Bird Communities of Beaver Wetlands and Forested Riparian Slopes along First- and Second-order Streams in Central Mississippi

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Abstract: Wetlands created by American beaver (*Castor canandensis*) provide habitat for a diversity of resident and migratory birds. To estimate bird community characteristics of beaver wetlands and adjacent riparian forests, we conducted point count surveys in five beaver wetlands and adjacent floodplain ridges of first- and second-order streams during winter 2001–2002 and spring 2002 in central Mississippi. Ninety bird species were recorded in beaver wetlands and 69 bird species were detected in adjacent upland forests. In beaver wetlands, we recorded 57 species during winter 2001–2002 and 69 species during spring 2002. In adjacent floodplain ridges, we recorded 37 species in winter months and 52 species during spring. Mean relative abundance of birds in beaver wetlands averaged 24.3 (± 6.8) in winter and 32.0 (± 8.3) in spring. Forests of adjacent ridges supported a mean abundance of 11.0 (± 2.5) birds in winter and 13.3 (± 2.9) in spring. Of the 90 species inhabiting beaver wetlands, 16 species were waterfowl (Order Anseriiformes), kingfishers (Order Coraciiformes), wading birds, shorebirds, and water birds (Orders Pelicaniformes, Charadiiformes, Ciconiiformes, and Suliformes). Twenty-seven bird species of beaver wetlands and 18 species of adjacent forested ridges were cavity excavators, cavity nesters, or aerially foraging insectivores. Both habitat types supported migratory and resident species of bottomland hardwood forests, and forested ridges supported upland species. Species of high conservation concern (Partners in Flight score > 16) were detected in both habitat types with selected species of warblers (Family Parulidae) and nuthatches (Family Sittidae) being most abundant in beaver wetlands. We believe that retention of beaver wetlands within first- and second-order streams that are adjacent to forested riparian areas can provide habitat for a diversity of bird species, including aquatic species and species of high conservation concern.

Key words: American beaver, avifauna, bird diversity, *Castor canadensis*, Mississippi, wetlands

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 65:62–70

Over 288,000 ha of traditional beaver wetlands (>5 years of age) and recent beaver-impounded sites exist in the southeastern states of the Gulf Coastal Plain of the United States (Arner and Hepp 1989, Jones and Leopold 2001, Swiff and Godwin 2010). Although beavers can cause damage to property, man-made structures, forests, and agricultural crops, studies have noted the ecological benefits of beaver wetlands (Jones and Leopold 2001, Muller-Schwarze and Sun 2003). Wetlands created by beavers often provide ecosystem services, including ground water recharge, outdoor recreation opportunities, improvement of water quality, slowing of surface water runoff and erosion processes, and creation of habitat for native plants, invertebrates, fish, amphibians, reptiles, mammals, and birds (Muller-Schwarze and Sun 2003).

Several studies have reported the importance of beaver wetlands to native bird communities (Arner and Hepp 1989, Muller-Schwarze and Sun 2003). Reese and Hair (1976) reported that beaver wetlands in South Carolina supported 92 species of birds, including wading birds, raptors, waterfowl, woodpeckers, and cavity-nesting songbirds. Also, beaver wetlands provide valuable nesting and brood habitat for wood ducks (*Aix sponsa*) and wintering habitat for dabbling ducks (Arner and Hepp 1989). In the northeastern United States, beaver wetlands provide important nesting and foraging habitat for American black ducks (*Anas rubripes*; Muller-Schwarze and Sun 2003). Bird diversity in beaver wetlands has been attributed to availability of surface water, variable and interspersed vegetation structure, standing and downed deadwood, and abundant plant and animal foods associated with aquatic and semi-aquatic habitats (Arner 1963, Jones and Leopold 2001). Beaver wetlands and streams that support beaver wetlands often are of greatest value to forest dwelling birds if forested buffers or streamside management zones are maintained at adequate widths to protect riparian forest, wetland, and stream habitats (Dickson 2001). Integral to the ecosystem services produced by beaver wetlands and associated riparian habitats are the ecological values produced by the indigenous animal communities (Muller-Schwarze and Sun 2003, Rosell et al. 2005). For example, diverse bird communities provide many ecosystem services, such as biological control of forest pest insects, leaf and woody detritus and nutrient recycling, seed and plant propagule dissemination, pollination of flowering plants, and recreational opportunities including bird watching and hunting (Sekercioglu 2007). These inherent ecosystem services are often not quantified or recognized during discussions and planning of management actions that impact bird conservation, beaver wetlands, and associated riparian habitats (Jones and Leopold 2001, Sekercioglu 2007).

