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A comparison between aquatic birds of lakes and coastal rivers in Florida

Mark V. Hoyer*, Sky K. Notestein, Thomas K. Frazer & Daniel E. Canfield Jr.
Department of Fisheries and Aquatic Sciences, University of Florida/Institute of Food and Agricultural Sciences, Gainesville, FL, USA
*(*Author for correspondence: E-mail: mvhoyer@ufl.edu)*

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Abstract

Aquatic birds were counted on five Gulf coast Florida rivers to determine if these river systems supported densities, biomass and species richness similar to those found on Florida lakes. Forty-two species were identified and for the species that were found on both Florida streams and lakes similar densities and biomass were encountered. As with Florida lakes, stream bird abundance and species richness were higher in winter months than in summer months, a consequence of migratory bird populations. Total bird abundance, biomass per unit of phosphorus, and species richness per unit of area were similar to data collected on Florida lakes. Thus, Florida rivers are capable of supplying sufficient resources to maintain bird densities, biomass and species richness values similar to lakes of equal size and nutrient concentrations and are therefore important habitats for aquatic bird populations. An examination of individual habitat characteristics indicates that water depth was inversely correlated and submersed aquatic vegetation was positively correlated with bird density, biomass and species richness within the river systems. While both habitat characteristics are important they are also inversely related making it difficult to separate the individual significance of each characteristic.

Introduction

Florida supports a rich and diverse population of aquatic birds, which increases dramatically in the winter as migratory populations move through (Hoyer & Canfield, 1990; Hoyer et al., 2001). However, nesting populations of many species have reportedly declined over the past few decades (Kushlan et al., 1984; Ogden, 1994). This decline has been attributed, in part, to the loss of wetland habitat. From 1950 to the mid-1970s, there was a tremendous loss of palustrine emergent wetlands (freshwater marshes and wet prairies including the Everglades) in Florida, accounting for 74% of the total wetland loss in the state (Hefner, 1986). With this reduction in wetland habitats, the importance of Florida's lake and river systems to aquatic bird populations may be increasing and warrants more study (Edelson & Collopy, 1990).

Most studies of aquatic birds have been conducted in marsh systems, with some studies examining aquatic bird populations using lake systems (Jenni, 1969; Johnson & Montalbano, 1984; Hoyer & Canfield, 1994). One research group from Hungary has monitored waterbirds and water quality on the Danube River, concluding that the river must be considered as aquatic habitat of international importance to waterbirds (Farago, 1997; Horvath & Bartalis, 1997). To our knowledge, there is no information on either bird abundance or species richness for Florida river systems. Approximately 1700 streams exist in Florida with an aggregate total length of approximately 17,000 km (Bass & Cox, 1988). The primary objectives of this study were to document the aquatic bird abundance, biomass and species richness along five coastal rivers and to compare these values to the abundance, biomass and species richness reported for Florida lakes (Hoyer & Canfield, 1994). In addition we examined relations among bird density, biomass, species richness and physical habitat characteristics of the five rivers.

Methods and materials

Study area

Five rivers were included in this study. The Chassahowitzka, Crystal, Homosassa, and Weeki Wachee are head waters of first magnitude springs while the Withlacoochee is a drainage river just below a dam at Inglis (Citrus County, Florida). All five occur within a region commonly referred to as the Springs Coast, an area of western peninsular Florida that extends from the Pithlachascotee River basin located north of Tampa Bay to the Waccasassa River area which is south of the Suwannee River Basin (Wolfe et al., 1990; Fig. 1). The Springs Coast watershed covers approximately 892 square miles (SWFWMD, 2001) and as the regional name suggests, spring-fed systems are a prevalent feature. All of these five rivers discharge directly into the Gulf of Mexico.

Over 4 million cubic meters of ground water are discharged annually into the Springs Coast region from a variety of point and diffuse seepage sources (Sinclair, 1978). This water is derived primarily from the Upper Floridan aquifer, which is at or near the surface in the Springs Coast region. The quantity and chemical composition of water discharged by many of the springs in this area are strongly influenced by tidal cycles (Yobbi & Knochenmus, 1989; Yobbi, 1992). The climate is subtropical, with mean annual precipitation ranging from 132 cm to 142 cm (United States Fish and Wildlife Service 1988).

Methods

Physical, chemical and biological data were generated using sampling methods similar to those employed by Canfield & Hoyer (1988) in their study of 17 inland Florida streams and described in detail by Frazer et al. (2001). In brief, water chemistry data and physical samples were collected during 10 quarterly sampling events between August 1998 and January 2001. In each of the five study systems, sampling was carried out at 10 transects (perpendicular to stream flow) regularly spaced along the length of the river, from just below the main spring to just above the marsh complex where the river opens and no longer has defined banks. For the Withlacoochee River, sampling was conducted from just below the dam at Inglis (Citrus County, Florida) to just above the marsh complex. Along each transect, physical and chemical parameters were sampled at three stations, one at the midpoint between the waters edge from bank to bank and one to either side of the midpoint approximately one-third the distance to the shore. Along each transect, submersed aquatic vegetation (SAV) was sampled at five stations, one located in the center of the river and two equidistant on either side of the center station. Submersed aquatic vegetation was sampled only three times during this study, during the summers of 1998, 1999 and 2000.

