5-1-1999

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Robert A. Kennamer
*Savannah River Ecology Laboratory, Aiken, SC*, rkennamer@srel.uga.edu

L. Brisbin Jr.
*Savannah River Ecology Laboratory, Aiken, SC*, brisbin@uga.edu

K. F. Gaines
*Savannah River Ecology Laboratory, Aiken, SC*

W. L. Stephens Jr.
*Savannah River Ecology Laboratory, Aiken, SC*

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**R.A. Kennamer**
**L. Brisbin, Jr.**
**K. F. Gaines**
**W. L. Stephens, Jr**
Savannah River Ecology Laboratory
P.O. Drawer E, Aiken, SC 29802
Phone: (803) 725-0387
FAX: (803) 725-3309
E-mail: kennamer@srel.edu

## Abstract

Responding to a U.S. Federal court order to improve discharged wastewater quality, Augusta, Georgia initiated development of artificial wetlands in 1997 to treat effluents. Because of the proximity to Augusta Regional Airport at Bush Field, the U.S. Federal Aviation Administration expressed concern for potential increased hazard to aircraft posed by birds attracted to these wetlands. We commenced weekly low-level aerial surveys of habitats in the area beginning January, 1998. Over a one-year period, 49 surveys identified approximately 42,000 birds representing 52 species, including protected Wood Storks and Bald Eagles, using wetlands within 8 km of the airport. More birds were observed during the mid-winter and fall/spring migratory seasons (1,048 birds/survey; October - April) than during the breeding/post-breeding seasons (394 birds/survey; May - September). In winter, waterfowl dominated the avian assemblage (65% of all birds). During summer, wading birds were most abundant (56% of all birds). Habitat changes within the artificial wetlands produced fish kills and exposed mudflats, resulting in increased use by wading birds and shorebirds. No aquatic birds were implicated in 1998 bird strikes, and most birds involved could safely be placed within songbird categories. Airport incident reports further implicated songbirds. These findings suggested that efforts to decrease numbers of songbirds on the airport property must be included in the development of a wildlife hazard management plan. Seasonal differences in site use among species groups should also be considered in any such plan. Other wetlands within 8 km of the airport supported as many or more birds than the artificial wetlands. With proper management of the artificial wetlands, it should be possible to successfully displace waterfowl and wading birds to other wetlands further from the airport.

## Introduction

Airports servicing metropolitan areas are frequently constructed away from urban centers, and the decisions regarding where to build them are usually based on socio-economic and political arguments rather than on biological factors. Consequently, airports are often placed in undeveloped areas that may have high potential as wildlife habitat and furthermore may also serve as sites for municipal waste treatment and disposal. Wetlands in particular, can be found in the vicinity of many airports because these habitats are generally left undeveloped and therefore may provide for aircraft approaches involving less risk to the non-flying public than approaches over developed areas. On the other hand, however, such wetlands not only attract a great diversity of wildlife, but the numbers of some species can often be quite large. Concern for the safety of aircraft thus increases when highly-mobile birds are attracted to wetlands within close proximity to airports.

In 1997, the Augusta - Richmond County Georgia Consolidated Government (hereafter Augusta) was placed under a Federal court order to improve the water quality of its discharges from the Messerly Wastewater Treatment Plant (WTP). The plant is located on the Doug Barnard Parkway, south of the city (Figure 1). Augusta officials opted to initiate the development of a “Constructed Wetlands Project” to “naturally” treat effluents from the WTP. The first phase of the wetland project that included four wetland cells totaling 60

acres (24 hectares [ha]) was completed and placed into operation by late 1997. Planned additions to the artificial wetlands eventually would increase the project size to 360 acres (144 ha). Because the Constructed Wetlands Project is on land adjacent to Augusta Regional Airport at Bush Field (Airport reference point: 32°22'11"N, 81°57'55"W; Figure 1), the Federal Aviation Administration (FAA) expressed concern that birds attracted to the artificial wetlands posed an increased risk of bird-aircraft strikes. As a result, Augusta officials were required by FAA Advisory Circular 139, Section 337, to conduct an ecological study on wildlife hazard management. To that end, Augusta enlisted the services of The University of Georgia's Savannah River Ecology Laboratory (SREL) in early 1998 to begin weekly aerial surveys in the vicinity of Bush Field to document habitat use by various species of birds. This paper summarizes data that were collected during the initial one-year period from late January 1998 - January 1999, over which time, 49 aerial surveys were conducted. This paper also summarizes the bird-aircraft strike and wildlife incident reports from Bush Field during calendar year 1998.

## Study Areas

Terminology used in this paper refers to specific areas of study as follows: *Wetland complex* is used to describe the total study area extending from the Butler Creek confluence on the Savannah River north to, and including, the Merry Land ponds (Figure 1). The wetland complex is subdivided into smaller areas referred to as *wetland study units*. Within the Constructed Wetlands Project are multiple wastewater treatment impoundments referred to as *wetland cells*.

Areas to the north and east of Bush Field were identified as containing the primary wetland habitats in the vicinity of the airport (Figure 1). A GIS habitat coverage developed at SREL by J. E. Pinder III from 1997 multispectral Landsat Thematic Mapper Data was used to produce a habitat characterization for this entire area. Habitat features (consolidated into 17 classifications) within and around the airport and found in Figure 1 (enclosed by the outermost black polygon) are characterized in Table 1; about 40% of that area is considered wetland habitat by this GIS coverage. Immediately to the north and northeast of Bush Field is the Augusta property where the Messerly Wastewater Treatment Plant and the Constructed Wetlands Project are located (Figure 1). Lands nearby and surrounding the Augusta Wastewater Treatment Plant include extensive natural wetlands (Phinizy Swamp and the lower Butler Creek area, Figure 1) that are primarily forested, and water-filled clay-mining and borrow pits (Merry Land Properties, Inc. ponds, Figure 1). Many of these latter man-made ponds have undergone natural succession and have become attractive to birds of the region, particularly migratory waterfowl. These wetland areas were surveyed for bird use in addition to the Constructed Wetlands Project.

For this study, the wetland complex was divided into five units (Figure 1). Total wetland areas within each study unit were initially estimated from National Wetlands Inventory (NWI) GIS coverages. Wetland study units (Figure 1) included: Augusta's Constructed Wetland Project (the four wetland cells proper, 24 ha), the "Natural Wetlands" of lower Butler Creek immediately surrounding the constructed wetlands (339.5 ha, NWI wetlands), the Phinizy Swamp Wildlife Management Area (WMA) managed by the Georgia Department of Natural Resources (above [324.6 ha, NWI wetlands] and below [290.7 ha, NWI wetlands] the Bobby Jones Expressway extension), and the Merry Land ponds (711.1 ha, NWI wetlands). The 1997 SREL GIS habitat coverage was used to produce a habitat characterization for each of the wetland study units (Table 2). These characterizations confirmed that relatively undisturbed/undeveloped natural study units such as the Upper and Lower Phinizy Swamp WMA and the Natural Wetlands unit were dominated by floodplain hardwood forests and swamp forests, accounting for 76, 69, and 44% of the total areas of these units, respectively, and each having less than 2% open water habitat. In contrast, the Merry Land ponds unit, with its clay-mining operation, had more than twenty times the open water habitat as the undisturbed/undeveloped natural study units (Table 2).