A primary reason for a reluctance to consider potential ecosystem services provided by beaver wetlands is the economic damage caused by foraging and water impoundment by American beaver (Arner and Hepp 1989, Swiff and Godwin 2010). In Mississippi, damage to forest resources, agricultural crops, property and structures, and roadways from beaver activity can exceed US $44 million annually (Swiff and Godwin 2010). Long term inundation and feeding by beaver on tree cambium have been cited as primary reasons for mortality in trees impacted by beaver activity (Arner 1963, 1964). Also, damage to timber resources that results in tree mortality can create negative ecological impacts, especially in areas of low elevations and topographic relief. For example, losses of mature bottomland hardwood forests in the Mississippi River Alluvial Valley associated with long term impoundment of water can result in loss of habitat for selected forest-dwelling birds and mortality in mast producing oaks (*Quercus* spp; Arner and Hepp 1989, Swiff and Godwin 2010).

In Mississippi, reduced trapping of beavers and fur market declines (i.e., 1960 through 1980) led to population increases in most regions of the state (Jones and Leopold 2001, Swiff and Godwin 2010). As a result of increasing beaver populations and subsequent property damage, statewide population management programs have been implemented in past decades (Swiff and Godwin 2010). Because beavers can produce positive and negative impacts in forested landscapes, public land managers are be faced with challenges in determining costs versus benefits of retention of beavers and their wetlands. Effective evaluations of positive and negative impacts are especially important on public and private lands where conservation of biological diversity, wetland protection, and outdoor recreation are components of multiple use goals (Cubbage et al. 1993).

Because limited data existed on bird communities of beaver wetlands in Mississippi, our primary objectives are to report bird species richness and relative abundance measured in five beaver wetlands and adjacent forests of floodplain ridges of first- and second-order stream in central Mississippi during winter and spring months.

Study Area

Our study sites were located in the Upper Coastal Plain and Interior Flatwoods Soil Resource Areas in Chickasaw, Choctaw, Lowndes, and Noxubee counties, Mississippi. Study areas were located on U.S. Forest Service lands of the Tombigbee National Forest (n = 3) and on non-industrial private lands (n = 2). Study sites were characterized by hardwood and pine-hardwood forests in alluvial floodplains of first- and second-order streams (U.S. Forest Service, unpublished data). Stream floodplains were characterized by low relief topography of fronts, flats, terraces, and ridges (Hodges 1997). In the absence of beaver impoundments, streams were typified by intermittent surface water flow and potential streambed drying during late summer and fall months. Floodplain ridges were typified by a mixture of mature bottomland hardwood and mixed pine-hardwood forests (Hodges 1997). Beaver wetlands usually exhibit 30%–50% open water interspersed with standing snags (≥3 standing snags/ ha), and emergent vegetation comprised primarily of grasses (*Saccharum* spp., *Panicum* spp.), rushes (*Juncus* spp.), sedges (*Carex* spp., *Cyperus* spp., *Rhynchospora* spp.), burreed (*Sparganium americanum*), buttonbush (*Cephalanthus occidentalus*), and alder (*Alnus serrulata*).

We selected five beaver wetlands based on the following criteria: 1) >5 years of age, 2) ≥10 ha of surface water present during mid-summer months, 3) surrounding forest cover type dominated by hardwood and mixed hardwood pine forests of >50 years of age, 4) confirmed beaver occupancy, and 5) no beaver control activities had occurred within 5 years prior to study initiation and no beaver control activity planned during the study period. We selected beaver wetlands of ≥5 years of age due to the potential for well established wetlands to support aquatic plant and invertebrate communities, abundant downed and standing snags, and potentially diverse midstory and overstory structure (Arner 1963, Arner and Hepp 1989, Muller-Schwarze and Sun 2003). We estimated age of beaver wetlands through referencing USDA Forest Service maps, land management records, and historical remote imagery. We measured wetland size utilizing existing geospatial coverages and databases maintained by USDA Forest Service and field inspection and geospatial estimations in 1999–2001 (unpublished data, Tombigbee Ranger District, U.S. Forest Service). We confirmed presence of beavers through spotlight counts, incidental sightings of animals, and surveys of occupied lodges, castor mounds, feeding sign, dams, and utilized channels (per Elbroch 2003, Jones and Leopold 2001). At each beaver wetland site, we identified an adjacent forest stand located on the outer ridge of the stream's floodplain according to the following criteria: 1) forest cover type was comprised primarily of >50 year old forests of mixed hardwood or hardwood and pine species, 2) forest stand size >10ha, 3) no silvicultural activity planned or implemented during the study period, 4) streamside management zone was at least 300 m in width, and 5) forest stand was located >200 m from the outermost perimeter of the 50-m radius circular plot of the point count stations located at the beaver wetland.

Methods

Avifauna Surveys

Within each wetland and adjacent ridge site, we established four point count stations which consisted of a center point encircled by a 100-m diameter circular plot (Ralph et al. 1993). We established wetland point count stations with the center point located at the wetland edge-shoreline interface with 50% of the 100-m circle encompassing wetland habitat and 50% encompassing shoreline habitat. For each wetland edge site, we established a paired point count station in adjacent forest habitat of floodplain ridges by establishing a compass line trajectory departing at an approximate 60^0 to 90^0 angle from the station center at the wetland edge. We located point count stations so that outer perimeter of circular plots were at least 100 m into the interior of each habitat type, and we maintained a distance of >200 m between the outer perimeter of the 100-m circle of all point count stations (Ralph et al. 1993).