Physical parameters

All sampling locations were determined and relocated with a differentially corrected GPS receiver. Coordinates were recorded at the endpoints (shoreline) of each in-river transect and the stream width at each transect was calculated using ArcView GIS software (Environmental Systems Research Institute, Inc., 1998). The following physical parameters were recorded during daylight hours coincident with the water chemistry-sampling regime (described below): stream velocity (m s^{-1}), bottom depth (m), light attenuation (K_d m^{-1}) and percent of incident light reaching the substrate. Depth was measured with a collapsible fiberglass survey rod while stream velocities were measured with a Marsh–McBirney model 201D portable flow meter. Light attenuation at each station was determined with the following equation;

$$K_d = [\ln(I_0/I_z]/z \tag{1}$$

where I_0 is incident irradiance at the water surface and I_z is light intensity at depth z (m) (Kirk, 1994). Li-Cor Instruments, Inc. quantum light sensors

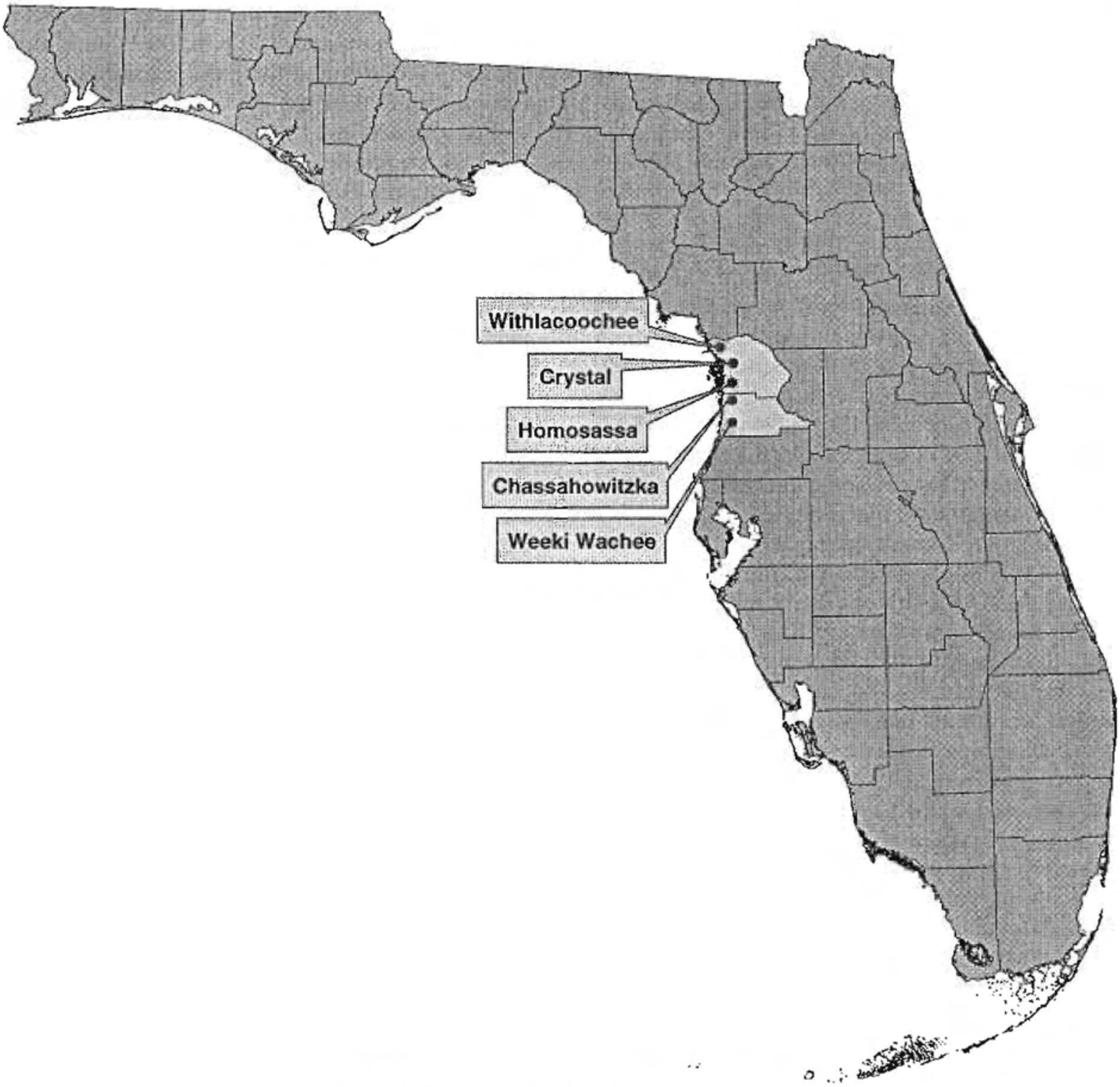

Figure 1. Location of five Florida Gulf coast rivers.

were employed to simultaneously measure surface and downwelling light intensity with a data logger. Light readings were taken at the deepest possible depth at each station (generally 0.25 m above the bottom substrate). Corrections to light attenuation calculations were not made for cloud cover or sun angle. K_d was used with water depth measurements to calculate the percent of incident radiation reaching the substrate. During vegetative sampling terrestrial canopy cover was visually estimated.

Chemical parameters

Surface water samples were collected in 250 ml acid-cleaned bottles and transported on ice to the laboratory where they were analyzed within 24 h of collection for total nitrogen (TN), and total phosphorus (TP). Total nitrogen concentrations ($\mu g\ l^{-1}$) were determined from whole water samples by oxidizing water samples with persulfate and determining nitrate-nitrogen concentrations with an Bran-Luebbe autoanalyzer with a cadmium column reduction method (American Public Health Association, 1992). Following persulfate digestion (Menzel & Corwin, 1965), total phosphorus concentrations ($\mu g\ l^{-1}$) were determined using the procedures of Murphy & Riley (1962).

