Wading Bird Use of Wastewater Treatment Wetlands in Central Florida, USA

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Abstract.—We documented the use of two wastewater treatment wetlands (secondarily treated urban sewage) in central Florida by wintering and breeding long-legged wading birds (Ciconiiformes), and compared densities of birds at these sites to a large, naturally fluctuating wetland nearby. Winter densities at all three sites in central Florida were much higher than at other natural wetlands in southern Florida and Nicaragua. White and Glossy Ibises (*Eudocimus albus* and *Plegadis falcinellus*) were much more common at the natural site in central Florida than at the wastewater sites, presumably because water depths at the latter sites were too deep for foraging. Densities of ardeids were not notably different among the sites. Breeding colonies of Wood Storks (*Mycteria americana*), Cattle Egrets (*Bubulcus ibis*) and Great Egrets (*Casmerodius albus*) formed at both wastewater sites during the study, probably because water conditions were stable. Great and Snowy Egrets (*Egretta thula*) that we followed from these colonies often foraged in the wastewater impoundments, but Wood Storks and White Ibises followed from wastewater and nearby colonies rarely did. These wastewater impoundments appeared to offer attractive feeding conditions to ardeids, but not to ibises or storks, and appear to have high value as colony sites. We outline a number of potential health risks for wading birds using these wetlands. *Received 2 September 1993, revised 6 January, 1994, accepted 2 February 1994.*

Key words.—Ciconiiformes, wastewater treatment, foraging ecology, wading birds, Ardeidae, *Eudocimus albus*, *Mycteria americana* White Ibis, Wood Stork.

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Wetlands of many types have been found to be economical filtration systems for the treatment of wastewaters containing biological and chemical pollutants (Fritz and Helle 1984, see section II of Hammer 1989), sparking both the creation of new wastewater treatment wetlands, as well as the conversion of natural or degraded wetlands to treatment uses. Although these practices do not involve a large proportion of wetlands in the southeastern United States at present, the creation of wastewater treatment wetlands and conversion of natural wetlands to treatment uses is likely to grow with increasing human population densities and tightening of surface water quality standards. Wastewater wetlands can accumulate heavy metals and other nondegrading compounds over time, and may also serve as temporary concentration sites for toxins and pollutants (Hammer 1989). Some may also have physical and biological characteristics which aid in the proliferation of waterbird parasites and diseases (Spalding *et al.* 1993).

Wastewater treatment wetlands are known to attract wildlife simply because they are wet areas (Harris and Vickers 1984, Wilhelm *et al.* 1989), but the effect of exogenous nutrient inputs and ensuing eutrophic conditions on wildife populations is less obvious. In controlled studies of northern Florida cypress domes, sewage additions reduced total biomass and diversity of benthic macroinvertebrates (Brightman 1984). At a similar cypress swamp treatment site, Smith (1992) found that mosquitofish (*Gambusia holbrooki*) and sailfin mollies (*Poecilia latipinna*) existed in greater densities and biomass, and grew faster and attained larger adult size, than in more natural control areas. Because of high nutrient conditions, wastewater treatment wetlands may also have very low dissolved oxygen at times, which forces fish to the surface to gulp air where they may become vulnerable to bird predation (Edelson 1990, Kersten *et al.* 1991).

Elevated biomass and/or increased availability of prey animals is predicted to attract long-legged wading birds, which show a number of adaptations for exploiting dense patches of prey organisms that are unpredictable in space and time (Kushlan 1986, Caldwell 1981, Master 1990). In Florida cypress domes, Harris and Vickers (1984) found that treated sewage effluent led to a decrease in the number of ciconiiform birds when compared to control sites. Edelson (1990) found that wading birds preferred feeding at a hypereutrophic lake to feeding in nearby oligotrophic ones, and in a study of over 300 Florida lakes, Hoyer and Canfield (1991) found that both abundance and species diversity of wading birds were elevated in eutrophic conditions. This attraction may extend to choices of breeding sites and choice of feeding sites while breeding. Kelly *et al.* (1993) found that nesting Great Egrets (*Casmerodius albus*) in the San Francisco Bay area were concentrated around the most biologically productive areas. Hafner *et al.* (1992) found that significant increases in foraging intake rates and reproductive success of Little Egrets (*Egretta garzetta*) were attributable to low oxygen conditions at foraging sites.