## Bird Survey Methods

Because of potential bias associated with multiple observers, all aerial surveys were conducted by a single observer. Our observer, W. L. Stephens, Jr., accompanied the pilot in a Cessna 172 aircraft; the pilot was instructed to fly at an altitude of approximately 50 - 60 m and an airspeed of about 130 km/h. Surveys consisted of complete coverages of the entire wetland complex under study by flying adjacent transects, thus providing what are considered true count data as opposed to randomized line-transect surveys which yield only estimates of bird abundance (this latter technique is often used when study areas are large geographic regions). Pilots were instructed to circle above larger flocks of birds while species were identified and counts made. Bird species and numbers of individuals were recorded directly onto field maps; after survey completion, observed birds were tallied by species within wetland study units and recorded on a summary data form. Additional data provided on each summary data form included: date, time of survey, general weather conditions at the time of the aerial survey (i.e., visibility, wind, temperature, rainfall), and Savannah River level (m) at Butler Creek. Any vehicles, boats, or people in the study areas were also noted. Generally, aerial surveys were conducted during the early-to-mid morning hours, with 34 of 49 (69%) of the surveys being started by 1000hrs; later surveys often resulted from delays due to heavy fog in the area. Typically, surveys lasted 1.5 - 2 hours.

The Statistical Analysis System (SAS Institute, Inc. 1989) was used to summarize aerial survey data and conduct specific statistical analyses described below. In some analyses, area estimates of habitats similar to those found in the Constructed Wetlands (i.e., open water, macrophytes, marsh, and stream habitats, see Table 2) were summed within each study unit and were used to convert counts of birds observed during aerial surveys into bird densities (birds/ha). Those summed areas used for estimating bird densities were as follows: Constructed Wetland Project (24 ha), Natural Wetlands (14.67 ha), the Lower Phinizy Swamp WMA (0.99 ha), Upper Phinizy Swamp WMA (7.74 ha), and the Merry Land ponds (326.07 ha). The Merry Land ponds unit thus contained over 13 times more of these habitat types than the Constructed Wetlands Project. Data were transformed (e.g., square-root, common log) as necessary to improve or meet requirements for data normality in parametric statistical tests. Fisher's Least Significant Difference (LSD) test was used to make multiple comparisons among class levels of the main effects or their interactions. The data were scaled to prevent log-transformation of values of zero. Least square means estimates from the resulting analyses were back-transformed, removing the scaling factors, to produce geometric means. We accepted statistical significance at the $P \leq 0.05$ level, but acknowledged marginal significance when probabilities approached the $P = 0.05$ level.

## Results and Discussion

Forty-nine aerial surveys were conducted at roughly weekly intervals during the period January 22, 1998 through January 21, 1999. During the week of the internationally attended Masters Golf Tournament (April 5-11), no aerial survey was attempted due to the substantial increase in aircraft traffic in the area. In addition, flights initiated on April 23, September 15, and December 22 were halted by Bush Field Air Traffic Control because of limited visibility in the area.

### Migratory vs. Non-Migratory Seasons

Over the 12-month study period, nearly 42,000 birds representing 52 species were recorded (Table 3). Counts of all bird species across the five wetland study units ranged from a maximum of 2,275 individuals on December 31 to a minimum of 74 birds on June 4 (Figure 2). By the end of April, the majority of local winter residents and transient migrants had departed the area for more northerly breeding areas. The 21 aerial surveys conducted from May 1 through September 30, 1998 were considered the breeding/post breeding seasons, hereafter referred to as the “non-migratory” season. The remaining 28 surveys conducted from January 22 through April 30, 1998 and from October 1, 1998 through January 21, 1999, represented the fall and spring migration periods together with the mid-winter period, hereafter collectively referred to as the “migratory” season.

The aerial survey data spanned two separate migratory periods (1997-98 and 1998-99), with Savannah River water levels contrasting sharply between these periods. Overall, bird numbers tended to decrease from the first to the second migratory period (1,289 vs. 918 birds/survey, respectively), coinciding with lower water conditions in the fall/winter of 1998-99. Likewise, numbers of birds at the Constructed Wetlands Project tended to decrease from the 1997-98 migratory season (307 birds/survey) to the 1998-99 migratory season (150 birds/survey). Although these tendencies were identified as marginally significant, they should be taken with caution since data from additional years of study will be required to adequately address any questions of annual variation in bird abundance.

During the migratory season, waterfowl (i.e., ducks, geese, and swans) and a closely allied species, the American Coot, dominated the avian assemblage observed during aerial surveys, accounting for an average of 65% of all birds seen (range: 18 - 93%). In contrast, during the non-migratory season, these same species accounted for an average of only 16% of all birds seen. During the non-migratory period, however, wading bird species dominated the observations, averaging 56% of all birds observed (range: 9 - 94%).

To determine whether bird numbers differed between migratory and non-migratory seasons across the entire wetland complex, and to determine if Savannah River water level fluctuations influenced bird numbers in the wetland complex similarly between seasons, we conducted an analysis of covariance (ANCOVA [homogeneity of slopes model], General Linear Models Procedure; SAS Institute, Inc. 1989). We used square-root-transformed total bird numbers pooled across wetland units from each of the 49 flights as the dependent variable, SEASON (i.e., migratory versus non-migratory) as a main class effect, RIVER LEVEL as the continuously distributed covariate, and their interaction. This model explained a significant amount of the variation in bird numbers ($F_{3, 45}$ = 12.7, $P$ = 0.0001, $R^2$ = 0.46). Total bird numbers differed between seasons (SEASON Type I Sums of Squares [SS]: $F_{1, 45}$ = 31.8, $P$ = 0.0001), with surveys conducted during the migratory season averaging 1,048 birds and those conducted during the non-migratory season averaging 394 birds.

The covariate effect was not significant (RIVER LEVEL Type III SS: $F_{1, 45}$ = 0.54, $P$ = 0.47) in the ANCOVA, indicating that there was no consistent effect of river level across seasons for the wetland complex as a whole. Slopes for the simple linear relationship between river level and bird numbers differed by season (INTERACTION Type III SS: $F_{1, 45}$ = 6.3, $P$ = 0.016), indicating that fluctuating river levels had different effects on birds in the migratory versus non-migratory seasons. The slope estimate for the relationship was positive for the migratory period, though not statistically different from zero ($P$ = 0.12), indicating no change in bird numbers with fluctuating river levels. In contrast, the slope estimate was negative and was marginally significant ($P$ = 0.058) during the non-migratory period, indicating that higher river levels were associated with fewer birds. Because of these marginal seasonal differences in river level effects at the geographic scale of the entire wetland complex, and the fact that the avian assemblages in the migratory and non-migratory seasons were dominated by different species groups (i.e., waterfowl in the migratory season and wading birds in the non-migratory season), all subsequent analyses were conducted separately for each season.

## Wetland Study Units within the Overall Wetland Complex

Temporal patterns of bird abundance at the Constructed Wetlands project were similar to patterns exhibited throughout the wetland complex as a whole (Figure 2). Counts of birds peaked at the Constructed Wetlands Project (980 individuals) on March 19 (Figure 2) with 93% of those birds being waterfowl and American Coots. Twenty-four bird species were identified at the artificial wetlands during aerial surveys (Table 4). Species observed most frequently on the Constructed Wetlands Project included Northern Shovelers, American Coots, Great Egrets, and a shorebird tentatively identified as a species of Yellowlegs (Table 4). Northern Shovelers, in particular, have been known to gather in sizable numbers on sewage lagoons, where they feed on abundant plankton (Bellrose 1980). Species occurring in the greatest numbers ($\geq$ 200 on an individual survey) on the artificial wetlands included Ring-necked Ducks, Lesser Scaup, American Coots, Cattle Egrets, Yellowlegs, and Red-winged Blackbirds (Table 5). Most of the birds commonly found at the artificial wetlands tended to be those species that consume large quantities of invertebrate fauna, and a

wetland of this type would be expected to harbor dense populations of such prey. An exception to this generalization would be the American Coot, which feeds primarily on aquatic vegetation, and algae in particular.