Aquatic vegetation

Sampling of submersed aquatic vegetation (SAV) was conducted during the period August through September for each year of the project, 1998, 1999, and 2000. SAV samples were collected at each transect coincident with the water samples. SAV refers to the total of both submersed macrophytes and macroalgae but for some analyses submersed macrophytes (aquatic macrophytes) and macroalgae (primarily filamentous algae) were analyzed separately. Along each transect, five stations were sampled for SAV, with one in the middle and two to either side approximately one-third and two-thirds the distance to the shoreline. At each of the resulting 50 stations for each river, a 0.25 m^2 quadrat was placed on the bottom and the above-ground biomass contained within the quadrat was removed by divers and transported to the surface. All submersed aquatic macrophytes and macroalgae were separated and spun in a nylon mesh bag to remove excess water. Samples were then weighed with calibrated hand-held scales and no attempt was made to remove attached periphyton. Weights were recorded to the nearest 10 g for samples less than 1 kg and to the nearest 100 g for samples greater than 1 kg.

Bird counts

Birds that were observed on or feeding from aquatic habitats were censused. Counts were conducted every time water chemistry data were collected with the exception of rainy days with extreme wind. This yielded eight census counts for Homosassa and Weeki Wachee rivers, seven counts for Chassahowitzka and Crystal rivers and six counts for Withlacoochee River. Birds were counted by two observers each watching a single shoreline as a boat was motored down the middle of the river from transect to transect during water sampling events. Counts were typically conducted between 9:00 a.m. and 2:00 p.m. Birds were identified to species except for gulls, terns and crows, and care was taken not to count birds twice that flushed ahead of the boat.

Total species richness was defined as the total number of species observed throughout the study on a given river. Section species richness was defined as the total number of species observed on a given section of river throughout the project. Total Bird abundance (birds km^{-2}) was the average of all counts for a given river divided by the surface area of the river. Literature values (Terres, 1980; Dunning, 1993) for the average biomass of each species, were multiplied by counts to yield bird biomass values. Total bird biomass (kg km^{-2}) was the average of all counts multiplied by biomass values for a given river divided by the surface area of the river. Section number 1 in the Weeki Wachee River is immediately below an amusement park and during the study feed was placed on large platforms to attract birds for park visitors to watch. For this reason data from Section 1 of the Weeki Wachee River was removed for analyses of bird abundance and biomass values. Section bird abundance (birds km^{-2}) and section bird biomass (kg km^{-2}) were defined as the average number and biomass estimated on a section of river throughout the study divided by the area of water in that section.

Data summaries and statistical analyses

Mean values for individual transects were based on all sampling events and used to summarize all physical, chemical and vegetative measures. For analyses of variance and regression analyses all variables were $\log_{10}$-transformed to accommodate heteroscedasticity in the data (Sokal & Rohlf, 1981). SAV biomass were sometimes equal to 0.0 kg wet wt m^{-2}, therefore 0.1 kg wet wt m^{-2} were added to biomass values prior to logarithmic transformation and subsequent statistical analyses. Additional analyses, when employed, are described in the Results and Discussion sections below. All statistical computations were performed with the JMP statistical software package (SAS Institute, Inc 2000). Statements of statistical significance imply $p < 0.05$.

Results and discussion

The average sectional area of each river where birds were counted ranged in size from 0.006 km^{-2} to 0.066 km^{-2}, while the whole surface area of the five rivers where birds were counted ranged from 0.105 km^{-2} to 1.293 km^{-2} (Table 1). The width, depth and flow of the five rivers ranged from 14.6 m to 185.1 m, 0.88 m to 3.96 m, and 0.04 m s^{-1} to 0.29 m s^{-1}, respectively. SAV was generally abundant in these rivers with the exception of the Withlacoochee River, which supported only an average of 0.01 kg wet wt m^{-2}. The average biomass of submersed macrophytes and macroalgae for the five rivers ranged 0.0 kg wet wt m^{-2} to 0.96 kg wet wt m^{-2} and 0.0 kg wet wt m^{-2} to 0.98 kg wet wt m^{-2}, respectively. Water clarity was generally sufficient in these rivers to allow an average of 23% of incident light to reach the bottom of the rivers. All of the rivers had very little canopy cover with the exception of the Weeki Wachee River, which averaged 20% canopy cover. The river waters contained moderate levels of nutrients with average total phosphorus and total nitrogen concentrations ranging from 10 to 32 μg l^{-1} and 291 to 516 μg l^{-1}, respectively.

The number of bird species identified in the five rivers ranged from 15 in the Withlacoochee River to 33 in the Homosassa River (Table 1). Species richness curves were constructed showing an increase in the number of bird species with each sampling event (Fig. 2). An evaluation of the cumulative species richness curves indicates that by the fifth or sixth sampling period the curves began to reach an asymptote. While this suggests that the river species richness values were representative of each system's potential maximum, it should be remembered that in a Florida lake it took approximately 32 consecutive monthly counts to reach a maximum species richness (Hoyer et al., 2001). These river species richness values are similar to the range of 1 to 30 species reported by Hoyer & Canfield (1994) for 46 Florida lakes. River densities averaged 278 birds km^{-2} and ranged from 58 birds km^{-2} to 647 birds km^{-2} (Table 1). These density values also fell within the

Table 1. Summary statistics for habitat characteristics, water chemistry and bird population parameters for 9 river sections from each of five Florida Gulf coast rivers