We recorded bird species richness and numbers of individual birds at each point count station during winter 2001–2002 (1 December 2001–10 February 2002) and spring 2002 (1 May–10 June 2002). We conducted a total of three surveys during each season at each of the point count stations between the hours of sunrise and 1000 hours central standard time. We recorded birds heard or observed within a 50-m radius of the center point of each point count station rather than extend surveys into >50-m distance bands to avoid potential bias associated with bird detectability in dense vegetation of beaver wetlands and to provide greater confidence in independence of bird activity at each station.

We calculated average abundance and species counts from three repeated surveys conducted at each point using each wetland and ridge site as the experimental unit. For comparisons between survey seasons, we derived the average species richness and relative abundance recorded over three repeated surveys in each season at each point count station in wetland and adjacent forest ridges. This approach yielded 80 observations over two seasons (4-point count stations in each of five study sites in two habitat types and two seasons). We used the Shapiro-Wilk normality test to estimate data distribution characteristics. We used a 2-way analysis of variance (PROC GLM, SAS Institute 2004) to investigate differences and interactions in bird abundance and species richness within different habitat types in winter and spring. We estimated bird community similarity in wetland and adjacent ridges by season using Renkonen's Similarity Index (Krebs 1999). We obtained conservation scores from Partners in Flight for birds of Physiographic Area 4 of the Southeast Gulf Coastal Plain (PIF Science Committee 2005). We referred to conservation scores to report occurrence and relative abundance of birds of high conservation priority detected in the two habitat types.

Results

During the study period, we recorded 97 bird species in all beaver wetlands and forested ridges with 90 species recorded in beaver wetlands and 69 species recorded in forested ridges (Table 1). In beaver wetlands, 57 species were detected in winter surveys, and 69 species were detected during spring surveys. In adjacent forest ridges, 37 and 52 species were detected during winter and spring, respectively. Beaver wetlands supported a relative abundance of 24.30 (±6.77) during winter and 31.98 (±8.30) during spring. Relative abundance of forested ridges was 10.80 (±2.50) in winter and 13.33 (±2.93) in spring.

Number of bird species detected differed by season with species numbers being higher in spring months than in winter months for both habitat types ($F_{1,76} = 58.09$, $P < 0.001$; Table 1). More bird species were detected in beaver wetlands than in riparian forest sites during spring and winter periods ($F_{1,76} = 71.74$, $P < 0.001$; Table 1). A significant interaction was detected between seasons and habitat types ($F_{1,76} = 8.50$, $P = 0.005$).

Relative abundance of birds differed between beaver wetland and riparian forest sites and between seasons (Table 1). Mean abundance of birds detected in beaver wetlands during winter months was less than mean abundance detected during spring months ($F_{1,76} = 6.08$, $P = 0.016$). Beaver wetlands supported a greater abundance of birds than did riparian forest sites during both seasons ($F_{1,76} = 60.85$, $P < 0.001$; Table 1). There was no significant interaction detected between seasons and habitat types ($F_{1,76} = 1.51$, $P = 0.217$).

Community similarity indices in beaver wetlands and forested ridges were 0.593 during winter months and 0.575 during spring months. At least 40% of the bird community composition differed between wetland and adjacent forested ridges during winter and spring. This difference in bird community similarity can be attributed to species richness of aquatic and semi-aquatic species, cavity excavators, secondary cavity nesters, and aerially foraging insectivores in beaver wetlands.

Of the 90 bird species detected in beaver wetlands, 25 species were detected only in beaver wetland habitats. Sixteen species required surface water of hydric to mesic soils for foraging or escape, loafing, or brood cover including belted kingfishers (*Megaceryle alcyon*), American woodcock (*Scolopax minor*), seven species of

Table 1. Mean relative abundance of each species of birds detected in five beaver wetlands and five adjacent floodplain ridges in central Mississippi in winter 2001–2002 and spring 2002.