At the Merry Land ponds, bird abundance was particularly higher than at the Constructed Wetlands Project from November 1998 through January 1999 (Figure 3). A peak of 1,885 birds was observed at the Merry Land ponds on December 31 (Figure 3), with 52% of the birds being waterfowl and American Coots. A greater diversity of bird species (44) was noted on the Merry Land ponds than on all the other wetland study units (Table 4). Most frequently encountered were Canada Geese, Wood Ducks, Mallards, Great Blue Herons, Great Egrets, Double-crested Cormorants, and American Anhingas, each occurring on more than half of the 49 surveys (Table 4). Species occurring in the greatest numbers (≥ 200 on an individual survey) were American Green-winged Teal, Gadwall, American Wigeon, Ring-necked Ducks, Ruddy Ducks, American Coots, Double-crested Cormorants, and gull species, the latter being dominated by the Ring-billed Gull (*Larus delawarensis*; Table 5).

Counts of birds from the Phinizy Swamp Wildlife Management Area, above and below the Bobby Jones Expressway extension, are presented in Figure 4. Habitats within these two study units were dominated by forested wetlands, thus increasing the difficulty of censusing birds from the air. Consequently, some bird species may be underrepresented in counts from these areas, in particular the year-round resident Wood Ducks. Despite this potential limitation, 27 bird species were identified in these two study units, with American Wigeon, Great Blue Herons and Great Egrets being the most frequently observed (Table 4). Only one species, American Wigeon, occurred in numbers ≥ 200 on an individual survey (Table 5). Breeding colonies of Great Blue Herons and Great Egrets were identified by aerial surveys in the southeastern portion of the Lower Phinizy Swamp unit. Details concerning these breeding colonies are discussed elsewhere.

Counts of birds from the Natural Wetlands found in the lower Butler Creek region surrounding the Constructed Wetlands Project were substantially higher in the first winter than in the second winter (Figure 5). Although much of this study unit is also comprised of forested wetlands as with the Phinizy Swamp units, cleared areas surrounding the artificial wetland cells (i.e., sites for planned artificial wetland additions) and the oxbow lakes near the river were the primary bird use areas identified in this study unit. A total of 37 bird species was identified using the Natural Wetlands unit, with Great Blue Herons and Great Egrets most frequently seen (Table 4). Bird species observed in greatest numbers (≥ 200 on an individual survey) included Ring-necked Ducks, Great Egrets, Cattle Egrets, and Red-winged Blackbirds (Table 5).

To examine whether bird numbers differed among the five wetland study units (i.e., Constructed Wetlands Project, Natural Wetlands, Lower Phinizy WMA, Upper Phinizy WMA, and Merry Land ponds), and to determine if Savannah River water level fluctuations influenced bird numbers similarly among the study units, we conducted ANCOVAs (homogeneity of slopes models; SAS Institute, Inc. 1989). We used common log-transformed total bird numbers from each unit during each of the 49 flights (N = 245) as the dependent variable, wetland study UNIT as the main class effect, and RIVER LEVEL as the continuously distributed covariate. The interaction was included to test for differences among wetland units in river level/bird count slopes. When non-significant, this interaction term was removed from the model, and the analysis was rerun. This statistical approach was performed separately for the migratory (N = 140 unit surveys) and non-migratory (N = 105 unit surveys) seasons for reasons discussed earlier.

For the migratory season, the full statistical model explained a significant portion of the variation in total bird numbers ($F_{9, 130} = 23.5$, $P = 0.0001$, $R^2 = 0.62$), with all effects in the model being significant (UNIT Type III SS [Intercept term]: $F_{4, 130} = 23.0$, $P = 0.0001$; RIVER LEVEL Type III SS: $F_{1, 130} = 9.2$, $P = 0.003$; INTERACTION Type III SS: $F_{4, 130} = 3.2$, $P = 0.014$). During the migratory season (Figure 6, top), significant differences in average numbers of birds (UNIT Type I SS: $F_{4, 130} = 47.3$, $P = 0.0001$) were found among the five study units, with all study units being different from one another (LSD tests, $P$s < 0.003). Total bird numbers were highest for the Merry Land ponds (mean = 536 birds/survey), followed by counts of birds observed at the Constructed Wetlands Project (mean = 154 birds/survey). Bird numbers averaged 53 birds/survey at the Natural Wetlands unit. Numbers of birds from the Upper and Lower Phinizy WMA were

lowest, averaging 17 and 5 birds/survey, respectively. Slope estimates from the river level/bird count relationship were positive for four of five study units, though only statistically different from a slope of zero in the case of the Natural Wetlands (slope = 0.067 ± 0.016SE). These results confirmed our observations that waterfowl made extensive use of the Natural Wetlands area surrounding the Constructed Wetlands Project under flood conditions.

Dominant species using the Constructed Wetlands Project during the migratory period were Blue-winged Teal, Northern Shovelers, Ring-necked Ducks, Lesser Scaup, and American Coots. We found some evidence that birds, particularly waterfowl, moved within the entire wetland complex to exploit the available resources. For example, peak use of the Constructed Wetlands Project on March 19 was accompanied by concurrent declines in the use of both the Merry Land ponds and the Natural Wetlands (Figures 3 and 5). During the migratory season, there was minimal bird use of the Lower Phinizy WMA (Figures 4 and 6, top), although we noted substantial waterfowl use of a single flooded borrow pit area just north of the Bobby Jones Expressway extension within the Upper Phinizy WMA (Figures 4 and 6, top).

For the non-migratory season ANCOVA (homogeneity of slopes model; $R^2 = 0.52$), the wetland unit effect (UNIT Type III SS: $F_{4, 95} = 7.9$, $P = 0.0001$) and the covariate (RIVER LEVEL Type III SS: $F_{1, 95} = 9.1$, $P = 0.003$) were statistically significant, but their interaction was not (INTERACTION Type III SS: $F_{4, 95} = 0.57$, $P = 0.69$). This model was subsequently rerun with the interaction term removed (reduced model: $F_{5, 99} = 20.3$, $P = 0.0001$, $R^2 = 0.51$), and both the wetland unit effect (UNIT Type III SS: $F_{4, 99} = 23.1$, $P = 0.0001$) and the covariate (RIVER LEVEL Type III SS: $F_{1, 99} = 9.3$, $P = 0.003$) were significant. During the non-migratory season (Figure 6, bottom), average numbers of birds observed at the Merry Land ponds (91 birds/survey), the Constructed Wetlands Project (87 birds/survey), and the Natural Wetlands (83 birds/survey) did not differ statistically (LSD tests, $P$s > 0.80), but were all significantly greater (LSD tests, $P$s = 0.0001) than average bird numbers observed at either the Upper or Lower Phinizy WMA (5 and 16 birds/survey, respectively). The significant river level effect and simultaneous non-significant interaction term in the first model run indicated that bird numbers at all wetland units responded similarly to river conditions during the non-migratory season. That common relationship among study units was then identified when the second model was run without the interaction term. The significant slope estimate (-0.029 ± 0.0096SE) indicated that birds were drawn to the entire wetland complex as river levels were lowered. The timing of low river conditions in mid-to-late summer coincided with the dispersal of wading birds from local breeding colonies, both from those located within the wetland complex as well as from others located outside the immediate study areas. This is probably a pattern of wading bird movements/distributions that may be expected to take place in most years in the area.

Dominant species using the Constructed Wetlands Project during the non-migratory season were Great Egrets, White Ibis, Great Blue Herons and sandpiper species, including Yellowlegs. During the June 11 aerial survey, an anomalous event was noted at the Constructed Wetlands Project. All vegetation in the wetland cells was dead or dying and dead fish were seen floating on the surface. In response to this event, numerous wading birds, particularly Great Egrets and Great Blue Herons, totaling 78 individuals, were actively foraging at the site, presumably on the dead fish. The subsequent drawdown of the wetland cells to allow replanting of the wetland vegetation exposed extensive mudflats in late June and July, and accounted for increased use of the wetlands by migrating shorebirds.

A substantial change in the pattern of bird distributions from the migratory to the non-migratory season occurred in the Upper and Lower Phinizy WMA. Wading bird use of the Lower Phinizy WMA area accounted for greater bird numbers than in the Upper Phinizy WMA during the non-migratory season (Figures 4 and 6), and was associated with wading bird colonies (discussed below) established in the former wetland unit.

