FINAL PERFORMANCE REPORT

Federal Aid Grant No. F15AF001197 (T-88-1)

Ecological Assessment of Ozark Watersheds Using Breeding Birds

Oklahoma Department of Wildlife Conservation

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Project Leader: Timothy J. O'Connell, PhD
Department of Natural Resource Ecology and Management,
Oklahoma State University

Samantha M. Cady, MS, Graduate Research Assistant
Department of Natural Resource Ecology and Management,
Oklahoma State University

(Louisiana Waterthrush brood nearing their fledging date. Samantha Cady photo.)

A. ABSTRACT

This project attempted to examine the relationship between the condition of riparian forests and the watershed condition of headwater streams that support the suite of forest songbirds that are species of greatest conservation need in the Oklahoma portion of the Ozark ecological region. Headwaters are the first line of defense against stream habitat degradation with respect to erosion, sedimentation, and non-point source pollutants; therefore, habitat restoration efforts frequently focus on headwaters through the revegetation of riparian zones, establishment of forested buffers, and bank stabilization. Ecological indicators that focus on riparian zones in headwaters may provide important information about overall watershed condition. To test this, we focused on first- and second-order streams and combined information about riparian bird abundance and forest condition to develop an indicator of watershed health and ecological importance for terrestrial wildlife. We attempted to use the Louisiana Waterthrush, a riparian obligate species for which territory density can be determined across a gradient of conditions, as a surrogate species for refining watershed health by comparing riparian structure and community composition against territory density and nest productivity. However, this proved to be infeasible due to low abundance of Louisiana Waterthrushes and high rates of nest failure. We documented fifty species of forest birds across watersheds in nine landscapes in the Ozarks, including six of the eight forest bird species of greatest conservation need. Bird species sorted along several gradients of forest condition, but canopy height, canopy cover, tree species richness and vegetation density in the understory were the best predictors of the composition and diversity of local forest bird assemblages.

B. BACKGROUND

Riparian zones are dynamic transitional areas that encompass the interface between a stream and its adjacent terrestrial environment and are recognized as hotspots of habitat heterogeneity (Naiman et al. 2005a) that can exhibit sharp microclimatic and vegetation gradients (Gregory et al. 1991). Specifically, riparian zones are strongly influenced by their stream system and often encompass a steep, localized change in temperature (Naiman et al. 2005b), increase in soil moisture/humidity, and change in canopy and understory vegetation (Moore et al. 2005). Riparian zones provide a wealth of ecosystem services, including nutrient uptake and filtering (Lowrance et al. 1984), high rates of productivity (Naiman and Decamps 1997), provision of refugia during climatic stress (Selwood et al. 2015), and support for terrestrial, semiaquatic, and aquatic species obligate to these areas (Kelsey and West 1998). A riparian zone is often a nexus of heterogeneous conditions supporting locally high biodiversity (Naiman et al. 1993, Woinarski et al. 2000).

The Oklahoma Department of Wildlife Conservation (ODWC) has identified the restoration of streams, springs, and riparian forests in the Ozark Plateau of eastern Oklahoma as a conservation priority with potential benefits to aquatic macroinvertebrates, fish, reptiles and amphibians, and birds (ODWC 2015). In this project, we examined headwaters of large stream systems in the Ozark Region to determine conditions associated with the best representation of riparian-associated breeding songbirds, including conservation priorities Cerulean Warbler, Hooded Warbler, Kentucky Warbler, Swainson's Warbler, Prothonotary Warbler, Louisiana Waterthrush, and Wood Thrush. This species assemblage is primarily comprised of facultative species that are drawn to vegetation and microclimatic conditions that are better represented in riparian zones than in adjacent uplands. In addition to these species, riparian forests provide habitat suitable for at least one riparian obligate, the Louisiana Waterthrush, which relies both on streambank morphology for nesting and on aquatic macroinvertebrates as a significant source of food for both the adults and nestlings. We proposed that in the Oklahoma portion of the Ozark Plateau, riparian songbirds integrate conditions spanning the immediate riparian corridor to the adjacent uplands (O'Connell et al. 2013); therefore, the ability of headwater watersheds to support multiple riparian songbirds should provide a broad indication of desirable conditions for other species in those systems. To address this goal, we pursued two objectives:

C. OBJECTIVES:

1. Conduct original field research on Louisiana Waterthrush and other riparian-associated songbirds in eastern Oklahoma to define specific management recommendations for riparian forest restoration.
2. Develop an integrated indicator of watershed condition in eastern Oklahoma that can provide assessments over broad areas and be readily adopted into existing monitoring programs.