In addition, wastewater treatment wetlands may also attract breeding and roosting waterbirds because they provide stable water conditions, an effective antipredator deterrent and prerequisite for nesting in many ciconiiform species. Wilhelm *et al.* (1989) found a 600% increase in numbers of ducks nesting at a northern Arizona treatment site, and Ogden (1991) documented a rapidly increasing proportion of southeastern U.S. Wood Storks nesting in impoundments in northern Florida. Ogden felt that stable water conditions in impoundments were a key factor in the move away from natural sites, and may have contributed to an increase in total numbers of nesting storks in central Florida.

In this study, we report on the densities of wading birds found at two manmade sewage and stormwater treatment wetlands in central Florida. We evaluate the relative attractiveness of these wastewater sites by comparing their densities with those at both a large natural marsh in the region, and in other tropical and subtropical marshes. We also document the relative importance of these wastewater wetlands as breeding and foraging sites.

METHODS

Study sites

The two wastewater treatment sites in central Florida were located east of Orlando (Iron Bridge site, 4.98 km², 28°33.8′N, 81°0.6′W) and immediately northeast of Mulberry (Mulberry site, 7.14 km², 27°54.6′N, 81°56.4′W, see Fig. 1). Both were constructed during the past ten years, were being used during the study for the treatment of urban stormwater runnoff and tertiary-treated human sewage, and consisted of a series of irregularly-shaped marsh impoundments through which treatment waters flow sequentially. The Iron Bridge site is located in an upland rural setting approximately 2 km west of a large complex of freshwater marshes bordering the St. Johns river. Although the Iron Bridge site is used seasonally as a municipal wildlife viewing park, it was closed to visitors for the period of study. The Mulberry site is surrounded by phosphate mining pits in various stages of activity and reclamation, a few naturally occurring lakes and small isolated wetlands, and hardwood riverine forests along the Peace river. No fluctuations in surface water levels were observed at either of the two wastewater treatment sites during the study.

We chose a 16.75 km² area of the freshwater marshes bordering (and including) the St. Johns river immediately south of Route 50 and within 5 km of the Iron Bridge site as a relatively natural comparison for the two wastewater sites. The water levels in the river and marshes fluctuated seasonally according to rainfall and flow; water levels were highest at the St. Johns site in October and December, and by May most of the surface of the marsh was dewatered. Parts of the marsh surface are used seasonally for cattle grazing, there is moderate recreation on the river, and the marsh is frequently disturbed by airboat traffic.

Bird densities

We estimated numbers of wading birds on the marsh surface of each of the three study sites by aerial survey on or within three days of 15 October and December 1991, and 15 February, March, April and May of 1992. All flights were conducted between 0700 and 1200 EST, with one observer on each side of a Cessna 182 single-engined high-winged aircraft. Surveys were flown at 80 kts airspeed and 61 m above ground level. A series of east-west transects across each wetland were flown to give complete coverage, with centers of adjacent transects 800 m apart. The observers on each side counted the birds which fell approximately 400 m on either side of the aircraft, using landmarks on either side of the wetland as guides. The same two observers were present in the same positions in the aircraft for all flights. On each flight date, the Iron Bridge site was surveyed first, the St. Johns site second, and the Mulberry site last.

Observers could not see directly underneath the aircraft, and birds in this area would not have been included in the counts. However, birds located ahead of the plane generally flushed into one of the two count paths on either side of the aircraft as we approached.

We counted Wood Storks (*Mycteria americana*), Great Blue Herons (*Ardea herodias*), Great Egrets (*Casmerodius albus*), White Ibises (*Eudocimus albus*), Glossy Ibises (*Plegadis falcinellus*), Snowy Egrets (*Egretta thula*), Tricolored Herons (*E. tricolor*), Little Blue Herons (*E. caerulea*), Cattle Egrets (*Bubulcus ibis*), and Black-crowned Night Herons (*Nycticorax nycticorax*). Cattle Egrets were not included in the density estimates since they are terrestrial feeders.

