BREEDING BIRD COMMUNITIES ON FOUR WATERSHEDS UNDER DIFFERENT FOREST MANAGEMENT SCENARIOS IN THE OUACHITA MOUNTAINS OF ARKANSAS

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Abstract—Concern for many migratory landbird species has led to an increased emphasis on managing ecosystems at scales beyond the stand level. We characterized breeding bird numbers, species richness, diversity, and evenness on four watersheds in the Ouachita Mountains of west-central Arkansas. These four watersheds represented different ownerships and management objectives, and thus differed markedly in many respects, including landcover composition and distribution, mean patch size, and edge density. Point count surveys were conducted by three observers on approximately 525 different 50-m radius plots each spring during 1995-1998, for a total of 2,108 plots. A total of 19,030 birds were encountered representing 97 species. Patterns in numbers of individuals, species richness, and diversity appeared associated with the level of spatial heterogeneity and landscape composition in each watershed. Numbers of individuals per plot, species per plot, and diversity per plot for migrant and resident species were generally all highest in watersheds with high levels of management activity and lowest in watersheds with low levels of management activity. Watersheds were similar in regard to cavity and canopy nesting bird community characteristics. Ground and shrub nesting bird community characteristics were related to amounts of available early successional habitats. Species of special concern were represented in all watersheds.

INTRODUCTION

Concern for many migratory landbird species has led to an increased emphasis on managing ecosystems at scales beyond the stand level. Birds are often viewed as indicators of ecosystem health due to their sensitivity to environmental variability (Maurer 1993). Growing evidence suggests that populations of many species of neotropical migratory birds (NTMB), (species that migrate each year between temperate breeding areas and tropical wintering areas) are declining and that these declines have accelerated in recent years (Robbins and others, 1989; Askins and others, 1990; Finch 1991). Available information suggests that these populations may be limited by circumstances on both their wintering and breeding habitat, as well as along their migration routes (Sherry and Holmes 1993). Factors that have been implicated on their breeding range include habitat destruction/alteration, forest fragmentation, increased nest parasitism by brown-headed cowbirds (*Molothrus ater*), and increased predation, especially in edge-dominated habitat.

Substantial knowledge exists on stand-level avian community relationships, but information is needed to assess the impacts of different types, intensities, and spatial arrangements of forest management practices on NTMB at the landscape/watershed level. In the Ozark-Ouachita Highland physiographic area, Hunter and others (1993) identified several neotropical migratory species to be declining in numbers, including 11 of 22 species that inhabit mature forest and 4 of 6 species that inhabit forest edges. Where landscapes are fragmented by agriculture/urbanization, fragmentation has been implicated in NTMB declines. However, the impacts on bird populations of forest fragmentation that result in a mosaic of different stand compositions and ages with little or no agriculture/urban inclusions (characteristic of much of the Ouachita Mountains) are unknown.

This paper reports on results of a 4-year study (1995 – 1998) of breeding bird communities on four watersheds under different levels of forest management intensity. Our objectives were to (1) compare avian community and nesting guild characteristics (numbers of individuals, species richness, diversity, and evenness) across watersheds, and (2) relate these community characteristics to landscape attributes. We documented community characteristics of migrant and resident species, as well as three nesting guilds: canopy nesters, cavity nesters, and ground and shrub nesters.

METHODS

Study areas

Four watersheds included in the Ouachita Mountain Ecosystem Management Research Project described by Guldin (this volume) and Tappe and others (this volume) served as the study areas. The watersheds were located in Garland and Saline Counties in the Ouachita Mountains near Hot Springs, Arkansas. Past and current forest management practices on each watershed reflected different combinations of forest ownership and distinct management strategies, thus providing a range of intensity of management activities. Consequently, these watersheds differ markedly in many respects, including landcover composition and distribution characteristics, mean patch size, and edge density (Tappe and others, in press).

The Little Glazypeau watershed (LG), consisting of 2,275 ha and managed largely for sawlog production by Weyerhaeuser

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Company, represented the most intensively managed watershed. Much of the second-growth shortleaf pine (*Pinus echinata*)-hardwood forest that originally covered this watershed had been harvested and planted to loblolly pine (*P. taeda*) plantations that ranged in size from 9 to 142 ha. These plantations are normally thinned twice, pruned up to approximately 5 to 8 m high, fertilized, and harvested at 30 to 35 years of age. Other unharvested and selectively harvested acreage in the watershed occurs on rocky ridge tops, on steep slopes, and in streamside management zones that were retained for watershed protection and to provide wildlife habitat diversity.

The North Alum Creek watershed (NAC) was of mixed ownership, with about half of the area under Weyerhaeuser Company management and half under USDA Forest Service management. This watershed encompasses 3,961 ha of land under a diverse range of management activities, ranging from no management to intensively managed loblolly pine plantations similar to that in the LG watershed. USDA Forest Service land within this watershed is primarily mixed shortleaf pine–hardwood forest and has been managed using a mixture of silvicultural approaches to obtain multiple objectives as set by the Ouachita National Forest.