D. METHODS:

Study Area and Site Selection

In 2016 and 2017 we sampled public and private land in the Ozark Plateau, which includes sampling within the Ozark Highland and Boston Mountains EPA Level III ecoregions (synonymous with the Ozark Region of the Oklahoma Comprehensive Wildlife Conservation Strategy) (Figure 1). The Ozark Plateau of northeastern Oklahoma is defined here as the area contained by the Arkansas/Missouri borders on the east, the Neosho River on the west, and the Arkansas River on the south. It represents hardwood forest typically used by forest birds native to the eastern temperate portion of North America. The Ozark Plateau is characterized by deeply dissected limestone and flint formations punctuated with seeps, springs, and caves (Blair and Hubbell, 1938). The region receives approximately 111–132 cm of annual rainfall (PRISM, 2004) and supports oak-hickory forest over most of its area. Dominant upland tree species include blackjack oak (*Quercus marilandica*), post oak (*Q. stellata*), black hickory (*Carya texana*), and winged elm (*Ulmus alata*). In riparian areas, sugar maple (*Acer saccharum*), eastern hop hornbeam (*Ostrya virginiana*), white oak (*Q. alba*) and Chinquapin oak (*Q. muehlenbergii* (Blair and Hubbell, 1938) can be common. This study area is comprised of five major (8-digit Hydrologic Unit Code) watersheds: Lake o' the Cherokees, Lower Neosho River, Illinois River, Dirty-Greenleaf Creek, and Robert S. Kerr Reservoir.

We sampled 254 points in 17, 12-digit Hydrologic Unit Code watersheds in Adair, Delaware, and Cherokee counties. Public lands sampled included: Cherokee, Cookson, Spavinaw, and Ozark Plateau Wildlife Management Areas, Natural Falls State Park, and Lake Eucha (City of Tulsa). Private lands sampled included The Nature Conservancy's Nickel Preserve, Saline Creek, and Spring Valley Ranch.

Site Selection and Field Techniques

We targeted survey sites within forested patches with an estimated 50% or greater canopy cover and sampled a total of 254 points. In 2016, we surveyed exclusively riparian points along first or second order streams (Figure 2). However, to widen the gradient of habitat structure to better understand bird habitat associations, we added some upland points to our survey effort in the 2017 field season (out of the 254 points surveyed, 202 were in riparian areas and 52 were in upland areas). Points were considered riparian if they (1) were located along a first- or second-order stream bed and (2) supported at least one key woody species often associated with riparian/mesic areas including common spicebush (*Lindera benzoin*), slippery elm (*Ulmus rubra*), American sycamore (*Platanus occidentalis*), bitternut hickory (*Carya cordiformis*), black walnut (*Juglans nigra*), red mulberry (*Morus rubra*), box elder (*Acer negundo*), willow (*Salix* spp.), bur oak (*Quercus macrocarpa*), flowering dogwood (*Cornus florida*), or cottonwood (*Populus deltoides*) (Hoagland 2000). Upland points were sited at least 200m upslope (measured in horizontal distance) from riparian points. Avian point counts were conducted twice during peak breeding season (May and June) in 2017, using an estimated 50-meter fixed radius. All adult birds detected by sight or sound were recorded but potential migrants were not included in analysis.

A suite of vegetation community and structure data were collected at each sample point and two subpoints. One subpoint was located 30 meters downstream from the original point location, (or 30 meters uphill, if upland) and the second subpoint was located 30 meters southwest from the original sample point. The point/subpoint layout was designed to capture typical vegetation attributes throughout the 50m point count radius, rather than at the observer's location alone. In 2017, at all bird sampling points and their corresponding subpoints (576 total vegetation sampling points) we: (1) used a clinometer to estimate canopy height of a co-dominant tree, (2) took a spherical densiometer reading in each cardinal direction to estimate canopy cover, (3) took a cover board reading in each cardinal direction and five meters from the observer to estimate understory density (Figure 3), and (4) recorded ground cover classes using a Daubenmire frame, (5). At each sample point and one of its subpoints (randomly selected *a priori*), all trees (dbh > 6cm) in a 10 X 10m plot were identified to species. Finally, we used a diameter tape to estimate dbh for all tree stems identified to species. There were some minor field data collection protocol changes between the 2016 and 2017 field seasons. These differences and their implications for data pre-processing have been noted in the metadata tab of the raw data spreadsheet (Excel file) that was provided to the ODWC should these data be used in future studies.