Parameters	Chassahowitzka	Crystal	Homosassa	Weeki Wachee	Withlacoochee
Habitat Characteristics					
Section Area (km^2)	0.022	0.066	0.042	0.006	0.012
Width (m)	93.8	185.1	127.9	14.6	28.2
Depth (m)	0.88	3.42	1.98	1.25	3.96
Flow (m s^{-1})	0.09	0.10	0.04	0.29	0.19
Light Attenuation (m^{-1})	1.44	0.96	1.10	1.01	1.00
% Light to Bottom	37.99	9.05	18.16	40.89	7.10
Macroalgae Biomass (kg wet wt m^{-2})	0.48	0.03	0.69	0.98	0.00
Macrophyte Biomass (kg wet wt m^{-2})	0.96	0.46	0.28	3.05	0.00
Water Chemistry					
Total Phosphorus (μg l^{-1})	22	30	24	10	32
Total Nitrogen (μg l^{-1})	418	291	416	516	475
Bird population					
Section species richness	13	11	15	8	5
Whole river					
River Area (km^{-2})	0.358	1.293	0.71	0.105	0.222
River Bird Abundance (Birds km^{-2})	268	141	276	647	58
River Bird Biomass (kg km^{-2})	291	181	331	682	69
River Bird Species Richness	28	23	33	22	15

Data for each section is the average of 10 quarterly samples collected between August 1998 and May 2000.

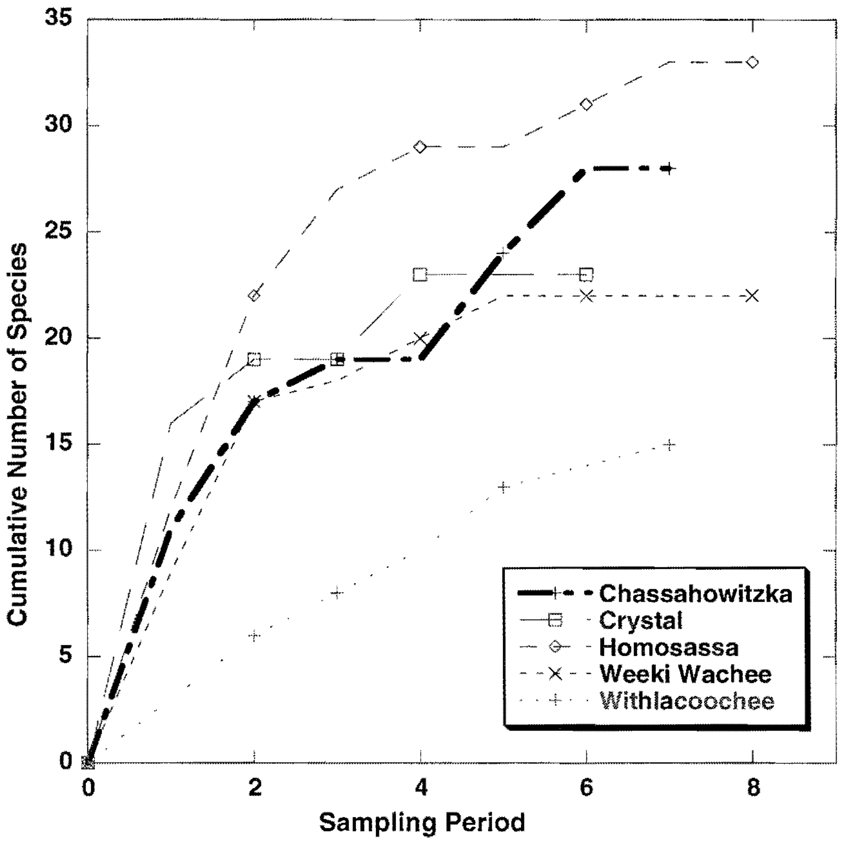

Figure 2. Cumulative aquatic bird species richness plotted by consecutive quarterly bird counts for five Florida Gulf coast rivers.

range of 7 birds km^{-2} to 803 birds km^{-2} reported by Hoyer & Canfield (1994) for Florida lakes. River biomass averaged 310 kg km^{-2} and ranged from 69 kg km^{-2} to 682 kg km^{-2}. All rivers except the Weeki Wachee River fell within the range of 1 kg km^{-2} to 465 kg km^{-2} reported by Hoyer & Canfield (1994) for Florida lakes. As mentioned above, the high values in the Weeki Wachee may be due to the large amount of artificial feeding that takes place near the headwaters of the river.

Combining data from all rivers, 42 species (39 species and 3 genera) of aquatic bird were identified (Table 2). There were several species (e.g., common loon, *Gavia immer* and greater scaup, *Aythya marila*) counted on the rivers that were not recorded by Hoyer & Canfield (1994) for 46 Florida lakes. This is most likely due to the fact that most of the lakes were located inland from the Gulf of Mexico or the Atlantic Ocean and not subject to visitations from birds primarily using Florida's coastal areas (Peterson, 1980). Where the species from the rivers did overlap with the lake data set, the bird density values were similar (Table 2). However, some of the migratory waterfowl species (e.g., Mallard, *Anas platyrhynchos*) were much more abundant in the lake systems.

Florida lakes show a large increase in bird abundance and species richness during winter months (Hoyer & Canfield, 1990; Hoyer et al., 2001). This also appears to be the case for bird populations on Florida rivers. Splitting the river bird counts into summer (May and August) and winter (February and November) periods and using an analysis of variance shows that both bird density (F-Ratio = 4.64; $p \leq 0.05$) and species richness (F-Ratio = 6.22; $p \leq 0.05$) have significant seasonal effects. Bird abundance averaged 193 birds km^{-2} in the summer and 377 birds km^{-2} in the winter and species richness averaged 9.7 in the summer and 13.1 in the winter.