The 1,535-ha Bread Creek watershed (BC), primarily USDA Forest Service land, has been managed according to prevailing Forest Service standards and guides for several decades. It is composed primarily of mixed shortleaf pine–hardwood forest that has been managed similar to USDA Forest Service land located in the NAC watershed.

The South Alum Creek watershed (SAC) represented the lowest management intensity. This 1,499-ha watershed, which is designated as the Alum Creek Experimental Forest, is almost entirely USDA Forest Service land and has received minimal management over the past several decades; it now consists of a mature, mixed forest over the majority of the area.

More detailed information on landcover characteristics and patch and landscape attributes can be found in Tappe and others (in press). Tappe and others (in press) ranked the watersheds in order of decreasing spatial and compositional heterogeneity as LG>NAC>BC>SAC.

Bird Surveys

Because of the large sizes of the watersheds, adequate coverage of all portions of each watershed was not logistically possible within a single year using permanent points. Thus, we installed 505 – 550 plots each year to allow for sampling all portions of each watershed. In 1995, nearly 113 km of transects with plots located approximately 200 m apart were established over the four watersheds. In 1996, the same transects were used, but new plots were located between the 1995 plots by shifting plot centers 100 m. In 1997, approximately 113 km of new transects were established between the original transects and a new set of plots were used. In 1998, new plots were located between the 1997 plots, along the same transects. This resulted in 2,108 sample plots over the duration of the study (table 1).

Birds were sampled between May 6 and June 9 each year using 50-m fixed-radius point counts. Each plot was censused once by three different observers. All counts lasted 5 minutes and were conducted within 3.5 hours of sunrise on days with little or no rain and with winds < 6-11 kph.

Analyses

Bird counts from each observer were combined to provide one data set for each point sampled within a given year. Species that are not known to breed in the Ouachita Mountains of Arkansas were not used in any analyses. Numbers of individuals, species richness, diversity (Shannon and Weiner 1963), and evenness were computed for each point for all breeding birds combined and for each of the following subsets: migrants (short- and long-distance combined), residents, canopy nesters, cavity nesters, and ground and shrub nesters. A 2-way analysis-of-variance was used to test ($\alpha \leq 0.05$) for year, watershed, and year-watershed interaction effects. If a year-watershed interaction existed, differences in the watershed effect were interpreted within years using a one-way analysis-of-variance. Mean separation was accomplished using Fisher's least significant differences (LSD) procedure. Because watersheds could not be replicated, means across the three observers within years constituted pseudoreplication. This limited our inference space, and thus constrained our results and conclusions to the four specific watersheds on which the study was conducted.

Table 1—Number of points used each year for sampling breeding bird communities on four watersheds under different levels of forest management activity in the Ouachita Mountains of Arkansas

	Year				
Watershed	1995	1996	1997	1998	Total
	number				
Little Glazypeau	124	117	154	141	536
North Alum Creek	235	226	232	224	917
Bread Creek	75	75	76	76	302
South Alum Creek	90	87	88	88	353
Total	524	505	550	529	2,108

Table 2—Species list[a] and frequencies of occurrence of birds identified during 50-m fixed-radius point counts during May–June 1995 through 1998 on four watersheds under different levels of forest management activity in the Ouachita Mountains of Arkansas[b]