Departures from Originally Proposed Methods

We encountered challenges during reconnaissance and data collection for field season 1 in 2016 that led to adjustments in our approach. First, we were limited in the ability to access suitable headwater stream reaches (e.g., 1st through 3rd order streams) that presented a gradient of conditions necessary for the development of a useful ecological indicator application. The great majority of stream reaches that we could access for sampling drained heavily forested watersheds with high canopy cover, or they were substantially degraded by agricultural development and contained a complex pattern of landownership (these reaches were generally owned by multiple private landowners on small lots that backed up to the stream bank). Access to these areas was generally restricted due to the large number of landowners who would need to cooperate for us to access standardized reach lengths. More difficult from an indicator standpoint, is that most reaches could be classified into one of only two conditions - intact or developed. This meant that there was a narrow gradient of condition for headwater streams in the Oklahoma Ozark Region. Without a wide gradient of condition, both development and application of an indicator are untenable (O'Connell et al. 2013).

At the start of the 2016 field season, we performed Louisiana Waterthrush nest searches with the goal of determining breeding success. The objective was to capture a higher resolution picture of watershed health than could be illustrated by point-count data (i.e. adults may be singing in "poor" habitat, but their nests may fail). However, because we were only able to locate a small number of active nests, and because 100% of those nests were depredated between the first two visits, we decided to abandon this effort. Instead, we refocused our effort on visiting more points in an attempt to better define conditions supporting the broader assemblage of riparian songbirds.

In 2016, in order to capture a cross-taxa picture of watershed health, we performed presence/absence amphibian and reptile surveys using a plot-less, time constrained method. During the survey period, a single crewmember searched suitable habitat within a 25-meter radius by turning small logs, woody debris, and rocks. All amphibians detected by sight or sound were recorded to determine presence/absence for each stream reach. However, due to the Oklahoma Ozark's karst topography, a large percentage of streamflow occurred below ground and a standardization of survey methods was not possible across all sites. We therefore found it difficult to compare amphibian populations across above-ground (gaining) and below-ground (losing) stream segments (i.e. above-ground streams have larger amphibian populations simply because they have surface flow, not necessarily because their watersheds are healthy). Approximate locations and fates of 2016 Louisiana Waterthrush nests as well as 2016 amphibian survey data were provided to ODWC in an Excel spreadsheet (Ozark Songbird Data tab).

Analysis: Objective 1

We analyzed community-level species scores along environmental gradients using a unimodal constrained ordination in Canoco version 5 (Ter Braak and Šmilauer, 2012). Because study points were clustered due to limited land accessibility, we used partial canonical correspondence analysis (pCCA) with covariate "area" to factor out variation explained by each of the nine property areas sampled (e.g. Cookson WMA, Cherokee WMA, Natural Falls State Park, etc.). For this analysis, to capture a snapshot of the bird community and to exclude between-year differences, we limited our analysis to the 2017 data. Response variables included songbird species presence/absence with rare species down-weighted (an option selected in Canoco 5 that reduces the effect of species with few occurrences). Environmental variables included basal area, canopy height, understory density, mature tree species richness, canopy cover, and riparian/upland point location (binary variable). Further, in order to assess habitat drivers of overall avian community diversity, species richness diagrams were derived using a loess smoother and the count of species present at each point as the response variable.