The abundance of aquatic organisms in Florida lakes as well as other lakes around the world has

Table 2. List of aquatic bird species identified and counted on five Florida Gulf Coast rivers between August 1998 and May 2000

Common name	Genus	Species	Lakes	Chassahowitzka	Crystal	Homosassa	Weeki Wachee	Withlacoochee
American Coot	*Fulica*	*Americana*	32.8	0.4	38.7	0.2	0	0
American White Pelican	*Pelecanus*	*erythrorhynchos*	0.9	0	0	2.1	0	0
Anhinga	*Anhinga*	*Anhinga*	10.8	14.8	2.6	10	9.5	4.5
Bald Eagle	*Haliaeetus*	*Leucocephalus*	1.7	0.8	0	0	0	0
Barn Swallow	*Hirundo*	*Rustica*		0	0	0.2	0	3.2
Belted Kingfisher	*Ceryle*	*Alcyon*	3.1	8	0.6	1.2	10.9	7.7
Black Vulture	*Coragyps*	*Atratus*	5.6	0.4	7.9	2.6	24.4	0
Black-crowned Night Heron	*Nycticorax*	*Nycticorax*	3.7	0	0	0	0	0.6
Boat-tailed Grackle	*Quiscalus*	*Major*	43.1	10.8	3.4	44.4	1.4	0
Brown Pelican	*Pelecanus*	*Occidentalis*		4.4	8.9	26.4	124.8	0.7
Bufflehead	*Bucephala*	*Albeola*		0	0	0.2	0	0
Cattle Egret	*Bubulcus*	*Ibis*	14.4	0	0	0	1.4	0
Common Loon	*Gavia*	*Immer*		2.4	0	0	0	0
Common Moorhen	*Gallinula*	*Chloropus*	26.2	1.2	0	0	0	0
Crows	Corvidae	sp.	15.6	0	0	23.9	0	0.6
Double-crested Comorant	*Phalacrocorax*	*Auritus*	9.5	13.6	12.8	29	16.3	11.6
Great Blue Heron	*Ardea*	*Herodias*	5.6	8	3.1	13.6	51.6	5.1
Great Egret	*Casmerodius*	*Albus*	5.9	10	3.7	9	59.7	0.6
Greater Scaup	*Aythya*	*Marila*		0	19.5	8.5	0	0
Green-backed Heron	*Butorides*	*Striatus*	4.3	2	0.1	0.7	14.9	3.2
Gulls	*Laridae*	*Larinae*	20.4	19.2	7.3	54.1	4.1	0
Hooded Merganser	*Lophodytes*	*cucullatus*		0	0	0.5	0	0
Killdeer	*Charadrius*	*vociferus*	3.7	0	0	1.1	0	0
Little Blue Heron	*Egretta*	*Caerulea*	2.4	12	0.4	2.5	17.6	0.6
Mallard	*Anas*	*platyrhynchos*	42.4	0	0	1.6	0	0
Mixed Vultures	*Coragyps*	sp.		53.9	23.5	7.9	0	0
Mottled Duck	*Anas*	*fulvigula*	2.1	0.8	0	0	63.8	0
Northern Harrier	*Circus*	*Cyaneus*	0.4	0	0	0.4	0	0
Osprey	*Pandion*	*haliaetus*	2.1	2.4	2.1	3.5	13.6	2.6
Pied-billed Grebe	*Podilymbus*	*podiceps*	1.1	7.6	1.7	3.7	0	1.3
Red-breasted Merganser	*Mergus*	*Serrator*		0	1.3	1.8	0	0
Red-shouldered Hawk	*Buteo*	*Lineatus*	1	1.6	0	0	2.7	0
Red-winged Blackbird	*Agelaius*	*phoeniceus*	19.4	39.9	0	0	0	0
Ring-necked Duck	*Aythya*	*Collaris*	31.6	0.4	0.3	1.2	0	0
Roseate Spoonbill	*Ajaia*	*Ajaia*		0	0	0	1.4	0
Snowy Egret	*Egretta*	*Thula*	3	5.2	1.7	3.3	6.8	0
Terns	Laridae	Sterninae	5	0	0.1	0.2	0	0
Tricolored Heron	*Egretta*	*Tricolor*	2.1	6	0.1	0.2	1.4	0
Turkey Vulture	*Cathartes*	*Aura*	7.6	31.9	0	2.8	8.1	14.8
White Ibis	*Eudocimus*	*Albus*	8.7	0	0.3	1.2	9.5	0
Wood Duck	*Aix*	*Sponsa*	7.5	9.2	0	17.4	36.6	0
Wood Stork	*Mycteria*	*americana*	1.8	1.2	0	0.5	166.9	0
Yellow-crowned Night Heron	*Nyctanassa*	*Violacea*		2	0.9	0	0	0.6

Mean of all counts (birds km^{-2}) for each river is listed with mean counts from 46 Florida lakes (Hoyer & Canfield, 1994).

been shown to be positively related to lake trophic state indicators. Chlorophyll concentrations (Canfield, 1983; Brown et al., 2000), zooplankton abundance (Canfield & Watkins, 1984), fish biomass (Jones & Hoyer, 1982; Bachmann et al., 1996), bird abundance (Nilsson & Nilsson, 1978; Suter, 1994) and even the abundance of top predators like the alligator (Evert, 1999) have all been shown to be positively related to the trophic status of the lake systems. In river systems direct relations between nutrients concentrations (primarily phosphorus) and periphyton biomass (Van Nieuwenhuyse & Jones, 1996; Lohman & Jones, 1999), aquatic plants (Sosiak, 2002) and fish biomass (Herrman, 1981; Hoyer & Canfield, 1991) have also been shown, suggesting that similar to lakes, the productivity of a river systems determines the overall abundance of aquatic organisms. Comparing the river bird data to lake bird data collected by Hoyer & Canfield (1994) shows that the river bird density, total phosphorus concentrations, and bird biomass all fall within the range of data collected on Florida lakes (Fig. 3).