Species	Scientific name	*n*	Total	Birds per 100 plots			
				LG	NAC	BC	SAC
			percent				
Red-eyed vireo	*Vireo olivaceus*	3,219	16.92	126.62	173.77	144.92	141.41
Pine warbler	*Dendroica pinus*	1,965	10.33	79.48	83.72	102.95	128.17
Indigo bunting	*Passerina cyanea*	1,556	8.18	107.02	81.64	45.90	25.35
Black and white warbler	*Mniotilta varia*	1,150	6.04	63.96	63.06	42.62	27.32
Carolina chickadee	*Parus carolinensis*	858	4.51	56.38	36.28	35.41	31.83
White-eyed vireo	*Vireo griseus*	798	4.19	75.60	37.38	14.43	0.85
Blue-gray gnatcatcher	*Polioptila caerulea*	708	3.72	75.42	23.83	21.64	4.51
Ovenbird	*Seiurus aurocapillus*	659	3.46	4.81	32.13	31.48	68.45
Yellow-breasted chat	*Icteria virens*	635	3.34	61.92	27.21	16.07	0.56
Prairie warbler	*Dendroica discolor*	613	3.22	55.64	26.34	22.62	0.56
Scarlet tanager	*Piranga olivacea*	592	3.11	19.96	31.26	25.57	33.80
Common yellowthroat	*Geothlypis trichas*	484	2.54	51.39	20.87	4.59	0.28
Tufted-titmouse	*Parus bicolor*	460	2.42	27.17	22.30	11.48	20.85
Hooded warbler	*Wilsonia critrina*	392	2.06	37.15	19.45	3.28	0.85
Carolina wren	*Thryothorus ludovicianus*	371	1.95	34.94	14.21	7.87	7.89
Cedar waxwing[b]	*Bombycilla cedrorum*	337	1.77	18.11	17.38	16.39	8.45
Northern cardinal	*Cardinalis cardinalis*	296	1.56	32.72	9.84	9.18	0.28
Kentucky warbler	*Oporomis formosus*	289	1.52	29.39	11.80	6.89	0.28
Summer tanager	*Piranga rubra*	272	1.43	16.45	13.11	7.21	11.55
Pileated woodpecker	*Dryocopus pileatus*	247	1.30	8.32	11.37	11.48	17.75
Great-crested flycatcher	*Myiarchus crinitus*	233	1.22	11.65	11.80	7.54	10.99
Yellow-billed cuckoo	*Coccyzus americanus*	210	1.10	7.21	13.44	10.16	4.79
American crow	*Corvus brachyrhynchos*	207	1.09	12.38	9.51	6.23	9.58
Bluejay	*Cyanocitta cristata*	200	1.05	5.36	7.43	12.79	18.03
American goldfinch	*Carduelis tristis*	194	1.02	23.84	4.81	2.30	3.94
Worm-eating warbler	*Helmitheros vermivorus*	189	0.99	11.46	10.93	5.57	2.82
Field sparrow	*Spizella pusilla*	188	0.99	19.22	7.32	5.25	0.28
Acadian flycatcher	*Empidonax virescens*	165	0.87	11.46	9.62	1.64	2.82
Rufous-sided towhee	*Pipilo erythrophthalmus*	132	0.69	14.42	5.68	0.66	0.00
Brown-headed cowbird	*Molothrus ater*	129	0.68	21.26	1.31	0.33	0.28
Hairy woodpecker	*Picoides villosus*	123	0.65	2.40	6.56	7.87	7.32
White-breasted nuthatch	*Sitta carolinensis*	87	0.46	2.03	6.23	0.98	4.51
Downy woodpecker	*Picoides pubescens*	76	0.40	7.58	2.62	2.95	0.56
Northern bobwhite	*Colinus virginianus*	73	0.38	4.81	4.48	1.64	0.28
Swainson's thrush[b]	*Catharus ustulatus*	68	0.36	1.85	4.59	4.59	0.56
Wild turkey	*Meleagris gallopavo*	66	0.35	1.66	4.15	1.97	3.66
Yellow-throated vireo	*Vireo flavifrons*	64	0.34	6.28	2.73	0.98	0.56
Eastern wood pewee	*Contopus virens*	63	0.33	7.21	1.97	1.31	0.56
Louisiana waterthrush	*Seiurus motacilla*	57	0.30	3.33	2.51	1.97	2.82
Broad-winged hawk	*Buteo platypterus*	52	0.27	2.03	2.51	1.97	3.38
Ruby-throated hummingbird	*Archilochus colubris*	46	0.24	4.62	2.08	0.00	0.56
Tennessee warbler[b]	*Vermivora peregrina*	37	0.19	1.85	2.19	1.31	0.85
Chimney swift	*Chaetura pelagica*	34	0.18	0.37	1.20	2.62	3.66
Northern parula warbler	*Parula americana*	29	0.15	4.81	0.22	0.33	0.00
Rose-breasted grosbeak[b]	*Pheucticus ludovicianus*	26	0.14	0.37	1.64	0.66	1.97
Black-throat green warbler[b]	*Dendroica townsendi*	24	0.13	2.40	0.44	0.66	1.41
Common flicker	*Colaptes auratus*	21	0.11	1.11	0.87	0.98	1.13
Blue grosbeak	*Guiraca caerulea*	21	0.11	0.92	1.09	1.97	0.00
Chuck-wills widow	*Caprimulgus carolinensis*	18	0.09	1.48	0.87	0.00	0.56
Mourning dove	*Zenaida macroura*	18	0.09	2.96	0.00	0.33	0.28
Wood thrush	*Hylocichla mustelina*	17	0.09	0.55	1.09	0.66	0.56
Red-shouldered hawk	*Buteo lineatus*	17	0.09	1.11	0.11	0.66	2.25
Brown thrasher	*Toxostoma rufum*	17	0.09	1.11	0.66	0.98	0.56

continued

Table 2—Species list[a] and frequencies of occurrence of birds identified during 50-m fixed-radius point counts during May–June 1995 through 1998 on four watersheds under different levels of forest management activity in the Ouachita Mountains of Arkansas[b] (continued)