	Survey period Winter 2001–2002				Survey period Spring 2002			
	Floodplain ridges ($n=5$)[b]		Beaver wetlands ($n=5$)[b]		Floodplain ridges ($n=5$)[b]		Beaver wetlands ($n=5$)[b]	
Bird group and taxonomic family Common name Scientific name (authority)[a]	**Mean abundance**[c]	**SE**	**Mean abundance**[c]	**SE**	**Mean abundance**[c]	**SE**	**Mean abundance**[c]	**SE**
Waterfowl, wading birds, shorebirds								
Order Anseriformes, family Anatidae								
Canada goose *Branta canadensis*	0.00	0.00	0.03	0.03	0.00	0.00	0.03	0.03
Gadwall *Anas strepera*	0.00	0.00	0.10	0.06	0.00	0.00	0.02	0.02
Hooded merganser *Lophodytes cucullatus*	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00
Green-winged teal *Anas crecca carolinensis*	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00
Mallard *Anas platyrhynchos*	0.00	0.00	0.42	0.15	0.00	0.00	0.05	0.04
Northern shoveler *Anas clypeata*	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Wood duck *Aix sponsa*	0.00	0.00	1.95	0.34	0.00	0.00	1.05	0.35
Order Ciconiiformes, family Phalacrocoracidae								
Double-crested cormorant *Phalacrocorax auritus*	0.00	0.00	0.62	0.57	0.00	0.00	0.00	0.00
Order Ciconiiformes, family Ardeidae								
Great blue heron *Ardea herodias*	0.00	0.00	0.57	0.19	0.02	0.02	1.57	0.56
Great egret *Ardea alba*	0.00	0.00	0.00	0.00	0.00	0.00	2.75	2.19
Green-backed heron *Butorides striata*	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.04
Little blue heron *Egretta caerulea*	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.04
Snowy egret *Egretta thula*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Order Ciconiiformes, family Ciconiidae								
Wood stork *Mycteria americana*	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05
Order Ciconiiformes, family Scolopacidae								
American woodcock *Scolopax minor*	0.00	0.00	0.03	0.02	0.00	0.00	0.00	0.00
Kingfishers								
Order Coraciiformes, family Alcedinidae								
Belted kingfisher *Megaceryle alcyon*	0.00	0.00	0.05	0.03	0.00	0.00	0.05	0.03
Raptors								
Order Ciconiiformes, family Accipitridae								
Cooper's hawk *Accipiter cooperii*	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Red-shouldered hawk *Buteo lineatus*	0.17	0.05	0.25	0.07	0.08	0.04	0.27	0.09
Red-tailed hawk *Buteo jamaicensis*	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00
Sharp-shinned hawk *Accipiter striatus*	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00
Order Ciconiiformes, family Ciconiidae								
Black vulture *Coragyps atratus*	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03
Order Strigiformes, family Strigidae								
Barred owl *Strix varia*	0.05	0.04	0.02	0.02	0.03	0.03	0.03	0.03
Great horned owl *Bubo virginianus*	0.02	0.02	0.02	0.02	0.02	0.02	0.00	0.00
Swifts and hummingbirds								
Order Apodiformes, family Apodidae								
Chimney swift *Chaetura pelagica*	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.03
Order Apodiformes, family Trochilidae								
Ruby-throated hummingbird *Archilochus colubris*	0.00	0.00	0.00	0.00	0.03	0.03	0.02	0.02
Upland gamebirds								
Order Columbiformes, family Columbidae								
Mourning dove *Zenaida macroura*	0.08	0.04	0.05	0.03	0.07	0.03	0.43	0.08
Order Galliformes, family Odontophoridae								
Northern bobwhite *Colinus virginianus*	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Cuckoos								
Order Cuculiformes, family Cuculidae								
Yellow-billed cuckoo *Coccyzus americanus*	0.00	0.00	0.00	0.00	0.42	0.09	1.17	0.11

a. Reference: http//www.itis.gov. This website is an integrated taxonomic information system maintained and sponsored by cooperative partnerships between agencies, organizations, and taxonomic specialists of United States, Canada, and Mexico.

b. Number of study sites in each habitat type.

c. For each season and habitat type, mean relative abundance was calculated as follows: Σ (Number of birds recorded at each point count station) ÷ 3 (3 = repeated number of surveys/season/point count station) = mean number of birds recorded over 3 repeated surveys at each point count station during each season] ÷ (4 point count stations per study site) (5 study sites per habitat type).