Species richness of many types of flora and fauna are related to area sampled (Flessa & Sepkoshi, 1978; Connor & McCoy, 1979), including aquatic birds (Elmberg et al., 1994; Suter, 1994; Paszkowski & Tonn, 2000). A comparison of the river data to lake data collected by Hoyer & Canfield (1994) shows that the whole river aquatic bird species richness and river area data fall within the range of data collected on lakes (Fig. 4).

The flow of energy, habitat availability and basic ecology of streams and lakes are considerably different (Hynes, 1970; Benfield, 1981). However, the above two comparisons suggest that rivers are capable of supplying sufficient resources to maintain bird densities and species richness values similar to lakes of equal size and nutrient concentrations. These comparisons, however, do not necessarily suggest that the relations between phosphorus and bird density or stream area and species richness among streams are functionally the same as lakes. The range in phosphorus concentrations and stream areas of these five Florida streams are insufficient to make this determination. The similarities between the stream and lake data, however, indicate that streams are important habitats for Florida's aquatic bird populations.

While a large portion of the variance in bird density and species richness among lakes systems can be accounted for by lake trophic status and lake area respectively, additional habitat characteristics can also account for considerable within lake variance. For example, aquatic macrophyte abundance has been shown to be a major variable in the distribution and abundance of aquatic birds in lake and wetland systems (Weller & Fredrickson, 1974; Johnson & Montalbano, 1984; Lillie & Evrard, 1994). Water depth has also been shown to be an important factor influencing distribution and abundance of aquatic birds in lakes and wetland systems (DuBowy, 1996; Davis & Smith, 1998; Colwell & Taft, 2000). Unfortunately, it is difficult to separate the effects of water depth from that of aquatic macrophytes on the distribution and abundance of aquatic birds as both factors are related in lake, coastal and river systems (Canfield et al., 1985; Duarte, 1991; Hoyer et al., 2004). Indeed, both factors are most likely working simultaneously with other factors to determine the distribution and abundance of aquatic birds (Bancroft et al., 2002).

Because we observed a significant positive relation between section species richness and section area (Table 3) we used the ratio of section species richness to section area to further examine species richness relations with other section habitat characteristics. Significant correlations between both section bird abundance and bird biomass, and macroalgae biomass, macrophyte biomass, water depth and percent light reaching the bottom of the river of the section were found (Table 3). However, when performing a stepwise multiple linear regression analyses using all of the habitat variables and a probability of 0.05 that must be attributed to a dependent variable for it to be considered a forward step, only macroalgae biomass accounted for significant variance in bird abundance (Table 4). Both macroalgae and width accounted for significant variance in bird biomass. Section species richness per unit area was significantly correlated with section area, macroalgae biomass, macrophyte biomass, water depth, percent light reaching the bottom of the river and river width (Table 3). Again, performing a stepwise multiple linear regression analyses using all of the habitat variables, only section area, macroalgae biomass and depth were significant (Table 4).