Because the wetland units surveyed were different in overall size and the amounts of habitat similar to that found within the Constructed Wetlands, an analysis based on counts alone potentially might not give a complete picture of the importance/attractiveness of these various study units to the birds. Therefore, similar ANCOVAs (with interactions, General Linear Models Procedure; SAS Institute, Inc. 1989) as described

above, were repeated for both the migratory and non-migratory seasons, using bird densities (common log-transformed) as the dependent variable.

For the migratory season, the full statistical model explained only a modest portion of the variation in the data ($F_{9, 130} = 2.9$, $P = 0.0037$, $R^2 = 0.17$), including a marginally significant effect of wetland unit (UNIT Type III SS [Intercept term]: $F_{4, 130} = 2.3$, $P = 0.062$) and a significant river level effect (RIVER LEVEL Type III SS: $F_{1,130} = 7.6$, $P = 0.007$); their interaction was marginally significant (INTERACTION Type III SS: $F_{4, 130} = 2.1$, $P = 0.086$). During the migratory season (Figure 7, top), significant differences in average bird density were detected among the five study units (UNIT Type I SS: $F_{4, 130} = 2.5$, $P = 0.043$). The Constructed Wetlands Project had significantly higher (LSD tests, $P$s < 0.015) average bird densities (6.1 birds/ ha/survey) than either the Upper Phinizy WMA (1.5 birds/ha/survey) or the Merry Land ponds (1.6 birds/ha/survey), and marginally greater (LSD test, $P = 0.06$) average bird densities than the Lower Phinizy WMA (2.4 birds/ha/survey; Figure 7, top). Constructed Wetlands Project average bird densities did not differ (LSD test, $P = 0.26$) from those at the Natural Wetlands (3.4 birds/ha/survey; Figure 7, top). These results contrasted with the results for total bird numbers showing that the Merry Land ponds had the highest numbers of birds. This difference can be attributed to the differential bird use of varying amounts of open water/marsh habitat within study units. Although Merry Land ponds had greater bird numbers than the Constructed Wetlands, birds at the Merry Land ponds were spread over a much larger area of comparable habitat (24 vs 326 ha at the Constructed Wetlands and Merry Land ponds, respectively). These results also confirmed some level of preference for the Constructed Wetlands, particularly for Northern Shovelers, Blue-winged Teal, and possibly Lesser Scaup during the migratory season (see Table 4, for waterfowl).

Because of the marginal significance of the interaction term, we chose not to remove it from the model, and instead, examined potential differences among wetland units in the river level/bird density relationships. Density of birds was positively related to river levels at the Natural Wetlands (slope = 0.068 ± 0.022SE) and at the Lower Phinizy WMA (slope = 0.045 ± 0.022SE) during the migratory season. Slope estimates for the river level/bird density relationship at other wetland units were not significantly different from zero ($P$s > 0.10).

For the non-migratory season, the interaction term in the full rank ANCOVA model was not significant (INTERACTION Type III SS: $F_{4, 95} = 1.05$, $P = 0.39$), and that term was subsequently dropped from the model. When the model was run again (reduced model: $F_{5, 99} = 15.3$, $P = 0.0001$, $R^2 = 0.44$), we found a significant study unit effect (UNIT Type III SS: $F_{4, 99} = 18.2$, $P = 0.0001$) and a marginally significant covariate effect (RIVER LEVEL Type III SS: $F_{1, 99} = 3.5$, $P = 0.063$) on bird density. Bird densities at the Lower Phinizy WMA (mean = 10.3 birds/ha/survey) were highest (Figure 7, bottom), but did not differ (LSD test, $P = 0.25$) from bird densities at the Natural Wetlands (mean = 5.5 birds/ha/survey), and were only marginally higher (LSD test, $P = 0.056$) than bird densities at the Constructed Wetlands Project (mean = 3.6 birds/ha/survey). Wading birds breeding in colonies at the Lower Phinizy WMA were responsible for this outcome, and largely for the differences between results for bird numbers and bird densities. Moreover, the low bird densities at the Merry Land ponds as compared to relatively high bird numbers there were once again attributable to the larger area of comparable habitat over which the birds were distributed at the Merry Land ponds. There was some level of preference shown by shorebirds and White Ibis for the Constructed Wetlands during the non-migratory season (see Table 4, for waders, Yellowlegs, and sandpipers). The marginally significant overall slope estimate (-0.026 ± 0.014SE) further suggested that more birds were using the entire wetland complex as river levels declined.

## Bird Use of Areas within the Artificial Wetland Cells

Because wetland cells in the Constructed Wetlands Project were designed and built with contoured bottoms, two different habitat types were established. These included (1) a central ponded region and (2) surrounding shallow-water areas where emergent marsh vegetation was planted. During aerial surveys of the Constructed Wetlands Project, bird locations were recorded within the wetland cells to determine if preferences existed for use of these specific habitats. To remove potential bias resulting from disturbances

to birds using the wetland cells, surveys were not included when vehicles and/or people on foot were observed at the site. Waterfowl used the ponded areas to a greater degree (78%) than the marsh areas (22%); American Coots also tended to use the ponded areas more (73%). In contrast, however, and as might be expected, wading birds used the marsh areas to a greater degree (97%). Wading birds using the ponded areas were restricted to the shoreline, while those using the marsh areas were found throughout accessible water depths. Elimination of the ponded areas of the artificial wetlands in future constructions and the maintenance of a shallow (< 3-4 inch depth) water regime with dense emergent vegetation has the greatest potential for reducing numbers of waterfowl, coots, and wading birds using such constructed wetlands.

## Wading Bird Breeding Colonies

During aerial surveys, breeding colonies of Great Blue Herons and Great Egrets were identified within the southeastern portion of the Lower Phinizy WMA (Figure 1). Great Blue Herons were first noted in the colony on February 5, and on February 12, Great Egrets began gathering nearby. A general dispersal of birds from the colony, particularly Great Blue Herons, was noted on June 18, indicating an approximate hatch time of the second week of April, assuming a 65-day nestling period. This estimate would suggest that egg laying by Great Blue Herons occurred during the second and possibly third week of March. In fact, by March 12, 30 Great Blue Heron nests were identified within the colony. Maximum numbers of nests observed were 30 and 20 for Great Blue Herons and Great Egrets, respectively. Great Egrets initiated nests a few weeks later than the Great Blue Herons, so that as late as July 16, 25 Great Egrets were still observed in the colony. By late July, activity in the vicinity of the colony had ceased. Future studies of the movement patterns of foraging adult wading birds from these colonies during the incubation and chick-rearing periods could provide additional important information on the potential hazard imposed by these breeding colonies.

## The 1997-98 El Niño Event, Local Water Conditions, and Bird Distributions

Wetland conditions (i.e., the extent of local drought or flooding) are important when considering bird distributions among study units. Although direct influence from the Savannah River is primarily limited to the lower Butler Creek region because of protection offered by the Augusta levee, local rainfall patterns can impact water depths throughout the wetland complex. We thought it useful to address wetland conditions during the migratory season of 1997-98, particularly those conditions that prevailed in the lower Butler Creek Natural Wetlands, including areas just outside of the Constructed Wetlands Project.

The El Niño event that dominated weather conditions in much of the southeast during the fall and winter of 1997-98 continued into early spring of 1998, bringing with it greater than average rainfall for the local area. Savannah River levels at Butler Creek during the first quarter of 1998 were well above long-term average levels (Figure 8) and these conditions persisted until June 1998. Aerial surveys indicated that large numbers of waterfowl (sometimes > 800; Figure 5) were using flooded lowland areas just outside of the Constructed Wetlands Project. These are areas that have been designated as sites of future constructed wetland cells. But, in their present unimpounded condition, these areas likely would not have been inundated in average years, and therefore typically would not have provided suitable habitat for so many waterfowl. Such anomalous waterfowl use of the Natural Wetlands unit surrounding the Constructed Wetlands Project may have influenced numbers of birds using the artificial wetland cells by drawing additional birds to the general area where they might be more likely to encounter the artificial wetlands.