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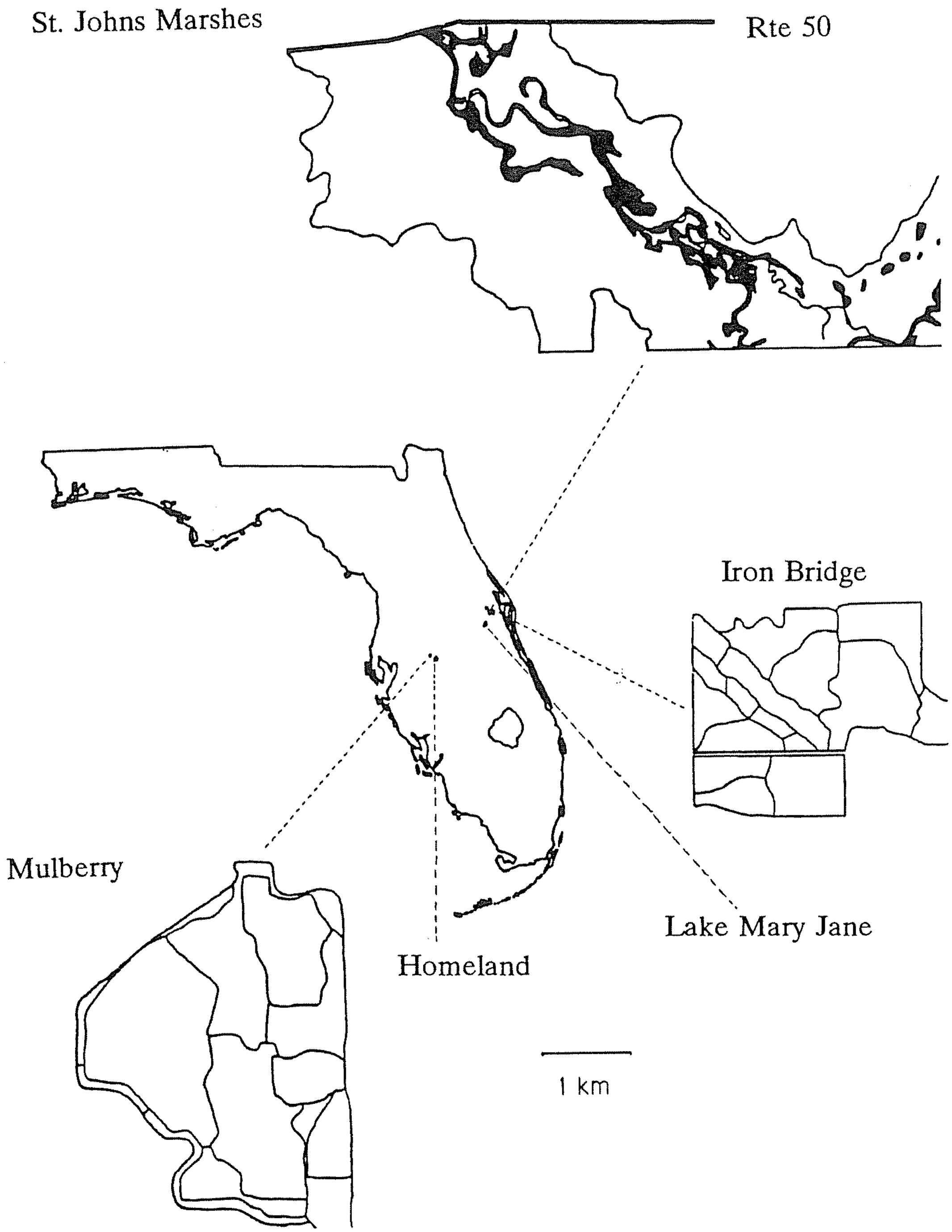

Figure 1. Locations of the study areas in central Florida. The Iron Bridge and Mulberry treatment wetlands, and St. Johns marshes are shown in to-scale outlines. Lines in the two treatment sites indicate the pattern of impoundments and roads. Dark areas within the St. Johns marshes indicate areas of open water or river channel.

Snowy Egrets and immature Little Blue Herons can be difficult to distinguish from an aircraft, and we combined these two species into a category called Small White Herons (SWH, following Hoffman *et al.* 1990).

Nesting colonies

We surveyed breeding colonies in the treatment sites on the March, April, and May survey flight dates by averaging repeated estimates made at both high

(500m) and low (80m) altitudes while cirling the colonies. In addition, ground counts of the Mulberry colonies were made available to us by Mr. Dave Hill of the Lakeland Wastewater Treatment Authority.