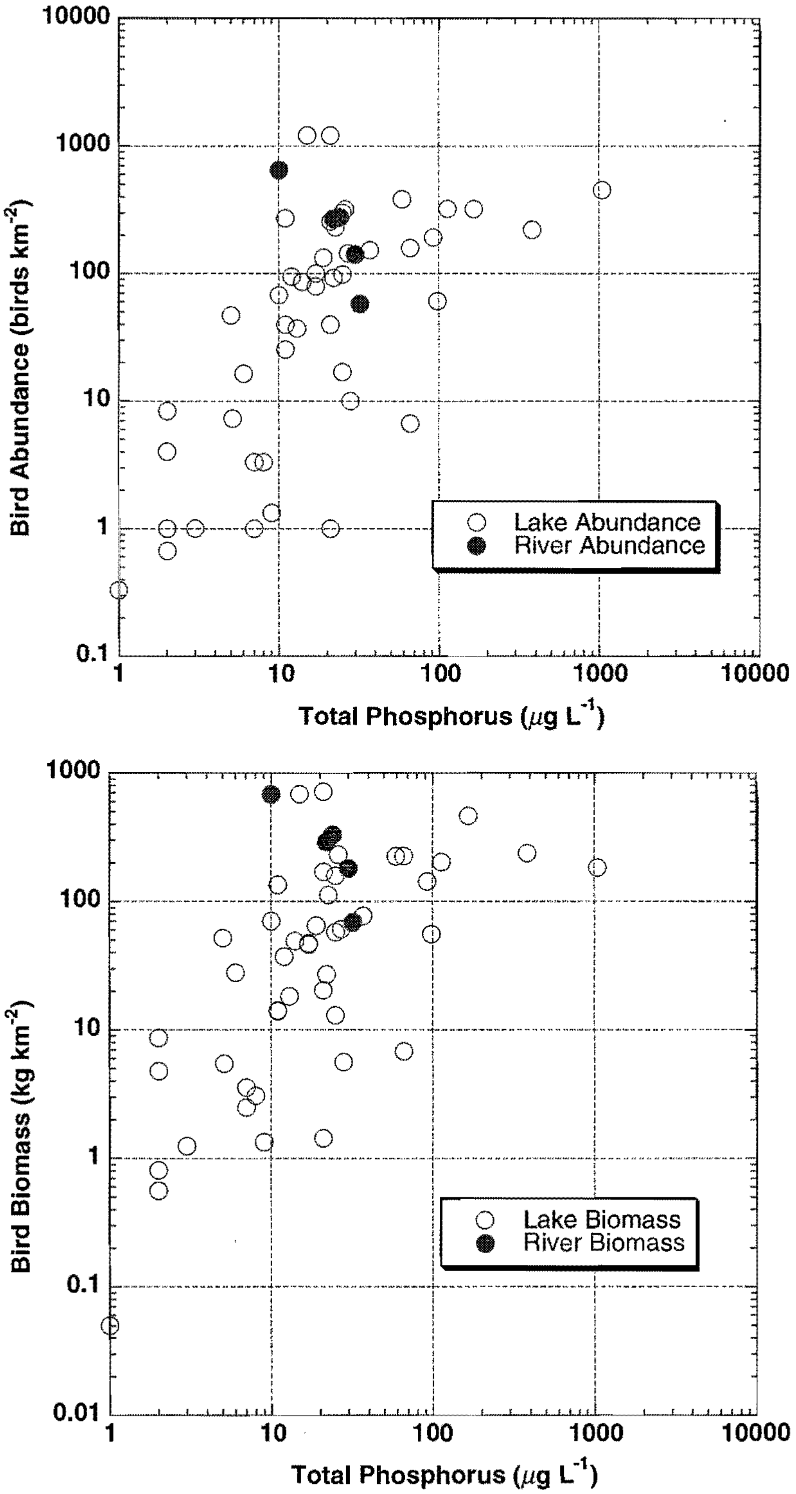

Figure 3. Relations between total phosphorus concentration and bird abundance (correlation coefficient for all data pooled = 0.63) and total phosphorus and bird biomass (correlation coefficient for all data pooled = 0.64) for five Florida Gulf coast rivers plotted with similar data from Florida lakes (Hoyer & Canfield, 1994).

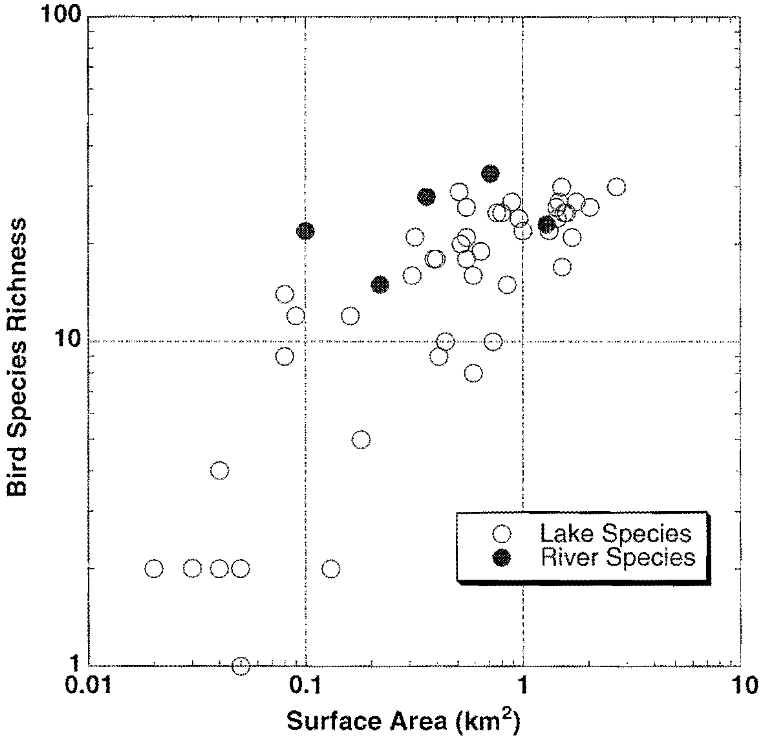

Figure 4. Relations between surface area and bird species richness (correlation coefficient for all data pooled = 0.83) for five Florida Gulf coast rivers plotted with similar data from Florida lakes (Hoyer & Canfield, 1994).

These data suggest that, as with lake systems, SAV and water depth are important habitat characteristics that can help determine the distribution and abundance of aquatic birds in river systems.

Both macroalgae and aquatic macrophytes were positively correlated with bird abundance, bird biomass and species richness per unit area, suggesting an important role of SAV in the distribution, abundance and biomass of aquatic birds in the five study rivers. This is not surprising considering that SAV can be a direct food for some species of aquatic birds and also provides habitat for macroinvertebrates and fish that are food for other aquatic birds (Kiorboe, 1980; Gawlik, 2002). However, individual bird species may require different types and quantities of SAV (Weller & Spatcher, 1965; Weller & Fredrickson, 1974). In Florida lakes, whole lake bird densities and species richness were not significantly correlated with whole lake aquatic macrophyte abundance (Hoyer & Canfield, 1994), although species composition changed dramatically with aquatic macrophyte abundance.