Species	Scientific name	*n*	Total	Birds per 100 plots			
				LG	NAC	BC	SAC
			percent				
American redstart	*Setophaga ruticilla*	17	0.09	1.29	1.09	0.00	0.00
Bay-breasted warbler[b]	*Dendroica castarea*	15	0.08	2.40	0.22	0.00	0.00
Magnolia warbler[b]	*D. magnolia*	15	0.08	0.55	0.77	1.31	0.28
Gray catbird	*Dumetella carolinensis*	15	0.08	0.92	0.87	0.66	0.00
Baltimore oriole	*Icterus galbula*	14	0.07	0.37	1.20	0.00	0.28
Red-bellied woodpecker	*Melanerpes carolinus*	14	0.07	1.85	0.44	0.00	0.00
Turkey vulture	*Cathartes aura*	9	0.05	0.18	0.87	0.00	0.00
Chipping sparrow	*Spizella paserina*	9	0.05	0.55	0.66	0.00	0.00
Veery[b]	*Catharus fuscescens*	8	0.04	0.37	0.33	0.00	0.85
Red-tailed hawk	*Buteo jamaicensis*	7	0.04	0.92	0.11	0.33	0.00
Chestnut-sided warbler[b]	*Dendroica pensylvanica*	7	0.04	1.11	0.11	0.00	0.00
Barred owl	*Strix varia*	7	0.04	0.18	0.33	0.00	0.85
Sharp-shinned hawk	*Accipiter striatus*	6	0.03	0.18	0.11	0.33	0.85
Orchard oriole	*Icterus spurius*	6	0.03	1.11	0.00	0.00	0.00
Belted kingfisher	*Ceryle alcyon*	6	0.03	0.18	0.33	0.33	0.28
Whip-poor-will	*Caprimulgus vociferus*	6	0.03	0.74	0.11	0.00	0.28
Nashville warbler[b]	*Vermivora ruficapilla*	6	0.03	0.18	0.33	0.66	0.00
Eastern kingbird	*Tyranus tyranus*	6	0.03	1.11	0.00	0.00	0.00
Eastern Phoebe	*Sayomis phoebe*	5	0.03	0.37	0.22	0.00	0.28
Swainson's warbler	*Limnothlypis swainsonii*	5	0.03	0.37	0.33	0.00	0.00
Eastern bluebird	*Sialia sialis*	5	0.03	0.74	0.11	0.00	0.00
Yellow warbler[b]	*Dendroica petechia*	4	0.02	0.18	0.33	0.00	0.00
Cooper's hawk	*Accipiter cooperii*	3	0.02	0.55	0.00	0.00	0.00
Brown-headed nuthatch	*Sitta pusilla*	3	0.02	0.00	0.33	0.00	0.00
Purple martin	*Progne subis*	3	0.02	0.00	0.33	0.00	0.00
Warbling vireo	*Vireo gilvus*	3	0.02	0.00	0.33	0.00	0.00
Great blue heron	*Ardea herodias*	2	0.01	0.00	0.22	0.00	0.00
Hermit thrush[b]	*Catharas guttatus*	2	0.01	0.00	0.22	0.00	0.00
White-throated sparrow[b]	*Zonotrichia albicollis*	2	0.01	0.37	0.00	0.00	0.00
Golden-crowned kinglet[b]	*Regulus satrapa*	2	0.01	0.18	0.00	0.00	0.28
Wilson warbler[b]	*Wilsonia pusilla*	2	0.01	0.18	0.00	0.33	0.00
Red-breasted nuthatch[b]	*Sitta canadensis*	2	0.01	0.37	0.00	0.00	0.00
Cerulean warbler	*Dendroica cerulea*	1	0.01	0.00	0.11	0.00	0.00
Yellow-bellied flycatcher[b]	*Empidonax flaviventris*	1	0.01	0.00	0.00	0.00	0.28
Blue-winged warbler[b]	*Vermivora pinus*	1	0.00	1.00	0.00	0.00	0.28
Red crossbill[b]	*Loxia curvirostra*	1	0.01	0.00	0.00	0.00	0.28
Red-winged blackbird	*Agelaius phoeniceus*	1	0.01	0.00	0.11	0.00	0.00
Great horned owl	*Bubo virginianus*	1	0.01	0.00	0.00	0.33	0.00
Song sparrow[b]	*Melospiza melodia*	1	0.01	0.00	0.00	0.33	0.00
Wood duck	*Aix sponsa*	1	0.01	0.00	0.11	0.00	0.00
Screech owl	*Otus asio*	1	0.01	0.00	0.11	0.00	0.00
Canada warbler[b]	*Wilsonia canadensis*	1	0.01	0.18	0.00	0.00	0.00
American woodcock	*Scolopax minor*	1	0.01	0.18	0.00	0.00	0.00
Blackburnian warbler[b]	*Dendroica fusca*	1	0.01	0.00	0.00	0.33	0.00
Total		19,030	100.00				

LG = Little Glazypeau; NAC = North Alum Creek; BC = Bread Creek; SAC = South Alum Creek.
[a] Common and scientific names follow Hamel (1992).
[b] Nonbreeding species.

RESULTS

A total of 19,030 birds representing 97 species were recorded over all watersheds and years (table 2). Six species comprised approximately 50 percent of the individuals recorded: red-eyed vireo (*Vireo olivaceus*), pine warbler (*Dendroica pinus*), indigo bunting (*Passerina cyanea*), black and white warbler (*Mniotilta varia*), Carolina chickadee (*Parus carolinensis*), and white-eyed vireo (*Vireo griseus*). With the exception of the rufous-sided towhee (*Pipilo erythrophthalmus*), species for which >50 individuals were recorded occurred in all watersheds. A large portion of species occurred most frequently in LG, followed in decreasing order by NAC, BC, and SAC. The pine warbler, ovenbird (*Seiurus aurocapillus*), and pileated woodpecker (*Dryocopus pileatus*) followed an opposite pattern, with their highest numbers occurring in SAC. Species such as the red-eyed vireo and the tufted-titmouse (*Parus bicolor*) occurred in similar numbers across all watersheds. Recorded numbers of nonbreeding migrants (table 2) were a reflection of the timing of our bird surveys and not a result of habitat differences between watersheds.