We tallied the numbers of birds on each transect, and summed these numbers over all transects for each wetland on any given date. We did not include the numbers of birds in colonies in the wastewater treatment areas in the total counts. We derived the densities of birds by dividing the total number of birds seen by the area of each wetland. The area of each wetland was measured from digitized 1:24000 U.S. Geological survey topographic maps using SPYGLASS software.

We compared densities of wading birds at the three study sites with similarly collected data from the Florida Everglades (Hoffman *et al.* 1990, Bjork and Powell 1993), southwestern Florida (Jelks 1991) and the northeastern coast of Nicaragua (Frederick and Spalding unpublished data). For each of these studies, we calculated densities based on the amount of wetted marsh available at the time of survey, rather than on the total wetland area.

Foraging dispersion

We documented the foraging locations of birds breeding at or near all three study sites by using fixed-wing aircraft to follow birds from colonies to the first site at which they landed and foraged. One observer visually followed focal birds or flocks in a Cessna 172, and maintained vertical and horizontal distances from the bird of at least 100 and 230 meters, respectively. We followed birds from colonies found within a 25 km radius of the wastewater sites, as located during aerial searches using previously located colonies as an initial guide (Nesbitt *et al.* 1982, Runde *et al.* 1991). The individuals we followed were selected randomly, as the first white-plumaged bird to leave the colony. We followed only white-plumaged species, and concentrated on Wood Storks, White Ibises, and Great and Snowy Egrets. We determined locations of foraging sites while in the air, using a combination of U.S. Geological Survey topographic maps, and a Trimble TransPac Global Positioning System instrument with a stated minimum accuracy of 100 meters. We followed birds to foraging sites from 24 April to 21 May 1992.

RESULTS

Bird densities

We found an increase in combined densities of all wading bird species from October through February, with noticeable decreases by April and May (Table 1). Peak densities occurred in February for the St. Johns and Mulberry sites, and in October at the Iron Bridge site. The St. Johns site showed by far the highest densities during December, February and March. High densities at the St. Johns site were largely attributable to the very large numbers of White Ibises, which had densities of between 50 and 120 animals/km^2. White Ibises constituted over 50% of the birds at the St. Johns site in December, February, March, and May. When White Ibises are removed from the density calculations (Fig. 2), the densities of Great and Snowy egrets were not obviously different among study sites. The St. Johns site attracted notably higher densities of Glossy Ibises than did the wastewater treatment sites (Fig. 2), generally as many or more Great and Snowy Egrets, and relatively high densities of Wood Storks.

The Iron Bridge site had variable species composition, dominated by ardeids during the fall and spring, and White Ibises during February and March. The Iron Bridge site showed higher species diversity than did the Mulberry site, and less of a tendency to be dominated by a single species. At the Mulberry site, Great and Snowy Egrets were the most numerous species. The Mulberry site attracted very few White Ibises and no Glossy Ibises.

All three sites appeared to have high densities of wading birds, relative to wetlands surveyed in a similar fashion in southern Florida and Nicaragua (Table 2).

Nesting colonies

The islands in the southern portion of the Mulberry site contained between 145 and 188 Wood Stork nests, 155-173 Great Egret nests (range of estimates results from differences between aerial and ground counts, no consistent differences by method), 12 Snowy Egret, 8 White Ibis, and 235 Double-crested Cormorant (*Phalacrocorax auritus*) nests. The Wood Stork and Great Egret nesting attempts at Mulberry were largely successful, but we were unable to determine the fate of the Snowy Egret nests.

At the Iron Bridge site we counted 18 Great Egret nests on 7 May, and 55 Cattle Egret nests on 18 May. The Cattle Egret colony was probably in its initial stages when we noted it; it may have grown considerably following the end of our studies. Aerial counts suggested that Great Egret nests at Iron Bridge were successful. The late timing of the Cattle Egret colony did not allow us to assess reproductive success.

Foraging dispersion

We followed a total of 166 breeding adults to foraging locations from colonies

Table 1. Numbers and densities of ciconiiform birds counted during aerial surveys of wastewater treatment marshes at Iron Bridge and Mulberry, Florida, and at marshes on the St. Johns river.