## Species with Protected Status

Avian species with protected status that utilize wetlands in the east-central Georgia region and that may be identified during bird surveys of wetlands in the vicinity of Bush Field Airport include Bald Eagles, Ospreys, and Wood Storks. In the State of Georgia, the Bald Eagle is considered threatened and the Wood Stork is considered endangered. Both of these species are protected by Federal laws requiring projects that use

Federal funds to assess the potential of such projects to impact the well-being of these species. Historically, Bald Eagles, Ospreys, and Wood Storks have been reported from areas near Augusta, including the U.S. Department of Energy's 78,000 ha Savannah River Site (SRS), only about 30 km to the east-southeast of Augusta (Norris 1963).

None of these 3 species were observed at the Constructed Wetland Project during aerial surveys. However, Bald Eagles were observed during aerial surveys over the Merry Land ponds on 5 occasions (January 22, 29, February 5, November 10, 1998; and January 4, 1999), and twice in the Natural Wetlands unit surrounding the Constructed Wetland Project (February 5, November 5, 1998). Three Osprey sightings were made at the Merry Land ponds (August 12, November 18, 1998; and January 15, 1999), and three Osprey sightings were also made in the Natural Wetlands unit (May 28, August 21, November 23, 1998). The endangered Wood Stork was observed at the Merry Land ponds on five surveys (August 21, September 25, October 2, November 18, 23, 1998) and on the Natural Wetlands unit twice (August 12, 21, 1998). The maximum numbers of Bald Eagles, Ospreys, and Wood Storks observed on single aerial survey dates were 3, 1, and 38, respectively.

## 1998 Bush Field Airport Bird Strikes

Bird Strike Reports from Bush Field Airport indicated that nine bird-aircraft strikes occurred in 1998 (Table 6). Seventy-eight percent of these strikes occurred during the non-migratory season. There was no indication that birds associated with aquatic wetland habitats were involved in any of the reported bird strikes for 1998; when species were noted, doves were most frequently cited as the species involved. In general, there was often a lack of certainty in the identifications made of the bird remains that were retrieved (Table 6). Most, however, would be placed into the category of small-to-medium-sized songbirds. Although photos of bird remains were referred to in some of these reports, we did not receive these photos for examination. For two of the log entries, birds simply were found dead on runways or taxiways and there was no accompanying documentation from an aircraft pilot that a strike had taken place (Table 6). Of the remaining bird strikes reported by pilots (N = 7), four occurred on/over the grounds of the airport, while only three apparently occurred as aircraft approached (twice) or had already departed (once) the airspace of Bush Field (Table 6). One pilot reported striking a "large bird" on approach to Runway 17 (see Figure 9) while at an altitude of 488 m (Table 6), possibly placing the aircraft over the Lower Phinizy WMA unit at the point of impact.

In addition to the nine reported bird strikes, Bush Field Airport logged 20 other Wildlife Incident Reports during 1998 (Table 7). Of the 17 incident reports dealing with birds (3 dealt with mammals), starlings were most frequently cited as the species being found on the airport grounds. Flock sizes from these starling incidents reportedly ranged from 20 to 70 birds (Table 7). Aquatic bird species were implicated in only 6 of 17 incident reports. These were reportedly gulls, "cow birds", and "cranes". "Cow bird" is a colloquial name commonly used in the area for the Cattle Egret. The reference to cranes undoubtedly indicates that some large, possibly wading bird, species was observed. Sandhill Cranes (*Grus canadensis*) would only rarely be seen in this region. A report of 10-15 "large black birds" on June 23 (Table 7) were likely to have been American Crows. Birds on the airport grounds were dispersed by Bush Field personnel, most often with the aid of acoustical scaring devices (e.g., horns, blank or shellcracker guns, etc.). In only 7 of 20 cases (35%) were bird dispersal directions consistent with movements to the wetland complex under study (i.e., N and NE; Table 7).

## Conclusions

Bird strike and incident reports from Bush Field Airport indicated that birds were often hit while on or over the airfield itself, which is typical (Blokpoel 1976). Most birds listed in the Bird Strike Reports, though some were not confidently identified to species, could safely be placed within the medium-sized songbird category. No bird strikes in 1998 were known to involve aquatic bird species. These results suggest that any efforts to reduce bird strike hazards must include a plan to decrease numbers of songbirds on the airport

property. This goal may be pursued by first trying to reduce the attractiveness of the site to birds by altering the ecology of the airport environment itself (Solman 1968). One recommendation would be the draining, filling, and leveling of areas on the airport grounds that may hold water on a temporary basis, particularly following rainstorms. Furthermore, changes in grassland management around the runways and taxiways (long vs. short grass, insecticide applications; e.g., Brough and Bridgman 1980, Milsom et al. 1985) could be adapted to minimize bird use. Such management options would have to be carefully considered and associated with investigations of bird use.

The results of the aerial surveys reported here indicate that seasonal differences in dominant species groups are also an important consideration when developing a wildlife hazard management plan for Bush Field Airport. Bird studies at numerous other airports have likewise identified seasonal patterns in bird abundance, and bird strikes as well (Blokpoel 1976, Milsom 1990). In Augusta, during winter and fall/spring migrations, peak numbers of birds were in the area, and waterfowl dominated the avian assemblage, accounting for an average of 65% of all birds counted. In contrast, during the breeding and post-breeding periods, medium-to-large wading birds were most abundant, accounting for 56% of the birds typically seen. During off-peak seasons for these species groups, relatively low numbers of the respective groups were observed.

Management practices used in wetland habitats can have dramatic effects on bird use. Examples in this study were provided during the marsh vegetation and fish die-offs in the artificial wetland cells in mid-June and during the subsequent pond draw-down in July. Wading birds quickly moved into the wetlands for opportunistic foraging during the fish kill in mid-June. Later, when the wetland cells were being drawn down for replanting of the marsh vegetation, the decreasing water depths increased the available mudflat habitat for migrating shorebirds. The drawdown continued to attract many wading birds from the surrounding area apparently because fish that were not initially killed were concentrated into smaller pools of water. The maintenance of more appropriate water conditions during peak periods of wading bird and shorebird abundance in the region may make the Constructed Wetlands Project less suitable for large numbers of these species. If water levels had remained high during the summer months, it is likely that many wading birds and shorebirds would have used other wetland habitats instead. With proper water level/habitat management at the Constructed Wetlands Project, we believe that many aquatic birds may be successfully displaced to other wetland sites located further from the airport.

Use of specific habitat types (i.e., open water vs. marsh) within the Constructed Wetlands by waterfowl and wading birds, suggests an advantage that may be gained by designing and constructing wetland cells without open water habitats. By allowing the marsh areas of the wetland cells to become densely vegetated with emergent herbaceous plants, a majority of the wading birds could be excluded. However, a potential problem with densely vegetated wetland cells could be an increased use by blackbirds. But, controlled seasonal burning of standing senesced emergent vegetation could minimize use by blackbirds.

In natural wetlands without water control capabilities, changing hydrologic conditions such as periods of flooding or drought are another important factor affecting bird use, although in many situations little can be done to ameliorate the undesired effects. Nevertheless, identification of wetland conditions favoring increased use by birds allows for increased awareness of potentially hazardous situations. In this study, we found relationships between bird abundance and Savannah River water levels. River level apparently was a suitable index to water conditions in at least some portions of the wetland complex. Savannah River level relationships to bird abundance differed by season, and was due to the types of birds that were most abundant in particular seasons and the habitat requirements of those birds.