Of the 97 recorded species, 76 are known to breed in the Ouachita Mountains of Arkansas. Of those breeding birds, year-watershed interactions existed for numbers of individuals per plot ($F = 3.63$; df = 9, 2092; $P < 0.001$), species per plot ($F = 3.76$; df = 9, 2092; $P < 0.001$), and diversity per plot ($F = 3.10$; df = 9, 2092; $P = 0.001$). Thus, these

Table 3—Mean (SE) breeding bird community metrics recorded on four watersheds under different levels of forest management activity in the Ouachita Mountains of Arkansas

	Year			
Watershed	1995	1996	1997	1998
	number of individuals per plot			
Little Glazypeau	8.81 A[a]	13.50 A	13.95 A	11.91 A
	(0.452)	(0.654)	(0.484)	(0.485)
North Alum Creek	6.02 B	8.33 B	11.36 B	10.30 B
	(0.266)	(0.289)	(0.354)	(0.422)
Bread Creek	4.61 C	5.88 C	8.73 C	8.07 C
	(0.359)	(0.357)	(0.652)	(0.533)
South Alum Creek	4.02 C	5.67 C	9.26 C	6.34 C
	(0.280)	(0.316)	(0.413)	(0.429)
	$F = 30.44$	$F = 59.88$	$F = 22.20$	$F = 20.77$
	df = 3, 520	df = 3, 501	df = 3, 546	df = 3, 525
	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$
	number of species per plot			
Little Glazypeau	5.56 A	7.77 A	9.03 A	6.87 A
	(0.240)	(0.290)	(0.250)	(0.240)
North Alum Creek	3.90 B	5.13 B	6.96 B	5.86 B
	(0.140)	(0.170)	(0.200)	(0.200)
Bread Creek	3.25 C	3.81 C	5.05 C	4.88 C
	(0.230)	(0.230)	(0.330)	(0.270)
South Alum Creek	2.63 C	3.54 C	5.47 C	3.74 D
	(0.150)	(0.170)	(0.210)	(0.200)
	$F = 35.60$	$F = 63.00$	$F = 45.64$	$F = 20.56$
	df = 3, 520	df = 3, 501	df = 3, 546	df = 3, 525
	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$
	diversity per plot			
Little Glazypeau	1.50 A	1.83 A	2.02 A	1.72 A
	(0.049)	(0.041)	(0.032)	(0.037)
North Alum Creek	1.13 B	1.41 B	1.73 B	1.51 B
	(0.039)	(0.035)	(0.029)	(0.036)
Bread Creek	0.96 C	1.13 C	1.35 C	1.38 B
	(0.069)	(0.061)	(0.068)	(0.053)
South Alum Creek	0.80 C	1.08 C	1.52 D	1.10 C
	(0.054)	(0.052)	(0.044)	(0.057)
	$F = 29.59$	$F = 48.53$	$F = 45.48$	$F = 28.19$
	df = 3, 520	df = 3, 501	df = 3, 546	df = 3, 525
	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$

[a] Means in a column followed by the same letter did not differ ($P > 0.05$).

variables were interpreted within years. Numbers of individuals per plot, species per plot, and diversity per plot were consistently highest in LG each of the 4 years, followed by NAC (table 3). BC and SAC recorded similar numbers each year, with SAC having the lowest species per plot in 1998 and the lowest diversity per plot in 1997 and 1998. No year-watershed interaction was found for evenness per plot (F = 0.95; df = 9, 1985; P = 0.483), and evenness per plot did not differ (F = 2.89; df = 3, 9; P = 0.094) among watersheds (LG = 0.94, SE = 0.002; NAC = 0.94, SE = 0.002; BC = 0.94, SE = 0.004; SAC = 0.93, SE = 0.003).

