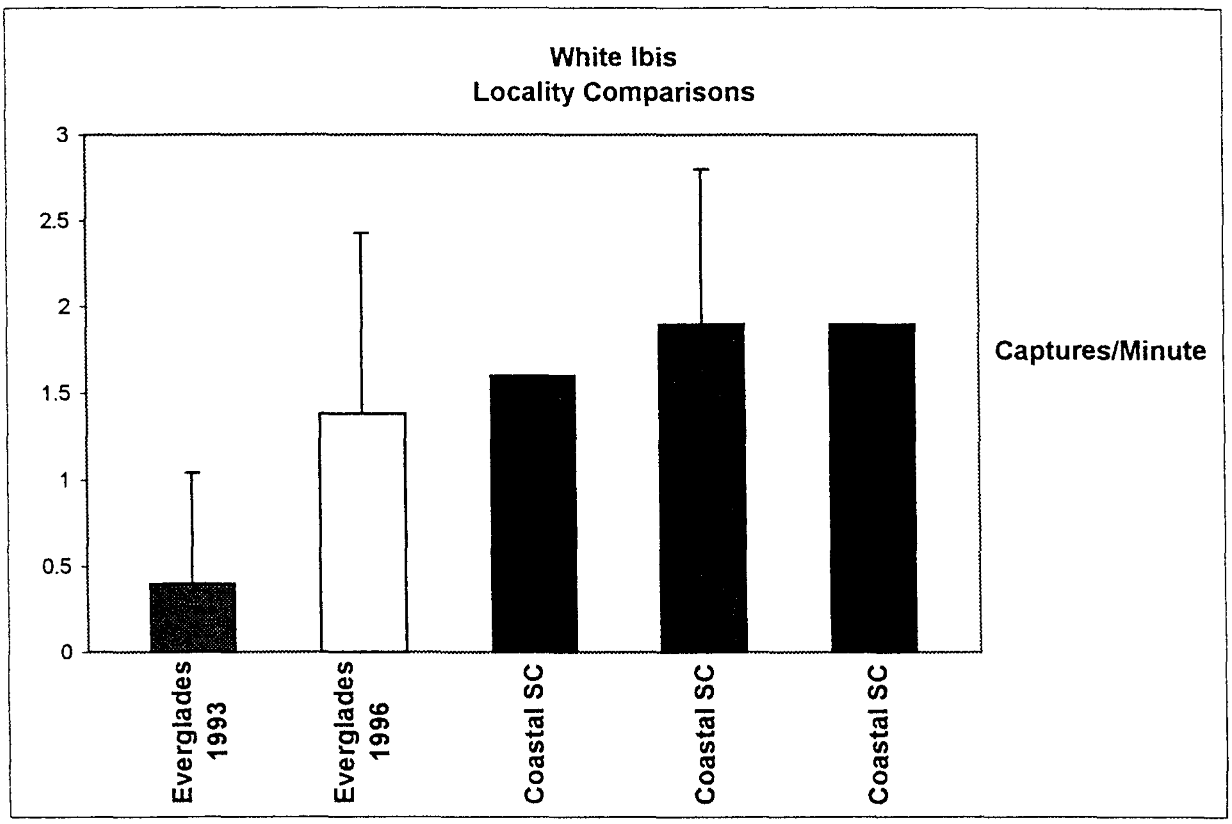




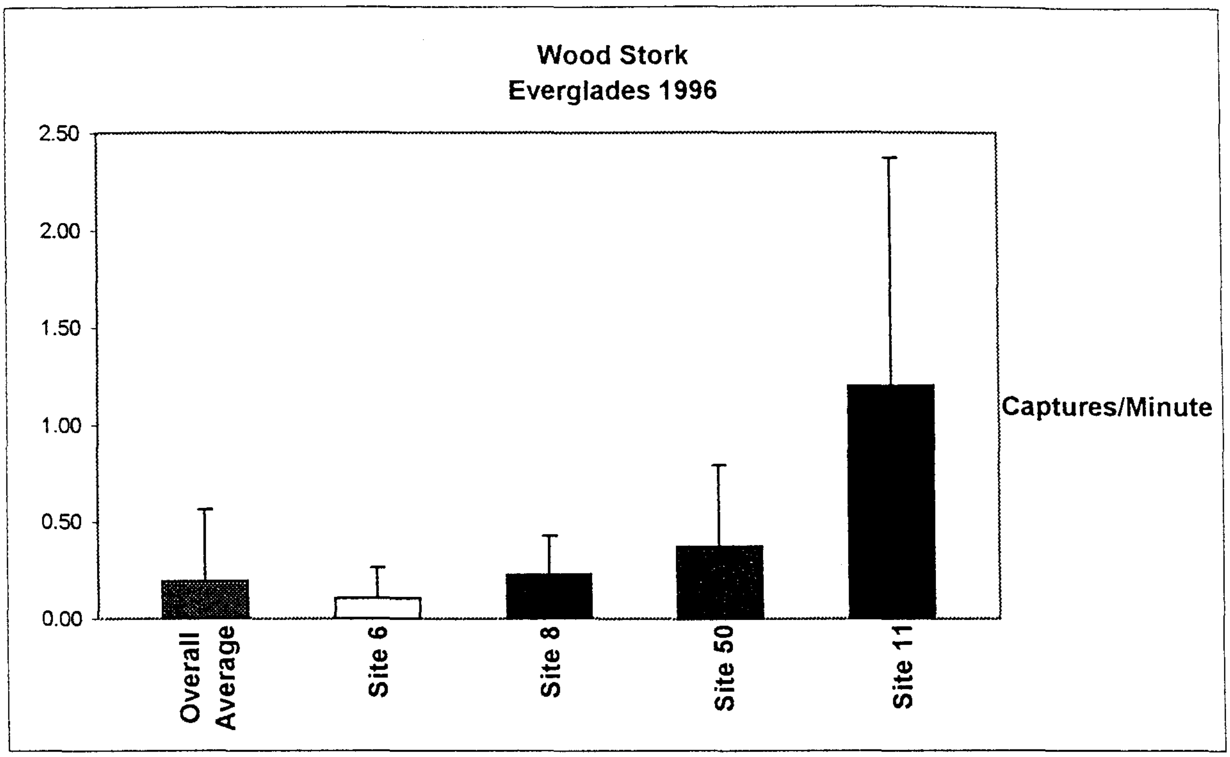
Figures. 3.5 and 3.6. Average capture rates for Snowy Egrets sampled in 1996 in the Everglades (top) and comparisons with other published studies (bottom).