We believe that the kinds of habitat management approaches described above can effectively control bird numbers around the Bush Field Airport. Bird species identified using the Constructed Wetlands Project at various times of the year are already typically found in the central Savannah River region. Aerial survey data showed that other wetland habitats within an 8-km radius around the airport support as many or more birds than the Constructed Wetlands. Moreover, many thousands of waterfowl and coots traditionally over-winter on reservoirs of the U.S. Department of Energy's SRS to the east-southeast of the wetland complex. Habitat changes there could represent yet another important factor influencing bird numbers in the vicinity of the

airport. For example, the 1991-94 partial drawdown of the SRS's largest reservoir, Par Pond, caused 3,000 to 5,000 coots to be completely displaced from the SRS. Christmas Bird Counts at the Merry Land ponds over that period showed increased numbers of coots there.

## Future Research Needs

There is a clear need for more careful identification of birds that are involved in aircraft strikes and wildlife incidents at Bush Field Airport. Reports of "large black birds" and "cranes" offer little confidence in the specific identification of any birds implicated in these reports. Photographic evidence and the training of personnel in bird identification can improve the information gathered by the reporting procedures used at the airport. Despite the limitations to existing bird strike data, there is nevertheless a need to examine Bird Strike Reports and Wildlife Incident Reports from the years prior to construction of the artificial wetlands, and to then make comparisons with reports following the wetland constructions. Such an analysis could determine whether patterns of bird strikes (e.g., seasonal, species groups involved) have changed relative to the habitat changes ongoing within the wetland complex.

These aerial surveys have provided the background needed to now design future studies critical to understanding the potential for the Constructed Wetlands to significantly alter the risk of bird strikes occurring at Bush Field Airport. Foremost is the need for additional years of bird surveys to address questions of annual variability in the temporal and spatial patterns that have now been identified. This is particularly the case now since the 1997-98 El Niño event apparently influenced bird abundance and distribution during at least some portion of the current study. But moreover, additional years of these surveys are needed because as the Constructed Wetlands Project expands and matures, habitat change will continue to produce changes in bird use of the area. Without concurrent monitoring of the bird populations, changes in the potential for bird strike hazards cannot be determined.

Finally, because wading birds are a dominant species in the summer months, more detailed attention must be given to the use of breeding colonies by these birds within the wetland complex. While only about 50 pairs of nesting birds were found in the Lower Phinizy WMA in 1998, breeding colonies of these species can change rapidly in size and can number into the hundreds. Additional studies should focus on the foraging flight patterns of birds using these colonies, as well as monitor the extent of nest success and colony expansion.

## Acknowledgments

The information presented in this paper resulted from activities conducted under a contractual agreement between the University of Georgia Research Foundation, Inc. (Savannah River Ecology Laboratory) and the Consolidated Government of Augusta - Richmond County, Georgia. We would like to extend our sincere thanks to Herb Cadle, Ed Johnson, and Elmer Segovia, first-rate pilots with Augusta Aviation, Inc., who, together with SREL observer W. L. "Cub" Stephens, spent more than 75 hours at less than 200 feet above the wetland complex surveying birds. J. B. Wall, attorney for the Consolidated Government of Augusta - Richmond County, was instrumental in defining the scope of our work and in contract arrangements. G. W. Eidson, President *Eco*Environmental Corporation, and who conducted pilot studies of the artificial wetlands for Augusta, met with us numerous times and generously shared information about the artificial wetlands. J. E. Pinder III of SREL allowed us to use a 1997 GIS habitat coverage, developed under his guidance, to quantify various habitats within our study areas. Al McDill, Manager at Bush Field Airport, now called Augusta Regional Airport at Bush Field, provided Bird Strike Reports and Wildlife Incident Reports. ZEL Engineers, Inc., of Augusta Georgia, provided us with CAD drawings of the Constructed Wetlands Project. D. S. Mizrahi of Clemson University, contributed a critical reading of an earlier report draft. D. J. Karapatakis assisted with our GIS needs. Preparation of this manuscript was supported in part by Financial Assistance Award Number DE-FC09-96SR18546 from the U.S. Department of Energy to the University of Georgia Research Foundation.

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Table 1. Habitat types and areas (hectares) within and around the Bush Field Airport, Augusta Georgia.[a]

| Habitat Type | Habitat Area |
|---|---|
| Unfilled excavations | 13.41 |
| Industrial / built up | 457.38 |
| Bare soil / bare surfaces | 128.79 |
| Herbaceous: sparse vegetation | 274.50 |
| Herbaceous: grasses & forbes | 556.83 |
| Agriculture: row crops | 488.88 |
| Agriculture: pasture and managed grassland | 624.15 |
| Scrub forests | 457.47 |
| Pines: sparse or open canopies | 149.04 |
| Pines: dense canopies | 5.13 |
| Hardwoods: evergreen | 102.78 |
| Hardwoods: uplands - floodplain | 718.47 |
| Hardwoods: floodplain | 817.29 |
| Hardwoods: swamps | 287.73 |
| Open water | 323.19 |
| Macrophytes, marshes & streams | 43.56 |
| Wetland scrub forests | 1.26 |
| Total | 5449.86 |

[a] See Figure 1 for delineation of the area covered by this habitat characterization.

Table 2. Habitat types and areas (hectares) of wetland units[a] surveyed for birds in the vicinity of Bush Field Airport, Augusta Georgia.

| Habitat Type | Upper Phinizy WMA | Lower Phinizy WMA | Merry Land Natural Complex | Total Ponds | Wetlands | Wetland |
|---|---|---|---|---|---|---|
| Unfilled excavations | 0.72 | 1.26 | 8.19 | 1.89 | 12.06 | |
| Industrial / built up | 0.36 | 0.09 | 99.72 | 11.61 | 111.78 | |
| Bare soil / bare surfaces | 0.09 | 0.00 | 48.87 | 18.81 | 67.77 | |
| Herbaceous: sparse vegetation | 0.27 | 0.36 | 52.02 | 25.74 | 78.39 | |
| Herbaceous: grasses & forbes | 9.00 | 4.14 | 112.32 | 75.78 | 201.24 | |
| Agriculture: row crops | 5.04 | 9.00 | 77.94 | 71.28 | 163.26 | |
| Agriculture: pasture and managed grassland | 9.99 | 9.90 | 29.97 | 77.76 | 127.62 | |
| Scrub forests | 16.29 | 15.21 | 102.24 | 76.23 | 209.97 | |
| Pines: sparse or open canopies | 6.30 | 10.26 | 32.76 | 19.26 | 68.58 | |
| Pines: dense canopies | 0.90 | 1.08 | 0.81 | 0.99 | 3.78 | |
| Hardwoods: evergreen | 33.75 | 40.59 | 4.05 | 7.11 | 85.50 | |
| Hardwoods: uplands -floodplain | 86.58 | 67.50 | 127.08 | 116.10 | 397.26 | |
| Hardwoods: floodplain | 126.36 | 93.69 | 126.27 | 156.96 | 503.28 | |
| Hardwoods: swamps | 72.81 | 46.62 | 102.78 | 37.80 | 260.01 | |
| Open water | 5.04 | 0.54 | 290.25 | 13.95 | 309.78 | |
| Macrophytes, marshes & streams | 2.70 | 0.45 | 35.82 | 0.72 | 39.69 | |
| Wetland scrub forests | 0.00 | 0.99 | 0.00 | 0.36 | 1.35 | |
| Total | 376.20 | 301.68 | 1251.09 | 712.35 | 2641.32 | |

[a] Wetland units characterized here are shown in Figure 1.