Migrant Birds

Year-watershed interactions existed for numbers of individuals per plot (F = 4.32; df = 9, 2035; P < 0.001), species per plot (F = 3.54; df = 9, 2035; P < 0.001), and diversity per plot (F = 3.02; df = 9, 2035; P = 0.001). Thus, these variables were interpreted within years. Numbers of individuals per plot, species per plot, and diversity per plot were consistently highest for migrants in LG, followed by NAC, each of the 4 years (table 4). Similar numbers were recorded on BC and SAC each year. SAC had the lowest species per plot and diversity per plot in 1995 and 1998. No year-watershed interaction was found for evenness per plot (F = 1.29; df = 9, 1759; P = 0.236). Evenness per plot was highest in

Table 4—Mean (SE) breeding bird community metrics for migrant species recorded on four watersheds under different levels of forest management activity in the Ouachita Mountains of Arkansas

	Year			
Watershed	1995	1996	1997	1998
	number of individuals per plot			
Little Glazypeau	6.27 A[a]	9.91 A	8.61 A	7.87 A
	(0.336)	(0.466)	(0.332)	(0.354)
North Alum Creek	4.53 B	6.44 B	7.81 A	7.00 B
	(0.203)	(0.252)	(0.279)	(0.289)
Bread Creek	3.27 C	4.16 C	5.65 B	5.14 C
	(0.256)	(0.287)	(0.471)	(0.426)
South Alum Creek	2.40 C	3.61 C	5.30 B	3.69 D
	(0.156)	(0.203)	(0.277)	(0.314)
	F = 33.19	F = 59.76	F = 18.50	F = 22.30
	df = 3, 498	df = 3, 492	df = 3, 539	df = 3, 506
	P < 0.001	P < 0.001	P < 0.001	P < 0.001
	number of species per plot			
Little Glazypeau	3.80 A	5.44 A	5.52 A	4.53 A
	(0.080)	(0.199)	(0.180)	(0.163)
North Alum Creek	2.94 B	3.64 B	4.61 B	4.01 B
	(0.117)	(0.134)	(0.151)	(0.153)
Bread Creek	2.31 C	2.62 C	3.21 C	3.24 C
	(0.173)	(0.176)	(0.237)	(0.228)
South Alum Creek	1.69 D	2.15 C	3.18 C	2.22 D
	(0.092)	(0.102)	(0.140)	(0.134)
	F = 30.29	F = 64.04	F = 32.43	F = 25.00
	df = 3, 498	df = 3, 492	df = 3, 539	df = 3, 506
	P < 0.001	P < 0.001	P < 0.001	P < 0.001
	diversity per plot			
Little Glazypeau	1.13 A	1.49 A	1.53 A	1.32 A
	(0.048)	(0.043)	(0.038)	(0.039)
North Alum Creek	0.87 B	1.06 B	1.30 B	1.13 B
	(0.037)	(0.037)	(0.035)	(0.041)
Bread Creek	0.64 C	0.76 C	0.91 C	0.94 C
	(0.068)	(0.062)	(0.071)	(0.069)
South Alum Creek	0.43 D	0.63 C	1.00 C	0.60 D
	(0.045)	(0.045)	(0.041)	(0.056)
	F = 31.88	F = 56.26	F = 34.67	F = 29.77
	df = 3, 498	df = 3, 492	df = 3, 539	df = 3, 506
	P < 0.001	P < 0.001	P < 0.001	P < 0.001

[a] Means in a column followed by the same letter did not differ (P > 0.05).

LG ($\bar{x}$ = 0.94, SE = 0.002) and BC ($\bar{x}$ = 0.94, SE = 0.004) and lowest in NAC ($\bar{x}$ = 0.93, SE = 0.002) and SAC ($\bar{x}$ = 0.92, SE = 0.005) (F c= 5.72; df = 3, 9; P = 0.018).

Residents

No year-watershed interactions existed for numbers of individuals per plot (F = 1.17; df = 9, 1760; P = 0.310), species per plot (F = 1.83; df = 9, 1760; P = 0.059), diversity per plot (F = 1.74; df = 9, 1760; P = 0.074), or eveness per plot (F = 1.18; df = 9, 1056; P = 0.303). LG had the highest individuals per plot (F = 25.53; df = 3, 9; P < 0.001), species per plot (F = 32.05; df = 3, 9; P < 0.001), and diversity per plot (F = 28.75; df = 3, 9; P < 0.001) of all watersheds (table 5). NAC, BC, and SAC were comparable for most community metrics. Evenness did not differ among watersheds (F = 2.19; df = 3, 9; P = 0.152).

Cavity Nesters

No year-watershed interactions existed for numbers of individuals per plot (F = 1.63; df = 9, 1201; P = 0.102), species per plot (F = 1.81; df = 9, 1201; P = 0.062), or diversity per plot (F = 1.69; df = 9, 1201; P = 0.087). There were no differences among watersheds for numbers of individuals per plot (F = 2.25; df = 3, 9; P = 0.150), species per plot (F = 2.81; df = 3, 9; P = 0.099), or diversity per plot (F = 2.95; df = 3, 9; P = 0.089) (table 6). A year-watershed interaction was found for evenness per plot (F = 2.72; df = 9, 457; P = 0.004), and evenness per plot did not differ between watersheds during 1995 (F = 2.40; df = 3, 90; P = 0.073), 1997 (F = 1.48; df = 3, 180; P = 0.223), or 1998 (F = 0.81; df = 3, 103; P = 0.494). Evenness per plot did differ in 1996 (F = 4.79; df = 3, 84; P = 0.004), with SAC having a lower value than all other watersheds.