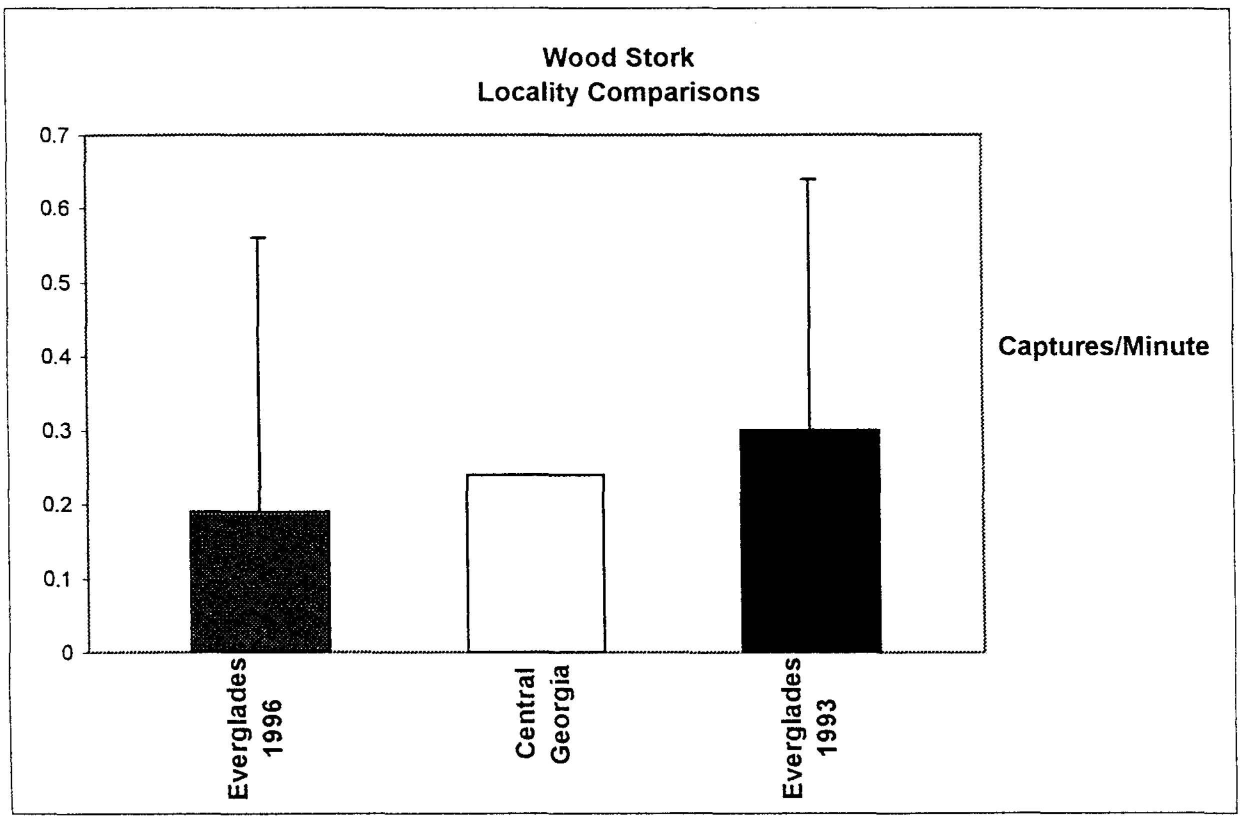
Figures 3.7 and 3.8





Figures 3.7 and 3.8. Average capture rates for White Ibis sampled in 1996 in the Everglades (top) and comparisons with other published studies (bottom).





Figures. 3.9 and 3.10. Average capture rates for Wood Storks sampled in 1996 in the Everglades (top) and comparisons with other published studies (bottom).

Table 3.3. Univariate correlations between capture rate and the variables listed in the first column. Correlations are significant at p = 0.05 (*), 0.01 (**) and 0.001 (***).

	Great Egret	Snowy Egret	White Ibis	Wood Stork
Time of Day	-0.029	-0.045	-0.040	**-0.252
Flock Size	***0.218	-0.121	-0.012	0.022
Pool Size	**-.433	-0.224	-0.228	-0.132
Periphyton	**-0.169	***0.237	0.025	-0.083
Emergent	***-0.209	**-0.204	-0.117	*-0.169
Submergent	0.093	*-0.170	0.068	-0.141
Water Depth	***-0.265	**-0.202	-0.002	***-.408
Distance to Floc	***-0.293	**-0.205	0.073	**-0.302
Water Temperature	***-0.308	*0.176	*-0.298	**-0.396
Wind Speed	-0.052	***-0.294	-0.109	**-0.199
Air temperature	*-0.147	0.030	*-0.157	**-0.255
Sun Angle	-0.034	*-0.165	0.009	*-0.159

It should be recognized that even the significant correlations in Table 3.3 may be misleading because they are all relatively weak, and all are univariate relationships. This analysis should therefore be treated as exploratory rather than definitive.

We found significant negative correlations between both water depth and depth to the flocculent layer, and prey capture rate, for Great Egrets, Snowy Egrets, and Wood Storks. In the case of Wood Storks, water depth appears to explain as much as 40% of the variability in capture rates, which can be considered a very robust results. This suggests that deeper water is avoided by most of the birds. The lack of a negative association for ibises may result from the small number of sites (and small range of depths) that we observed them in.

We found a strong negative association between water temperature and capture rate for Great Egrets, and weaker but significant relationships for the other three species. This suggests that as water temperatures cool, capture rates decrease. However, the associations for air temperature were generally less significant, suggesting that the temperature effect is through the prey animals, rather than directly on the activity levels of the birds themselves. This fits with published results showing lowered fish activity and refuge-seeking with decreasing temperatures, and a strong negative association between Great Egret nesting success and temperature.