Date Surveyed	Site Surveyed	Number of birds GE	SWH	WI	GBH	GLI	LB	TCH	BCNH	WS	UK	Total Seen	Total birds/km²
23 Oct 91	Iron Bridge	107	88	6	1	0	30	17	0	0	5	267	53.6
	St. Johns Marshes	22	7	3	5	0	0	0	0	0	2	39	2.3
	Mulberry	7	3	1	0	0	0	0	0	0	13	28	3.9
17 Dec 91	Iron Bridge	10	33	0	10	15	8	1	0	0	0	77	15.4
	St. Johns Marshes	261	168	1034	50	26	42	24	11	0	0	1,620	96.7
	Mulberry	66	66	0	2	0	0	0	0	0	0	134	18.8
24 Feb 92	Iron Bridge	42	11	59	11	0	1	3	1	0	1	129	25.9
	St. Johns Marshes	182	214	2031	4	288	22	1	0	0	6	2,748	164.0
	Mulberry	126	15	4	18	0	0	0	0	0	82	247	34.6
18 Mar 92	Iron Bridge	16	3	106	8	0	2	2	0	1	0	138	27.7
	St. Johns Marshes	141	89	860	6	82	2	5	2	40	0	1,227	73.3
	Mulberry	22	11	8	2	7	4	0	0	12	0	91	12.8
15 Apr 92	Iron Bridge	38	26	35	5	1	1	4	0	19	1	130	26.1
	St. Johns Marshes	121	76	133	10	0	4	0	0	3	4	355	21.2
	Mulberry	16	10	0	2	0	1	0	0	13	0	42	5.9
19 May 92	Iron Bridge	18	4	9	8	0	4	0	0	0	8	55	11.0
	St. Johns Marshes	43	19	307	3	5	7	4	0	6	5	438	26.2
	Mulberry	37	29	9	1	0	1	2	0	2	8	260	36.4

Abbreviations: GE = Great Egret, SWH = combined Snowy Egret and immature Little Blue Heron, WI = White Ibis, GBH = Great Blue Heron, GLI = Glossy Ibis, LB = adult Little Blue Heron, TCH = Tricolored Heron, BCNH = Black-crowned Night Heron, UK = unidentified wading birds.

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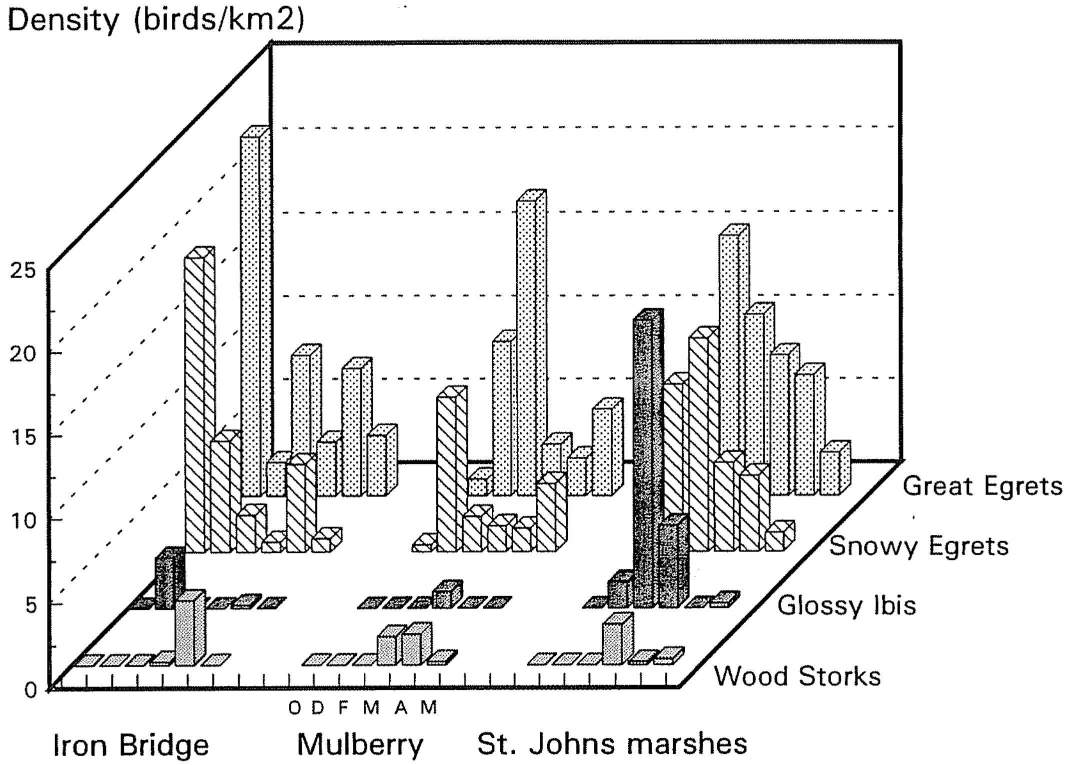