Table 3. Species list and guild groupings compiled from aerial bird surveys conducted in the vicinity of Bush Field Airport, Augusta Georgia.

| Guild | Common Name | Scientific Name |
|---|---|---|
| **Waterfowl** | | |
| | Snow Goose | *Chen caerulescens* |
| | Canada Goose | *Branta canadensis* |
| | Wood Duck | *Aix sponsa* |
| | American Green-winged Teal | *Anas crecca* |
| | American Black Duck | *Anas rubripes* |
| | Mallard | *Anas platyrhynchos* |
| | Blue-winged Teal | *Anas discors* |
| | Northern Shoveler | *Anas clypeata* |
| | Gadwall | *Anas strepera* |
| | American Wigeon | *Anas americana* |
| | Ring-necked Duck | *Aythya collaris* |
| | Lesser Scaup | *Aythya affinis* |
| | Bufflehead | *Bucephala albeola* |
| | Hooded Merganser | *Lophodytes cucullatus* |
| | Ruddy Duck | *Oxyura jamaicensis* |
| **Rails** | | |
| | Purple Gallinule | *Porphyrula martinica* |
| | Common Moorhen | *Gallinula chloropus* |
| | American Coot | *Fulica americana* |
| **Waders** | | |
| | Great Blue Heron | *Ardea herodias* |
| | Great Egret | *Casmerodius albus* |
| | Snowy Egret | *Egretta thula* |
| | Little Blue Heron | *Egretta caerulea* |
| | Cattle Egret | *Bubulcus ibis* |
| | Green-backed Heron | *Butorides striatus* |
| | White Ibis | *Eudocimus albus* |
| | Wood Stork | *Mycteria americana* |
| **Divers** | | |
| | Common Loon | *Gavia immer* |
| | Pied-billed Grebe | *Podilymbus podiceps* |
| | Double-crested Cormorant | *Phalacrocorax auritus* |
| | American Anhinga | *Anhinga anhinga* |

Table 3, continued

## Other species

| | |
|---|---|
| Black Vulture | *Coragyps atratus* |
| Turkey Vulture | *Cathartes aura* |
| Osprey | *Pandion haliaetus* |
| Mississippi Kite | *Ictinia mississippiensis* |
| Bald Eagle | *Haliaeetus leucocephalus* |
| Northern Harrier | *Circus cyaneus* |
| Red-shouldered Hawk | *Buteo lineatus* |
| Red-tailed Hawk | *Buteo jamaicensis* |
| Wild Turkey | *Meleagris gallopavo* |
| Yellowlegs species | *Tringa* spp. |
| Sandpiper species | Family *Scolopacidae* |
| Gull species | *Larus* spp. |
| Rock Dove (Domestic Pigeon) | *Columba livia* |
| Mourning Dove | *Zenaida macroura* |
| Belted Kingfisher | *Ceryle alcyon* |
| Red-headed Woodpecker | *Melanerpes erythrocephalus* |
| Pileated Woodpecker | *Dryocopus pileatus* |
| Swallows | Family *Hirundinidae* |
| Crow (American and/or Fish) | *Corvus* spp. |
| Loggerhead Shrike | *Lanius ludovicianus* |
| Red-winged Blackbird | *Agelaius phoeniceus* |
| Eastern Meadowlark | *Sturnella magna* |

Table 4. Numbers of aerial surveys when bird species were observed, by study unit, between January 22, 1998 and January 21, 1999 (total of 49 surveys).

| Common Name | Upper Merry Land Phinizy Ponds | Lower Phinizy WMA | Constructed Wetlands | Natural Wetlands | |
|---|---|---|---|---|---|
| **Waterfowl:** | | | | | |
| Snow Goose | 1 | | | | |
| Canada Goose | 45 | 1 | | 2 | |
| Wood Duck | 26 | 4 | 3 | | 5 |
| Am. Green-winged Teal | 6 | | | | 5 |
| American Black Duck | 1 | | | | 1 |
| Mallard | 38 | 1 | 3 | 8 | 10 |
| Blue-winged Teal | 2 | | | 12 | 2 |
| Northern Shoveler | 1 | | | 22 | 2 |
| Gadwall | 6 | | | 2 | 3 |
| American Wigeon | 12 | 13 | | 6 | 7 |
| Ring-necked Duck | 20 | 3 | | 15 | 9 |
| Lesser Scaup | 3 | | | 9 | |
| Bufflehead | 1 | | | 1 | |
| Hooded Merganser | | | | | 2 |
| Ruddy Duck | 4 | 1 | | | |
| **Rails:** | | | | | |
| Purple Gallinule | 1 | | | | |
| Common Moorhen | 1 | | | | |
| American Coot | 21 | 1 | 1 | 22 | 1 |
| **Waders:** | | | | | |
| Great Blue Heron | 42 | 10 | 13 | 17 | 23 |
| Great Egret | 41 | 28 | 39 | 31 | 45 |
| Snowy Egret | 2 | | 1 | | 1 |
| Little Blue Heron | | | 1 | 2 | |
| Cattle Egret | 6 | 6 | 6 | 2 | 10 |
| Green-backed Heron | | 2 | | | 1 |
| White Ibis | 4 | 1 | 1 | 16 | 11 |
| Wood Stork | 5 | | | | 2 |
| **Divers:** | | | | | |
| Common Loon | 4 | | | | |
| Pied-billed Grebe | 18 | | | 2 | |
| Double-crested Cormorant | 29 | 5 | 1 | 5 | 12 |
| American Anhinga | 27 | | | 1 | 8 |

Table 4, continued

| | | | | | |
|---|---|---|---|---|---|
| **Other species:** | | | | | |
| Black Vulture | 6 | 7 | 2 | | 10 |
| Turkey Vulture | | | | | 1 |

| | | | | | |
|---|---|---|---|---|---|
| Osprey | 3 | | | | 3 |
| Mississippi Kite | | | 1 | | 1 |
| Bald Eagle | 5 | | | | 2 |
| Northern Harrier | 1 | | | 4 | 2 |
| Red-shouldered Hawk | 1 | | 1 | | |
| Red-tailed Hawk | 12 | 1 | 1 | | 12 |
| Wild Turkey | 2 | | 1 | | 9 |
| Yellowlegs species | 3 | | | 34 | 2 |
| Sandpiper species | 2 | | | 4 | 1 |
| Gull species | 18 | 1 | | 1 | 2 |
| Rock Dove (Pigeon) | 9 | | | | 3 |
| Mourning Dove | 13 | 1 | 1 | | 1 |
| Belted Kingfisher | 3 | 1 | | | |
| Red-headed Woodpecker | | 1 | | | |
| Pileated Woodpecker | | 1 | | | 1 |
| Swallows | 2 | | | | |
| Crow (American or Fish) | 17 | 2 | 2 | 4 | 11 |
| Loggerhead Shrike | 1 | | | | |
| Red-winged Blackbird | 11 | 3 | 1 | 1 | 4 |
| Eastern Meadowlark | | | | | 1 |

Table 5. Maximum numbers of each bird species observed during aerial surveys, by study unit, between January 22, 1998 and January 21, 1999 (total of 49 surveys).

| Common Name | Upper Merry Land Phinizy Ponds | Lower Phinizy WMA | Constructed WMA | Natural Wetlands | Wetlands |
|---|---|---|---|---|---|
| **Waterfowl:** | | | | | |
| Snow Goose | 35 | | | | |
| Canada Goose | 150 | 2 | | 16 | |
| Wood Duck | 32 | 35 | 5 | | 15 |
| Am. Green-winged Teal | 200 | | | | 135 |
| American Black Duck | 8 | | | | 5 |
| Mallard | 77 | 5 | 10 | 50 | 27 |
| Blue-winged Teal | 20 | | | 175 | 22 |
| Northern Shoveler | 10 | | | 155 | 5 |
| Gadwall | 220 | | | 25 | 175 |
| American Wigeon | 730 | 250 | | 50 | 75 |
| Ring-necked Duck | 215 | 60 | | 450 | 575 |
| Lesser Scaup | 31 | | | 200 | |
| Bufflehead | 3 | | | 4 | |
| Hooded Merganser | | | | | 4 |
| Ruddy Duck | 200 | 50 | | | |
| **Rails:** | | | | | |
| Purple Gallinule | 5 | | | | |
| Common Moorhen | 1 | | | | |
| American Coot | 575 | 6 | 10 | 400 | 50 |
| **Waders:** | | | | | |
| Great Blue Heron | 20 | 3 | 31 | 43 | 19 |
| Great Egret | 171 | 33 | 71 | 55 | 231 |
| Snowy Egret | 7 | | 52 | | 75 |
| Little Blue Heron | | | 1 | 1 | |
| Cattle Egret | 153 | 32 | 60 | 200 | 416 |
| Green-backed Heron | | 1 | | | 1 |
| White Ibis | 16 | 5 | 25 | 135 | 58 |
| Wood Stork | 8 | | | | 37 |
| **Divers:** | | | | | |
| Common Loon | 17 | | | | |
| Pied-billed Grebe | 26 | | | 3 | |
| Double-crested Cormorant | 432 | 7 | 8 | 5 | 15 |
| American Anhinga | 23 | | | 1 | 3 |