Both Great and Snowy Egrets , and Wood Storks showed significant negative correlations between the density of emergent vegetation and capture rate, implying that capture rate increases in more open areas. This makes sense for these two species, which forage primarily by sight. The lack of association of these variables for Wood Storks and White Ibises may make sense because both species are tactile foragers. However, the density of periphyton was significantly correlated in a positive direction with Snowy Egret capture rates, and correlated *negatively* with those of Great Egrets. This may reflect differences in either foraging behavior or target prey animals of the two species.

Snowy Egrets and Wood Storks both showed significant negative correlations of capture rate with wind speed, with capture rates declining at higher wind speeds. Although this may imply an effect of wind on the ability of these species to employ their foraging behaviors effectively, it may also result from a correlation between wind speed and cold temperatures. Many of the days with windy conditions were associated with cold fronts, which often brought cold temperatures and sometimes overcast or rainy conditions. Similarly, the relationship may be with time of day, since wind generally increased as the mornings progressed. A multivariate analysis will allow detection of such autocorrelation within the independent variables.

Although all species had decreasing capture rates as the day progressed, this was significant for only one species, the Wood Stork. At this stage it is not clear whether there is a relationship.

Discussion

The focus of this study is to determine which environmental variables exert a large influence on wading bird foraging success in the freshwater marshes of the Everglades. Although we could have wished for more sites to become active in 1996 (five out of 17 had flocks of birds), and for fewer airboat breakdowns, the 1996 season has been relatively productive. Although a larger sample size of sites is clearly needed for full analysis, we already have indications that water depth, water temperature, wind speed, and vegetation have significant influences on wading bird foraging success in wet prairie habitats. Perhaps more importantly, we have discovered only weak effects of time of day, periphyton coverage, submergent vegetation, air temperature and sun angle. This may allow some reduction in the number of variables to be analyzed in future work, a key requirement for successful multivariate analysis.

It should be noted that significant progress is being made on the effects of prey density and depth on wading bird foraging in an experimental way through Dale Gawlik's work in the Test Cells of the South Florida Water Management District. These experiments have significance for this study, since any agreement between the results of the two studies is likely to make both considerably more powerful. For instance, the Test Cell experiments must necessarily eliminate many variables that would be extant in a field situation (vegetation, multiple prey types, unenclosed pools) in order to isolate specific effects. Corroboration with our field data would therefore lend considerable credence to those results, and we plan to work collaboratively with Dale on direct comparisons.

We plan several significant improvements in data collection and analysis for 1997. First, we are in the process of fitting a second airboat for the observation tower, so that breakdowns in one boat will leave us with the option of using the second, an option we did not have in 1996. We have also realized that prey density may change rapidly during the spring season, perhaps too rapidly to be measured by the semi-monthly sampling performed by the FIU/Jacksonville University team. We therefore plan to supplement those measurements with samplings of our own at intervals in between the scheduled semimonthly samplings, using the same methodology. This should greatly increase the spread of prey densities available for analysis, and greatly increase the accuracy of associations between prey characteristics and wading bird foraging success.

We also plan to evaluate the influence of prey and environmental characteristics at more of a landscape scale, by relating these variables to numbers of wading birds at each site, rather than to foraging success. During 1996, we concentrated on those sites that reliably had foraging flocks. Other sites (which had a broader array of environmental variables) had few or no birds, but were not assayed for either wading bird use, or for foraging success. To remedy this situation, we plan to fly over each of the prey sampling sites at low altitude once per month, and count all wading birds in the area. This will allow a second way to evaluate the effect of prey and environmental characteristics, namely choice of site.

We also plan to include dissolved oxygen as a variable in our models. Dissolved oxygen can have a powerful effect on the distribution of prey items in the water column (Lewis 1970), as well as on the communities of prey animals. Hafner et al. (1993) found Little Egrets (Egretta garzetta) captured more prey at sites that had low oxygen for short periods of the morning than at those that did not, a difference which translated into higher productivity of young. We suspect that oxygenation of the water column in the Everglades may differ dramatically with time of day and with season, and this variable may have an important effect on the availability of prey items (Cech et al. 1985).

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