Similar to many studies on lake and wetland systems (Boshoff et al., 1990; Colwell & Taft, 2000; Bancroft et al., 2002), stream water depth was negatively correlated with bird abundance, bird biomass and species richness per unit area. Unfortunately, the sampling design employed here was not rigorous enough to statistically measure the changes in bird abundance as tidal fluctuations changed the water depth in the rivers. However, our observations during this study suggest that foraging activity and bird abundance was greatest along the shoreline, where most of the SAV occurs, during low tides. Examining the impact of lake water level on six species of wintering herons and egrets, DuBowy (1996) found that larger (longer-legged) species tended to be found in deeper water, although these species were frequently found with other smaller birds in shallow water. Similarly, great blue herons and great egrets were observed in river sections that had average depths of 2.00 m and 1.97 m, respectively, while river sections with little blue and tricolored herons averaged 1.4 m and 1.33 m, respectively (Table 5).

Table 3. Pearson product-moment pairwise correlations between section bird abundance (birds km^{-2}), ratio of section species richness to area (species ha^{-1}) and habitat characteristics and water chemistry variables

Dependent variable	Independent variable	Correlation	Probability
Log_{10} Bird abundance	Log_{10} Section Area (ha)	−0.2509	0.0961
Log_{10} Bird abundance	Log_{10} Width (m)	−0.0369	0.8097
Log_{10} Bird abundance	Log_{10} Depth (m)	−0.5467	0.0001
Log_{10} Bird abundance	Log_{10} Flow (m s^{-1})	−0.0894	0.5638
Log_{10} Bird abundance	Log_{10} Light Attenuation (m^{-1})	−0.0947	0.5359
Log_{10} Bird abundance	Log_{10} % Light to Bottom	0.6450	0.0000
Log_{10} Bird abundance	Log_{10} Macroalgae	0.7160	0.0000
Log_{10} Bird abundance	Log_{10} Macrophytes	0.5586	0.0001
Log_{10} Bird biomass	Log_{10} Section Area (ha)	−0.0738	0.6338
Log_{10} Bird biomass	Log_{10} Width (m)	0.1499	0.3313
Log_{10} Bird biomass	Log_{10} Depth (m)	−0.4230	0.0042
Log_{10} Bird biomass	Log_{10} Flow (m s^{-1})	−0.1683	0.2808
Log_{10} Bird biomass	Log_{10} Light Attenuation (m^{-1})	0.0102	0.9475
Log_{10} Bird biomass	Log_{10} % Light to Bottom	0.4663	0.0014
Log_{10} Bird biomass	Log_{10} Macroalgae	0.5273	0.0002
Log_{10} Bird biomass	Log_{10} Macrophytes	0.3854	0.0098
Log_{10} Section species richness	Log_{10} Section Area (ha)	0.4886	0.0000
Log_{10} Section species ha^{-1}	Log_{10} Width (m)	−0.5646	0.0001
Log_{10} Section species ha^{-1}	Log_{10} Depth (m)	−0.5170	0.0003
Log_{10} Section species ha^{-1}	Log_{10} Flow (m s^{-1})	0.3647	0.0149
Log_{10} Section species ha^{-1}	Log_{10} Light Attenuation (m^{-1})	−0.0859	0.5748
Log_{10} Section species ha^{-1}	Log_{10} % Light to Bottom	0.6089	0.0000
Log_{10} Section species ha^{-1}	Log_{10} Macroalgae	0.6236	0.0000
Log_{10} Section species ha^{-1}	Log_{10} Macrophytes	0.4877	0.0007

Data were collected from nine sections in each of five Florida Gulf Coast rivers ($n = 45$) between August 1998 and May 2000.

Table 4. Multivariate linear regression models with significant variables after running stepwise multiple regression between section bird abundance section bird biomass, section species richness per unit area and width, depth, flow, light attenuation, percent light to the bottom, macroalgae biomass and macrophyte biomass

Dependent variable	Independent variables	F	$p > F$	r^2
Log_{10} section bird abundance	0.77*Log_{10} macroalgae	45.2	< 0.05	
Whole model	Intercept = 2.93	45.2	< 0.05	0.52
Log_{10} section bird biomass	3.55*Log_{10} macroalgae	19.9	< 0.05	
	0.29*Log_{10} Width	4.0	< 0.05	
Whole model	Intercept = 2.38	10.7	< 0.05	0.34
Log_{10} Section species richness per unit area	−0.39*Log_{10} Width	21.4	< 0.05	
	−0.39*Log_{10} Depth	5.5	< 0.05	
	0.30*Log_{10} Macroalgae	9.4	< 0.05	
Whole model	Intercept = 1.65	22.8	< 0.05	0.63

Table 5. Mean depth of river sections in which each of six heron and egret species were observed

Species	Body mass (g)	Number counted	Mean water depth (m)	Standard error
Tricolored Heron	300	16	1.33	0.21
Little Blue Heron	400	50	1.42	0.12
Snowy Egret	350	39	1.82	0.17
Great Egret	1000	92	1.97	0.12
Great Blue Heron	3500	100	2.00	0.11
Green-backed Heron	225	23	2.12	0.30

These data suggest that water depth is indeed an important factor determining the distribution of some aquatic birds in these five rivers.

Conclusions

Forty-two species were identified on the five Florida Gulf Coast rivers and for the species that were found in both Florida rivers and lakes similar densities and biomass were encountered. Similar to Florida lakes both bird abundance and species richness was higher in winter months than summer months when migratory populations are utilizing the river systems. Total bird abundance and biomass values per unit of phosphorus and individual river species richness per unit of area were also similar to data collected on Florida lakes. Water depth and presence of SAV were two major factors determining the distribution and abundance of aquatic birds in the river systems. Both factors appear to be important but they are inversely correlated making it difficult to separate the magnitude each factor has on stream bird populations. The similarities between river and lake bird populations suggest that these systems in Florida are supplying similar resources for aquatic bird populations, and both should be considered to be valuable resources for avian fauna.

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