Table 1. *(Continued)*

	Survey period Winter 2001–2002				Survey period Spring 2002			
	Floodplain ridges ($n=5$)[b]		Beaver wetlands ($n=5$)[b]		Floodplain ridges ($n=5$)[b]		Beaver wetlands ($n=5$)[b]	
Bird group and taxonomic family Common name *Scientific name* (authority)[a]	Mean abundance[c]	SE	Mean abundance[c]	SE	Mean abundance[c]	SE	Mean abundance[c]	SE
Perching birds								
Order Passeriformes, family Bombycillidae								
Cedar waxwing *Bombycilla cedrorum*	0.02	0.02	0.38	0.22	0.00	0.00	0.00	0.00
Order Passeriformes, family Cardinalidae								
Blue grosbeak *Passerina caerulea*	0.000	0.00	0.00	0.00	0.15	0.06	0.22	0.06
Indigo bunting *Passerina cyanea*	0.00	0.00	0.00	0.00	0.47	0.08	0.83	0.11
Northern cardinal *Cardinalis cardinalis*	0.93	0.13	1.22	0.14	1.35	0.13	1.53	0.13
Scarlet tanager *Piranga olivacea*	0.00	0.00	0.00	0.00	0.05	0.03	0.00	0.00
Summer tanager *Piranga rubra*	0.00	0.00	0.00	0.00	0.35	0.09	0.30	0.07
Order Passeriformes, family Corvidae								
American crow *Corvus brachyrhynchos*	0.77	0.14	0.72	0.15	0.60	0.11	0.73	0.09
Blue jay *Cyanocitta cristata*	0.47	0.09	0.90	0.18	0.38	0.12	0.25	0.07
Fish crow *Corvus ossifragus*	0.02	0.02	0.17	0.08	0.02	0.02	0.15	0.06
Order Passeriformes, family Emberizidae								
Chipping sparrow *Spizella passerina*	0.20	0.08	0.63	0.21	0.03	0.02	0.02	0.02
Eastern towhee *Pipilo erythrophthalmus*	0.35	0.08	0.62	0.12	0.68	0.11	0.32	0.07
Fox sparrow *Passerella iliaca*	0.00	0.00	0.05	0.04	0.00	0.00	0.00	0.00
Song sparrow *Melospiza melodia*	0.00	0.00	0.08	0.06	0.00	0.00	0.00	0.00
Swamp sparrow *Melospiza georgiana*	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05
White-throated sparrow *Zonotrichia albicollis*	0.00	0.00	0.18	0.12	0.00	0.00	0.00	0.00
Order Passeriformes, family Fringillidae								
House finch *Carpodacus mexicanus*	0.00	0.00	0.12	0.10	0.00	0.00	0.00	0.00
American goldfinch *Carduelis tristis*	0.05	0.04	0.58	0.21	0.00	0.00	0.10	0.05
Order Passeriformes, family Hirundinidae								
Barn swallow *Hirundo rustica*	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.03
Northern rough-winged swallow *Stelgidopteryx serripenis*	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.12
Order Passeriformes, family Icteridae								
Brown-headed cowbird *Molothrus ater*	0.00	0.00	0.00	0.00	0.07	0.04	0.28	0.14
Common grackle *Quiscalus quiscula*	0.20	0.13	2.27	0.58	0.05	0.04	1.72	0.55
Orchard oriole *Icterius spurious*	0.00	0.00	0.05	0.04	0.02	0.02	0.07	0.03
Red-winged blackbird *Agelaius phoeniceus*	0.00	0.00	0.03	0.03	0.00	0.00	0.33	0.09
Order Passeriformes, family Mimidae								
Brown thrasher *Toxostoma rufum*	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00
Gray catbird *Dumetella carolinensis*	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00
Northern mockingbird *Mimus polyglottos*	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Order Passeriformes, family Paridae								
Carolina chickadee *Poecile carolinensis*	1.37	0.23	1.77	0.24	0.28	0.07	0.98	0.16
Tufted titmouse *Baeolophus bicolor*	0.98	0.14	1.82	0.19	1.00	0.10	1.60	0.14
Order Passeriformes, family Parulidae								
Black-and-white warbler *Mniotilta varia*	0.00	0.00	0.00	0.00	0.07	0.03	0.05	0.03
Common yellowthroat *Geothlypis trichas*	0.00	0.00	0.08	0.04	0.03	0.02	1.15	0.18
Hooded warbler *Wilsonia citrina*	0.00	0.00	0.00	0.00	0.03	0.02	0.10	0.05
Kentucky warbler *Oporornis formosus*	0.00	0.00	0.00	0.00	0.20	0.07	0.22	0.06
Louisiana waterthrush *Seiurus motacilla*	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.09
Northern parula *Parula americana*	0.00	0.00	0.03	0.02	0.10	0.05	0.35	0.08
Pine warbler *Dendroica pinus*	1.43	0.14	0.88	0.14	1.12	0.15	0.35	0.08
Prairie warbler *Dendroica discolor*	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00

a. Reference: http//www.itis.gov. This website is an integrated taxonomic information system maintained and sponsored by cooperative partnerships between agencies, organizations, and taxonomic specialists of United States, Canada, and Mexico.

b. Number of study sites in each habitat type.

c. For each season and habitat type, mean relative abundance was calculated as follows: ∑ (Number of birds recorded at each point count station) ÷ 3 (3 = repeated number of surveys/season/point count station) = mean number of birds recorded over 3 repeated surveys at each point count station during each season] ÷ (4 point count stations per study site) (5 study sites per habitat type).