Canopy Nesters

Year-watershed interactions existed for numbers of individuals per plot (F = 2.55; df = 9, 1963; P = 0.007), species per plot (F = 1.99; df = 9, 1963; P = 0.037), and diversity per plot (F = 1.87; df = 9, 1963; P = 0.050). Thus, these variables were interpreted within years. In 1995 and 1997, there were no differences in numbers of individuals per plot between watersheds (table 7). Numbers of individuals per plot were highest in LG in 1996 and lowest in BC in 1998. In 1995 and 1996, species per plot was highest in LG, with no differences in the other watersheds. Species per plot was lowest in SAC in 1998. Diversity per plot was highest in LG in 1996, with inconsistent differences in other years. No year-watershed interaction was found for evenness per plot

Table 5—Mean (SE) breeding resident bird community metrics recorded on four watersheds under different levels of forest management activity in the Ouachita Mountains of Arkansas

Watershed	Individuals per plot	Species per plot	Diversity per plot	Evenness per plot
	- - - - - - - - - - - - - *number* - - - - - - - - - - - - -			
Little Glazypeau	4.21 A[a]	2.77 A	0.81 A	0.94
	(0.238)	(0.253)	(0.263)	(0.267)
North Alum Creek	2.95 B	1.96 B	0.51 B	0.94
	(0.172)	(0.100)	(0.159)	(0.190)
Bread Creek	2.76 B	1.79 C	0.43 C	0.95
	(0.211)	(0.165)	(0.242)	(0.279)
South Alum Creek	3.08 B	1.83 BC	0.44 C	0.93
	(0.263)	(0.194)	(0.255)	(0.237)

[a] Means in a column followed by the same letter did not differ (P > 0.05).

Table 6—Mean (SE) cavity nesting bird community metrics recorded on four watersheds under different levels of forest management activity in the Ouachita Mountains of Arkansas

Watershed	Individuals per plot	Species per plot	Diversity per plot	Evenness per plot
	- - - - - - - - - - - - *number* - - - - - - - - - - - -			
Little Glazypeau	2.29	1.57	0.34	0.94
	(0.080)	(0.041)	(0.022)	(0.010)
North Alum Creek	2.02	1.48	0.29	0.92
	(0.064)	(0.032)	(0.017)	(0.013)
Bread Creek	1.89	1.33	0.20	0.93
	(0.115)	(0.051)	(0.029)	(0.027)
South Alum Creek	2.07	1.38	0.25	0.85
	(0.110)	(0.051)	(0.027)	(0.034)

Table 7—Mean (SE) canopy nesting bird community metrics recorded on four watersheds under different levels of forest management activity in the Ouachita Mountains of Arkansas

Watershed	Year			
	1995	1996	1997	1998
		number of individuals per plot		
Little Glazypeau	3.13	5.29 A[a]	5.42	4.84 A
	(0.190)	(0.654)	(0.268)	(0.248)
North Alum Creek	2.82	4.05 B	4.92	4.89 A
	(0.134)	(0.289)	(0.186	(0.194)
Bread Creek	2.58	3.59 B	4.86	4.30 AB
	(0.189)	(0.357)	(0.430)	(0.310)
South Alum Creek	2.60	3.65 B	5.57	3.94 B
	(0.203)	(0.316)	(0.262)	(0.225)
	F = 1.68	F = 8.53	F = 1.62	F = 3.13
	df = 3, 449	df = 3, 477	df = 3, 531	df = 3, 506
	P = 0.170	P < 0.001	P = 0.184	P = 0.025
		number of species per plot		
Little Glazypeau	2.08 A	2.89 A	3.32 A	2.72 A
	(0.103)	(0.290)	(0.129)	(0.112)
North Alum Creek	1.80 B	2.27 B	2.78 BC	2.53 A
	(0.062)	(0.170)	(0.088)	(0.075)
Bread Creek	1.77 B	2.13 B	2.53 B	2.45 AB
	(0.096)	(0.230)	(0.140)	(0.127)
South Alum Creek	1.65 B	2.01 B	2.97 AC	2.22 B
	(0.093)	(0.170)	(0.109)	(0.114)
	F = 3.84	F = 12.09	F = 7.38	F = 3.39
	df = 3, 449	df = 3, 477	df = 3, 531	df = 3, 506
	P = 0.010	P < 0.001	P < 0.001	P = 0.018
		diversity per plot		
Little Glazypeau	0.58 A	0.83 A	1.00 A	0.81 A
	(0.047)	(0.041)	(0.042)	(0.042)
North Alum Creek	0.47 B	0.66 B	0.83 BC	0.74 A
	(0.030)	(0.035)	(0.031)	(0.029)
Bread Creek	0.46 AB	0.59 B	0.74 C	0.72 AB
	(0.052)	(0.061)	(0.055)	(0.050)
South Alum Creek	0.41 B	0.54 B	0.94 AB	0.63 B
	(0.045)	(0.052)	(0.038)	(0.049)
	F = 2.65	F = 7.39	F = 6.47	F = 2.98
	df = 3, 449	df = 3, 477	df = 3, 531	df = 3, 506
	P = 0.049	P < 0.001	P < 0.001	P = 0.031

[a] Means in a column followed by the same letter did not differ (P > 0.05).