Table 5, continued

**Other species:**

| | | | | | |
|---|---|---|---|---|---|
| Black Vulture | 3 | 3 | 4 | | 60 |
| Turkey Vulture | | | | | 2 |
| Osprey | 1 | | | | 1 |
| Mississippi Kite | | | 1 | | 2 |
| Bald Eagle | 3 | | | | 1 |
| Northern Harrier | 1 | | | 1 | 1 |
| Red-shouldered Hawk | 1 | | 1 | | |
| Red-tailed Hawk | 2 | 2 | 1 | | 2 |
| Wild Turkey | 1 | | 6 | | 8 |
| Yellowlegs species | 40 | | | 215 | 15 |
| Sandpiper species | 20 | | | 120 | 4 |
| Gull species | 325 | 4 | | 10 | 5 |
| Rock Dove (Pigeon) | 125 | | | | 10 |
| Mourning Dove | 79 | 2 | 6 | | 24 |
| Belted Kingfisher | 2 | 1 | | | |
| Red-headed Woodpecker | | 1 | | | |
| Pileated Woodpecker | | 1 | | | 1 |
| Swallows | 25 | | | | |
| Crow (American or Fish) | 34 | 2 | 2 | 10 | 45 |
| Loggerhead Shrike | 1 | | | | |
| Red-winged Blackbird | 100 | 75 | 150 | 300 | 200 |
| Eastern Meadowlark | | | | | 6 |

Table 6. Bush Field Airport Bird Strike Log entries for 1998.

| Runway/ Date Recovered | Situation Time | Taxiway[a] | Type of | Remains at Strike | Bird |
|---|---|---|---|---|---|
| 16 Jul 98 | 00:17 | 17 | Approach/alt. unknown | “small” bird | No |
| 23 Jul 98 | 22:30 | 17 | Approach/landing roll | owl | Yes |
| 31 Aug 98 | 09:15 | 17 | Approach/landing roll | sparrows (2) | Yes |
| 08 Sep 98 | 08:15 | 26 | Departure/climbing out | “small” bird | No |
| 08 Sep 98 | 20:55 | 17 | Approach/alt. 1600ft | “large” bird | No |
| 14 Sep98 | AM | 17/35 | Unknown/no pilot report | starling | Yes |
| 14 Sep 98 | 19:10 | 17 | Approach/landing roll | wrens/doves (2) | Yes |
| 05 Oct 98 | lateAM | A | Unknown/no pilot report | dove | Yes |
| 03 Nov 98 | 22:10 | 35 | Approach/runway end | doves (2) | Yes |

[a] See Figure 9, map of Bush Field Airport, for runway/taxiway locations.

Table 7. Bush Field Airport Wildlife Incident Reports for 1998[a].

| Runway/ Date | Time | Wildlife Taxiway[b] | Number Observed | Dispersal Indicated | Direction |
|---|---|---|---|---|---|
| 10 Feb 98 | 07:15 | 17/35 | fox | 1 | SE |
| 24 Feb 98 | 10:25 | C | blackbirds | 5 | W |
| 08 Mar 98 | 13:30 | 8/26 | gulls | 50-75 | N, NE |
| 09 Mar 98 | 10:30 | 17/35 | gulls | 20-30 | N |
| 24 Mar 98 | 08:30 | 8/26 | turkeys | 6-7 | S |
| 03 Jun 98 | 21:00 | 8/26 | deer | 1 | ? |
| 23 Jun 98 | 06:20 | 17/35 | “large black birds” | 10-15 | W, NW |
| 16 Aug 98 | 09:54 | A, 17/35 | “white cranes” | 2 | SW, E |
| 17 Aug 98 | 08:45 | east of 17/35 | “cow birds” | 3 | NE |
| 05 Sep 98 | 07:45 | 8/26 | starlings | 50-60 | S |
| 05 Sep 98 | 08:45 | 8/26 | starlings | 60-70 | S |
| 05 Sep 98 | 09:15 | 8/26 | starlings | 60-70 | S |
| 07 Sep 98 | 07:30 | 8/26 | starlings | 30-50 | S |
| 16 Sep 98 | 08:00 | E, 8/26 | starlings | 50-60 | E, SE, NE |
| 09 Oct 98 | 18:45 | 17/35 | “crane” | 1 | N |
| 17 Oct 98 | 11:15 | 17/35 | “crane” | 2 | NE |
| 16 Nov 98 | 07:45 | A, C, 17/35 | dove, starling? | 3 | found dead[c] |
| 16 Nov 98 | 09:30 | 17/35 | starlings | 30 | W |
| 17 Nov 98 | 08:30 | 17/35 | starlings | 20 | ? |
| 20 Dec 98 | 13:45 | 8/26 | deer | 1 | E |

[a] Wildlife Incident Reports were also filed for all bird strike incidents listed in Table 6, but are not duplicated here.

[b] See Figure 9, map of Bush Field Airport, for runway/taxiway locations.

[c] These birds were not reported as bird strikes in the Bush Field Airport Bird Strike Log as was the case for Table 6 entries dated 14 Sep and 5 Oct when other birds were similarly found dead without strike documentation from an aircraft pilot.

## Figure Legends

Figure 1. Habitat characterization map showing wetland study units and wading bird breeding colonies in the vicinity of Augusta Regional Airport at Bush Field, Georgia, USA.

Figure 2. Total counts of birds observed during aerial surveys of all study wetlands and the Constructed Wetlands Project, near Augusta Regional Airport at Bush Field, Georgia, USA, January 1998 - January 1999.

Figure 3. Total counts of birds observed during aerial surveys of the Merry Land ponds and the Constructed Wetlands Project, near Augusta Regional Airport at Bush Field, Georgia, USA, January 1998 - January 1999.

Figure 4. Total counts of birds observed during aerial surveys of the Upper and Lower Phinizy Swamp WMA, near Augusta Regional Airport at Bush Field, Georgia, USA, January 1998 - January 1999.

Figure 5. Total counts of birds observed during aerial surveys of the Natural Wetlands and the Constructed Wetlands Project, near Augusta Regional Airport at Bush Field, Georgia, USA, January 1998 - January 1999.

Figure 6. Geometric means (i.e., back-transformed least square means) and 95% confidence intervals (rectangles) of total counts of birds observed during migratory (top) and non-migratory (bottom) season aerial surveys of all wetlands near Augusta Regional Airport at Bush Field, Georgia, USA, January 1998 - January 1999.

Figure 7. Geometric means (i.e., back-transformed least square means) and 95% confidence intervals (rectangles) of bird densities observed during migratory (top) and non-migratory (bottom) season aerial surveys of all wetlands near Augusta Regional Airport at Bush Field, Georgia, USA, January 1998 - January 1999.

Figure 8. Monthly means (horizontal lines) and 95% confidence intervals (rectangles) for water levels on the Savannah River, Georgia, USA, 1984 - 1996. The solid line represents monthly mean water levels during 1998 (El Niño effect year) when aerial bird surveys were conducted over wetlands near Augusta Regional Airport at Bush Field, Georgia, USA.

Figure 9. Map of Augusta Regional Airport at Bush Field, Georgia, USA, identifying runways and taxiways.