Figure 2. Densities of four wading bird species counted at the three study sites. Data for White Ibises are not shown. Bars from left to right for each site depict densities in October, December, February, March, April, and May surveys.

Table 2. Peak densities recorded at the three study sites in central Florida, compared with similar values measured in other subtropical or neotropical wetlands. Measurements in all cases were peak annual densities, or were taken at the time of year when wading birds are most abundant in each habitat. Densities were in all cases based on the amount of wetted area of each marsh.

Location	Reference	Density
Central Florida		
Iron Bridge	This study	53.6
St. Johns marshes	"	164.0
Mulberry	"	36.4
South Florida		
Central Everglades	Hoffman *et al.* 1990	10.9
Coastal Everglades	Bjork and Powell 1993	23.7
Southwest Florida		
Ringling/Mcarthur Preserve	Jelks 1991	6.2
Coastal Nicaragua		
Miskito Coast Protected Ares	Frederick and Spalding (unpublished)	12.2

in both wastewater sites and from the nearest two colonies we could locate outside the wastewater sites (see Fig. 1 for relative locations of the latter). The Lake Mary Jane colony (#612037 in Runde *et al.* 1991) was located on an island in a freshwater lake 27 km to the southwest of the Iron Bridge site; it contained 300 White Ibis, 900 Great Egret and an undetermined number of Snowy Egret nests. The Homeland colony (#616129 in Runde *et al.* 1991) was located approximately 14 km southeast of the Mulberry site in an inactive phosphate mining impoundment; on 15 April it contained approximately 500 White Ibis, 300 Great Egret, and an undetermined number of Snowy Egret nests.

Great Egrets nesting within the Mulberry and Iron Bridge impoundments also used them for foraging. Sixty and thirty five percent of flights from these colonies ended within the same wastewater impoundment, respectively; likewise 75.3% of Snowy Egret flights from Mulberry ending in the colony impoundment (see Table 3). The two Wood Storks followed from the Mulberry site landed within the wastewater treatment wetland. Six Wood Storks which we had tracked for over 4 km from the colony site were ultimately lost in clouds. Our ground observations indicated that Wood Storks seen landing at the Mulberry site were probably roosting and sunning rather than feeding.

None of the sites appeared to be attractive to birds foraging from surrounding colony sites. None of the birds followed from the Homeland or Lake Mary Jane colonies landed in or near either of the wastewater impoundments, or in the St. Johns marshes.

DISCUSSION

Overall densities of wading birds at all of the study sites in central Florida were higher than those obtained for larger and relatively pristine wetlands in south Florida, and coastal Nicaragua. This was particularly so for the St. Johns site, which appears to show the highest density of long-legged wader so far recorded for any wetland (see Table 2). The St. Johns marshes appears to be a wetland of regional and perhaps international importance for wintering wading birds. These comparisons also suggest that central Florida is an area of generally very high wading bird densities during the winter and early spring.

The density comparisons within the three sites suggest that White and Glossy Ibises were not consistently attracted to the wastewater impoundments. This statement is somewhat equivocal, since White Ibises were found in high densities during two of the surveys at the Iron Bridge site. At the least, the attraction was not consistent, and could have been a coat-tail effect due to the close proximity of the St. Johns marshes. Although Wood Storks were found on surveys in the Mulberry impoundment, they were apparently not using the impoundment for foraging. All three species forage tactilely, and prefer shallow water for foraging (Kahl 1964, Kushlan 1977). We surmise that the deeper water depths of the impounded areas are generally unattractive to tactile foragers.

Table 3. Numbers of birds followed from colonies in central Florida to first foraging sites, and percent of flights ending in wastewater treatment sites.