Table 1. *(Continued)*

	Survey period Winter 2001–2002				Survey period Spring 2002			
	Floodplain ridges (*n* = 5)[b]		Beaver wetlands (*n* = 5)[b]		Floodplain ridges (*n* = 5)[b]		Beaver wetlands (*n* = 5)[b]	
Bird group and taxonomic family Common name Scientific name (authority)[a]	**Mean abundance**[c]	**SE**	**Mean abundance**[c]	**SE**	**Mean abundance**[c]	**SE**	**Mean abundance**[c]	**SE**
Perching birds								
Order Passeriformes, family Parulidae								
Prothonotary warbler *Protonotaria citrea*	0.00	0.00	0.05	0.03	0.22	0.08	1.18	0.14
Yellow-breasted chat *Icteria virens*	0.00	0.00	0.00	0.00	0.90	0.12	1.00	0.13
Yellow-rumped warbler *Dendroica coronata*	0.15	0.05	0.33	0.13	0.00	0.00	0.00	0.00
Yellow-throated warbler *Dendroica dominica*	0.00	0.00	0.00	0.00	0.02	0.02	0.12	0.05
Yellow warbler *Dendroica petechia*	0.07	0.07	0.00	0.00	0.00	0.00	0.03	0.03
Order Passeriformes, family Sittidae								
Brown-headed nuthatch *Sitta pusilla*	0.00	0.00	0.00	0.00	0.10	0.05	0.08	0.05
Red-breasted nuthatch *Sitta canadensis*	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00
White-breasted nuthatch *Sitta carolinensis*	0.00	0.00	0.00	0.00	0.02	0.02	0.05	0.04
Order Passeriformes, family Troglodytidae								
Carolina wren *Thryothorus ludovicianus*	0.88	0.12	0.77	0.11	0.77	0.10	0.93	0.10
Order Passeriformes, family Turdidae								
American robin *Turdus migratorius*	0.67	0.29	0.63	0.31	0.05	0.04	0.00	0.00
Eastern bluebird *Sialia sialis*	0.05	0.03	1.25	0.69	0.00	0.00	0.07	0.04
Hermit thrush *Catharus guttatus*	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00
Wood thrush *Hylocichla mustelina*	0.00	0.00	0.00	0.00	0.02	0.02	0.23	0.08
Order Passeriformes, family Polioptilidae								
Blue-gray gnatcatcher *Polioptila caerulea*	0.25	0.11	0.28	0.11	0.27	0.08	0.70	0.12
Order Passeriformes, family Regulidae								
Golden-crowned kinglet *Regulus satrapa*	0.02	0.02	0.03	0.03	0.00	0.00	0.00	0.00
Ruby-crowned kinglet *Regulus calendula*	0.02	0.02	0.05	0.04	0.00	0.00	0.00	0.00
Order Passeriformes, family Tyrannidae								
Acadian flycatcher *Empidonax virescens*	0.00	0.00	0.02	0.02	0.12	0.05	0.38	0.01
Eastern kingbird *Tyrannus tyrannus*	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.07
Eastern phoebe *Sayornis phoebe*	0.05	0.04	0.17	0.06	0.00	0.00	0.02	0.02
Eastern wood-pewee *Contopus virens*	0.03	0.02	0.02	0.02	0.40	0.08	0.78	0.10
Great crested flycatcher *Myiarchus crinitus*	0.00	0.00	0.23	0.10	0.12	0.04	0.75	0.12
Order Passeriformes, family Vireonidae								
Blue-headed vireo *Vireo solitarius*	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Red-eyed vireo *Vireo olivaceus*	0.00	0.00	0.02	0.02	0.62	0.11	0.65	0.11
White-eyed vireo *Vireo griseus*	0.00	0.00	0.03	0.02	0.62	0.11	1.07	0.12
Yellow-throated vireo *Vireo flavifrons*	0.00	0.00	0.02	0.02	0.22	0.06	0.28	0.07
Woodpeckers								
Order Piciformes, family Picidae								
Downy woodpecker *Picoides pubescens*	0.03	0.02	0.28	0.08	0.05	0.04	0.20	0.06
Hairy woodpecker *Picoides villosus*	0.00	0.00	0.10	0.05	0.07	0.04	0.18	0.07
Northern flicker *Colaptes auratus*	0.03	0.02	0.03	0.02	0.00	0.00	0.15	0.05
Pileated woodpecker *Dryocopus pileatus*	0.13	0.04	0.28	0.07	0.27	0.07	0.35	0.10
Red-bellied woodpecker *Melanerpes carolinus*	0.58	0.08	0.92	0.11	0.52	0.07	1.40	0.13
Red-headed woodpecker *Melanerpes erythrocephalus*	0.58	0.10	1.98	0.21	0.22	0.05	1.48	0.15
Yellow-bellied sapsucker *Sphyrapicus varius*	0.03	0.02	0.08	0.04	0.00	0.00	0.02	0.02
Unidentified species	0.00	0.00	0.02	0.02	0.02	0.02	0.02	0.02

a. Reference: http//www.itis.gov. This website is an integrated taxonomic information system maintained and sponsored by cooperative partnerships between agencies, organizations, and taxonomic specialists of United States, Canada, and Mexico.

b. Number of study sites in each habitat type.

c. For each season and habitat type, mean relative abundance was calculated as follows: Σ (Number of birds recorded at each point count station) ÷ 3 (3 = repeated number of surveys/season/point count station) = mean number of birds recorded over 3 repeated surveys at each point count station during each season] ÷ (4 point count stations per study site) (5 study sites per habitat type).

wading birds and water birds, and seven species of waterfowl (Table 1). Other species that were only detected in wetland habitats included northern rough-winged swallow (*Stelgidopteryx serripennis*), barn swallow (*Hirundo rustica*), chimney swift (*Chaetura pelagica*), Louisiana waterthrush (*Parkesia motacilla*), red-winged blackbird (*Ageliaus phoeniceus*), and swamp sparrow (*Melospiza georgiana*).