(F = 0.85; df = 9, 1480; P = 0.570), and evenness per plot did not differ (F = 0.973; df = 3, 9; P = 0.445) among watersheds (LG = 0.92, SE = 0.004; NAC = 0.92, SE = 0.003; BC = 0.92, SE = 0.006; SAC = 0.92, SE = 0.005).

Ground and Shrub Nesters

A year-watershed interaction existed for numbers of individuals per plot (F = 1.99; df = 9, 1628; P = 0.037); thus, this variable was interpreted within years. Numbers of individuals per plot were consistently highest in LG and lowest in SAC over all years (table 8). No year-watershed interactions existed for species per plot (F = 0.93; df = 9, 1628; P = 0.499), diversity per plot (F = 0.84; df = 9, 1628; P = 0.582), or evenness per plot (F = 0.55; df = 9, 1035; P = 0.841). Species per point and diversity per point were consistently highest in LG and lowest in SAC over all years (table 9). Evenness did not differ among watersheds.

DISCUSSION AND CONCLUSIONS

Because this study focused on differences and similarities of breeding bird community characteristics among watersheds, replication was not feasible. Thus, our inferences and conclusions are limited to the bird communities and landscapes contained within the specific watersheds we studied.

Table 8—Mean (SE) numbers of individual ground and shrub nesting birds per plot recorded on four watersheds under different levels of forest management activity in the Ouachita Mountains of Arkansas

	Year			
Watershed	1995	1996	1997	1998
Little Glazypeau	5.13 A[a]	7.26 A	6.04 A	5.99 A
	(0.409)	(0.654)	(0.484)	(0.485)
North Alum Creek	3.41 B	4.08 B	5.05 B	4.76 B
	(0.234)	(0.289)	(0.354)	(0.422)
Bread Creek	2.66 B	2.98 BC	4.32 B	3.50 C
	(0.350)	(0.357)	(0.652)	(0.533)
South Alum Creek	1.19 C	1.85 C	2.59 C	2.47 C
	(0.083)	(0.316)	(0.413)	(0.429)
	$F = 21.53$	$F = 29.99$	$F = 14.34$	$F = 11.96$
	df = 3, 364	df = 3, 392	df = 3, 467	df = 3, 405
	$P = < 0.001$	$P < 0.001$	$P < 0.001$	$P = < 0.001$

[a] Means in a column followed by the same letter did not differ ($P > 0.05$).

Table 9—Mean (SE) ground and shrub nesting bird community metrics recorded on four watersheds under different levels of forest management activity in the Ouachita Mountains of Arkansas

Watershed	Species per plot	Diversity per plot	Evenness per plot
	no.		
Little Glazypeau	3.70 A	1.07 A	0.94
	(0.094)	(0.027)	(0.003)
North Alum Creek	2.75 B	0.73 B	0.94
	(0.075)	(0.024)	(0.003)
Bread Creek	2.27 C	0.57 C	0.96
	(0.123)	(0.044)	(0.004)
South Alum Creek	1.41 D	0.25 D	0.94
	(0.053)	(0.024)	(0.010)

[a] Means in a column followed by the same letter did not differ ($P > 0.05$).

The differing ownerships, management objectives, and intensities of forest management activity among watersheds influenced breeding bird communities. Spatial and compositional habitat heterogeneity was highest in LG (Tappe and others, in press) and was reflected in higher numbers of individuals per point, species per point, and diversity per point for both migrants and residents. Lower values were seen in BC and SAC, with NAC being intermediate. Thus, these patterns appear to follow Tappe and others (in press) ranking of spatial heterogeneity in the watersheds (LG > NAC > BC > SAC).

Patterns of community characteristics within nesting guilds were not as consistent as when birds were separated into migrant and resident species. Though somewhat variable, watersheds were comparable during most years in respect to canopy nesters. Community characteristics of cavity nesters were the same for all watersheds. Each watershed provided some suitable habitat for species in these nesting guilds. Ground and shrub nesters had their lowest numbers of individuals per point, species per point, and diversity per point in SAC and their highest in LG, with NAC and BC being intermediate to these values. Values for ground and shrub nesters reflected the amount of suitable, early successional habitat found in each watershed. LG was composed of approximately 22 percent young/open and thin/open pine stands whereas SAC was composed of approximately 1 percent young/open and thin/open pine stands (Tappe and others, in press).

Each watershed was characterized by differing breeding bird community structure. LG provided a variety of early-successional and medium-aged habitats. Several species prefer these habitats, many of which are species of concern, including the black and white warbler, prairie warbler (*Dendroica discolor*), and worm-eating warbler (*Helmitheros vermivorus*). SAC provided a relatively homogenous landscape of more mature forest, thus benefitting species such

as the ovenbird and scarlet tanager (*Piranga olivacea*). NAC and BC both provided landscapes that included differing proportions of each of these habitats, supporting differing bird communities. Thus, the spatial structure and composition of each watershed resulted in differing breeding bird community associations.

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