Colony followed from:	Great Egret	Snowy Egret	White Ibis	Wood Stork	Total
Mulberry					
No. birds followed	49	23	3	2	76
% foraging in treatment site	60.4	73.9	33.3	100	64.6
Lake Mary Jane					
No. birds followed	9	5	51	0	65
% foraging in treatment site	0	0	0	0	0
Homeland					
No. birds followed	3	1	3	0	7
% foraging in treatment site	0	0	0	0	0
Iron Bridge					
No. birds followed	17	1	0	0	19
% foraging in treatment site	35.3	100	0	0	46

There were no consistent differences in densities of Great and Snowy egrets among study sites, although we were not able to test this hypothesis rigorously. Whether this lack of differences is real, or an artifact of the short duration of the study, is impossible to determine. Certainly the density differences among sites were greatest for ibises and storks, and least for the ardeid species. Because ibises and storks are considered quite sensitive to water depths (Kushlan 1976, Powell 1987, Edelson 1990), this pattern suggests that the deeper depths of the wastewater areas were an important variable determining the species composition of waders.

Both wastewater treatment sites proved attractive for breeding Ciconiformes during 1992, and both have had colony formation in at least two previous years. Both sites are situated in regions with relatively large numbers of colonies identified in statewide surveys conducted during the late 1970's and late 1980's (Nesbitt *et al.* 1982, Runde *et al.* 1991). In the Iron Bridge area, the vast majority of these colonies were located on coastal islands. The primary feature attracting wading birds to nest in these sites is likely the permanent deep water surrounding nest trees or islands (Ogden 1991). Both sites attracted Great and Snowy Egrets, and the Mulberry site attracted Wood Storks. However, neither site attracted nesting White Ibises in large numbers despite breeding colonies of ibises in the immediate vicinity of both wastewater sites.

Neither treatment site attracted birds from nearby colonies that were external to the impoundments. This suggests only that the wastewater sites were not attractive, and should not be interpreted to mean that the wastewater sites did not offer good foraging conditions. Birds from the other colonies might have found adequate or better foraging at sites closer to their home colonies, or might simply never have discovered the relatively small wastewater impoundments. The lack of foraging in wastewater areas by White Ibises from either Lake Mary Jane or Homeland colonies, however, seems to reinforce the earlier conclusion that ibises avoid the wastewater sites as foraging areas.

Both wastewater sites are tiny patches embedded in a much larger matrix of wetlands that are inherently attractive to both wintering and breeding wading birds. It is not clear how attractive these wastewater sites would be to wading birds if they were located in an area more generally depauperate in wading bird populations. The fact that both sites regularly support breeding colonies, and that breeding is at least superficially successful demonstrates that these areas have high value as nesting substrate. The main attractant appears to be the deep, permanent water underneath nests, an otherwise unpredictable condition in the freshwater wetlands of central Florida (Ogden *et al.* 1980, Kushlan 1990, Ogden 1991). The areas also have foraging value for breeding Great and Snowy egrets, though not for Wood Storks or White Ibises. Taken together, this information suggests that the two wastewater treatment areas offer habitat for a number of different ciconiiform species.

In this study, we were unable to investigate potential health risks to birds foraging in the wastewater areas. The nematode parasite *Eustrongylides ignotus* can have significant impacts upon the health of adult birds, and especially upon the survival of nestlings, which recieve the parasite in regurgitated fish (Spalding *et al.* 1993). Spalding and Forrester (1993) have shown that the parasite is found only in sites which have elevated nutrient inputs, and/or disturbed soil conditions (Spalding and Forrester 1993); both conditions are common to nearly all wastewater treatment sites. The parasite was found in a White Pelican (*Pelicanus erythrorhynchos*) which died from a flock at the Iron Bridge site. *Eustrongylyides ignotus* has a very wide distribution in the United States, making it a potential risk for most wastewater treatment sites. Until the factors affecting the distribution and proliferation of the parasite are better understood, it must be considered as a serious potential hazard of wastewater treatment wetlands for piscivorous birds. In addition, the accumulation of contaminants from sewage and stormwater runnoff in sediments at treatment areas, as well as the potential for concentration of those contaminants in wading birds is poorly researched, and could also pose a major health hazard. The finding that wastewater treatment sites may attract wading birds emphasizes the need for immediate research in

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ACKNOWLEDGMENTS

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