Cavity excavators and nesters were most abundant in beaver wetlands and comprised 18 of the species detected in beaver wetlands. The most frequently recorded cavity excavators were red-bellied and red-headed woodpeckers (*Melanerpes carolinus, M. erythrocephalus*). Secondary cavity nesters detected in greatest relative abundance in wetlands during spring months included prothonotary warblers (*Protonotaria citrea*), nuthatches (family Sittidae), eastern bluebirds (*Sialis sialis*), tufted titmice (*Baeolophus bicolor*), Carolina chickadees (*Poecile carolinensis*), and great-crested flycatchers (*Myiarchus crinitus*); Carolina chickadees, tufted titmice, and Carolina wrens (*Thyothorus ludovicianus*) were the most common cavity nesters detected in both habitat types.

Bird species that were common to both habitat types during winter and spring months included northern cardinal (*Cardinalis cardinalis*), American crow (*Corvus brachyrhynchos*), pine warbler (*Setophaga pinus*), and blue jay (*Cyanocitta cristata*; Table 1). The most common winter migrant that detected both habitat types was American robin (*Turdus migratorius*). Species of birds that were detected only in forested ridge habitats included northern bobwhite (*Colinus virginianus*), prairie warbler (*Setophaga discolor*), scarlet tanager (*Piranga olivacea*), sharp-shinned hawk (*Accipiter striatus*), Cooper's hawk (*Accipiter cooperii*), and blue-headed vireo (*Vireo solitarius*; Table 1).

Bird species of high conservation priority were detected in both habitat types. Highest priority bird species detected during spring months in wetlands were prothonotary warbler, Kentucky warbler (*Geothlypis formosa*), Acadian flycatcher (*Empidonax virescens*), orchard oriole (*Icterus spurious*), nuthatches, hermit thrush (*Catharus guttatus*), and wood thrush **(***Hylocichla mustelina***;** Table 1). In forested ridges, birds of conservation concern included Northern bobwhite, prairie warbler**,** hermit thrush, and scarlet tanager (*Piranga olivacea*).

Discussion

Results of our study are similar to other studies that reported a diversity of birds in beaver wetlands (Reese and Hair 1976, Muller-Schwarze and Sun 2003). For example, Reese and Hair (1976) reported that 92 species of birds used beaver wetlands in South Carolina. Similarly, we detected 90 species of birds in beaver wetlands. Approximately 18% of the species that we detected in beaver wetlands were aquatic and semi-aquatic species that depend on the variety of plant and animal food sources available in beaver wetlands (Arner and Hepp 1989, Scwharze-Mueller and Sun 2003). For these bird species, the presence of beaver wetlands on forested landscapes may be essential for foraging, loafing, or reproduction (Arner and Hepp 1989).

In addition to aquatic and semi-aquatic species, a variety of cavity nesters, excavators, and aerial foraging insectivores were detected in wetland habitats which may have been related to nesting cover and foraging conditions available in and along wetland edges. Habitat conditions within beaver wetlands, such as open water interspersed with emergent herbaceous plants and shrubs of variable heights (>3 m in height), may have created desirable nesting conditions for thicket-nesting species and substrate for aquatic vertebrate and invertebrate food sources (Pennak 1953, Muller-Schwarze and Sun 2003). Invertebrate food sources (e.g., larvae of midges, mosquitoes, mayflies, and dragonflies) are important to many birds detected in wetlands (Muller-Schwarze and Sun 2003). Further, hatches and metamorphosis of flying insects from wetland surface waters of beaver wetlands produce an abundance of flying insect prey that may be exploited by flycatchers, swifts, swallows, and bats (Muller-Schwarze and Sun 2003).

Another feature of the wetlands that appeared to influence bird communities was the presence of standing snags and living cavity trees. Wetlands were typified by >3 snags/ha and >2 living cavity trees/ha along wetland edges. In adjacent forested ridges, standing snags densities averaged ≤1 snag/ha and densities of living cavity trees were similar to that of wetland edges. Many standing snags in wetlands and along wetland edges were due to tree mortality caused by beaver foraging and damming activities (Arner 1963, Arner and Hepp 1989). Forest stand composition and age class (>70 years of age) potentially influenced abundance of living and dead cavity trees in both habitat types (Hamilton et al. 2005). These forest conditions were a result of silvicultural practices that protected forested buffers at ≥200 m in width from wetland edges and > 100 m from streams (unpublished data Forest Management Plan, USFS Tombigbee Ranger District).

Other studies have reported an abundance of cavity nesting birds in beaver wetlands (Reese and Hair 1976). In our study, woodpecker species were typically the most abundant cavity excavators and nesters in wetland sites, and highest numbers of these species were detected during spring breeding periods. Also, we detected other cavity nesters (e.g., nuthatches, prothonotary warblers, and flycatchers) in greatest numbers in beaver wetlands during spring months.

We detected birds of high conservation value in both habitat types. Wetlands supported a greater number of species with PIF scores of >16. These results were similar to those summarized by Muller-Schwarze and Sun (2003), who reported use of beaver wetlands by neotropical migrant birds of high conservation concern, such as prothonotary warbler, yellow-billed cuckoo (*Coccyzus americanus*), and northern parula (*Setophaga americana*). Although greater numbers of high conservation concern species were detected in our beaver wetlands, we recommend that adjacent forested floodplains be retained to support greater species richness of birds associated with wetland and riparian forest habitats.

Although we did not quantify influences of surrounding forest landscapes, we submit that adjacent forests influenced bird communities within wetland and forested ridge sites of our study (Dickson 2001). For example, three beaver wetlands on public lands supported the greatest numbers of bird species. These sites were characterized by larger size streamside management zones and wetland buffers than those of private lands. On forest ridge sites, interior and adjacent forest stand conditions influenced the presence of selected bird species. Forest composition within ridge study sites were comprised of mixed hardwood pine and hardwood forests with interspersed vine and thicket cover in areas of storm damage. Bird communities detected in these habitats were typified by species of mature bottomland and upland hardwood forests (Hamilton et al. 2005). However, several bird species detected in these sites were probably present due to adjacent habitat types which had been managed through selective tree harvests and shelterwood regeneration cuts. For example, on one study site, forest management in an adjacent area had created early successional habitat of ≤ 15 years of age, and detection of northern bobwhite in this site was potentially due to the adjacent early successional habitat (Burger 2001).

Based on our results, we recommend that future studies be conducted in beaver wetlands to assess their potential role in maintenance of landscape level biological diversity. In our study, we measured species numbers and abundance of birds in wetlands and adjacent forests; however, we did not design our study to compare bird community characteristics in the presence of beaver wetlands versus absence of beaver wetlands which would require the location of similar riparian areas with and without beaver wetlands. Challenges we encountered in attempting this type of design included difficulties in location of adequate study sites including beaver wetlands that were >5 years of age with no planned control or drainage and riparian habitats that had streamside management zones of adequate widths for point count survey methodologies. Because our streams were first- and second-order streams that often dried during summer and fall months, protected streamside management zones were often ≤50 m in width if wetlands were not present. However, different sample methods for birds may be necessary to accommodate varying widths of streamside management zones of first- and second-order streams that lack floodplain wetlands. Also, greater inferences could be gained with greater numbers of study sites within multiple forest types and inclusion of habitat evaluation surveys along with bird community measurements.

From our study, we gained a greater understanding of the bird communities in beaver wetlands of >5 years of age and adjacent forest ridges associated with first- and second-order streams in central Mississippi. This information was utilized in revisions of Forest Management plans for Tombigbee National Forest and resulted in the retention of beaver and beaver wetlands on forested landscapes in areas where damage was limited to tree mortality (Forest Management Plan, Tombigbee National Forest, unpublished). Abundant food resources and diverse habitat structure in beaver wetlands provided valuable wintering and breeding habitat for many bird species. In addition to nongame birds and waterfowl, Arner (1964) reported that aquatic mammals, such as American otter (*Lutra canadensis*) and mink (*Mustela vison*), benefited from retention of beaver wetlands in forested landscapes. Other studies have reported beaver wetlands as important habitats for amphibians, reptiles, fish, and invertebrates (Rosell et al. 2005). Today, federal listing of the Mitchell's Satyr butterfly (*Neonympha mitchelli mitchellii*) has increased interest in beaver wetland conservation due to the dependency of this rare species on shrub-sedge dominated wetlands (U.S. Fish and Wildlife Service 1998). Because of the habitat provided by beaver wetlands for birds and other wildlife, we recommend the continued consideration of retention and protection of beaver wetlands in areas where extensive damage to property, agricultural crops, flood control structures, and roadways is not a problem (Schwarze-Muller and Sun 2003). Further, we support the approach recommended by Arner (1964) who reported that management of beavers on the landscape should entail selective management of beaver numbers when damage issues arise, but called for protection of beaver wetlands in areas where damage was not an issue. On public lands, this integrative approach could enhance effectiveness of conservation of biological diversity and enhance recreational opportunities associated with beaver wetlands and minor streams of central Mississippi.

Acknowledgments

We appreciate the support of the Forest and Wildlife Research Center of Mississippi State University and funding and background information provided by the USDA Forest Service. We appreciate the field survey efforts of J. Robertson and R. Singleton. We dedicate this paper to Dr. D. H. Arner, who has spent much of his 91-year lifetime studying American beavers and the habitats they create.

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