Analysis: Objective 2

To determine whether there are any overarching habitat trends that support diverse riparian bird communities, we tested the impacts of canopy cover, canopy height, understory density and tree species richness (explanatory variables) on the number of riparian bird species present at each sample point. Specifically, the response variable in our model was the number of species present from the following list: Acadian Flycatcher, Black-and-white Warbler, Blue Grosbeak, Carolina Wren, Indigo Bunting, Kentucky Warbler, Louisiana Waterthrush, Northern Parula, Pine Warbler, Red-eyed Vireo, Scarlet Tanager, Summer Tanager, Swainson's Warbler, White-eyed Vireo, Worm-eating Warbler, Yellow-throated Vireo, and Yellow-throated Warbler (both facultative and obligate riparian species). We used generalized linear models with a Poisson distribution and Akaike's Information Criterion model selection using package bbmle and lme4 in Program R. Additionally, we mapped the health of each watershed sampled according the number of riparian bird species supported in the area. Because watersheds were sampled unevenly, we standardized each watershed by sampling effort to allow fair comparisons.

E. RESULTS AND DISCUSSION:

Objective 1

Assemblages of breeding birds in Ozark forests in Oklahoma sorted along gradients of structural vegetation attributes at our scale of inquiry. Canopy height and canopy cover explained significant variation in all models, as did the compositional effect of tree species richness and vegetation density in the understory. Basal area of stands was generally not informative to Ozark Plateau models. We detected 50 bird species and 72 species of mature trees. The twenty most commonly detected bird and tree species are shown in Table 1 and Table 2 respectively.

Bird species richness was highest at intermediate levels of understory density, canopy cover, tree species richness and canopy height (Figure 4). This is likely a reflection of diverse habitat associations across many species causing the "average" suitable habitat to fall along the middle of each habitat attribute gradient. Generalist species, including Tufted Titmouse and Red-bellied Woodpecker, did not show a strong association with any environmental variable (Figure 5). Black-and-white Warbler was associated with moderately open canopy. This pattern shows a marginal departure from some documented Black-and-white Warbler life history descriptions. For example, in eastern Texas, Black-and-white Warbler was generally associated with tall, dense canopy (Conner et al. 1983). Eastern Wood-Pewee was associated with upland sites with open canopy and low understory density. Louisiana Waterthrush, the riparian obligate, strongly selected riparian sites with tall, closed canopy and high tree species richness. Northern Parula, Acadian Flycatcher, Kentucky Warbler, and Yellow-throated Vireo similarly selected riparian areas with tall, closed, canopy and high tree species richness. Worm-eating Warbler selected points that tended toward an open understory. While we were able to characterize the habitat association of the Louisiana Waterthrush, we were not able to use its reproductive success to develop a more refined model that could integrate habitat condition with productivity.

Objective 2

To capture a wider gradient of bird habitat attributes, in 2017 we added upland points to our sampling design. We assessed the difference in canopy height, canopy cover, horizontal cover (understory density), tree diversity and basal area between upland and riparian points. All variables except basal area had significantly different values in riparian areas than in upland areas (Table 3)

We found a clear, positive association between riparian associated bird species richness and forest canopy height (Table 4). We did not find support for strong impacts by horizontal cover, canopy cover, or tree species richness on overall riparian bird species richness, but it's important to note that these results do not suggest that these variables have no impact on riparian communities. It is likely that there are species-specific responses that are not captured when the riparian community is aggregated and assessed as a whole.

After using a standardized abundance of riparian-associated birds as an indicator of watershed health, we mapped all watersheds sampled in 2016 and 2017 (Figure 6). Notably, the top-ranked watersheds (36–50 riparian birds per five points sampled) overlay Cookson and

Cherokee WMAs, indicating that these areas are biodiversity hotspots for riparian songbirds. Standardized abundance maps for selected forest bird species by watershed are provided in Appendix 1.

Management Implications

We found that the predominantly forested landscapes of the Ozark Region in Oklahoma support riparian associated bird species throughout. The region is diverse in topography, in tree species composition, and even in underlying bedrock to the degree that many riparian zones mark subterranean streams. Despite this diversity, however, all potential habitat predictors of riparian associated birds were unimportant provided that large trees and mostly closed-canopy conditions were present. This was particularly true on wildlife management areas, especially Cookson and Cherokee WMAs that supported the most species-rich assemblages of riparian birds in the region, and higher bird diversity overall than the surrounding private land.

Although this result might not seem to be in keeping with management interest in opening canopies through prescribed fire and other disturbances on WMAs, those activities would be unlikely to affect riparian species richness where they are pursued in uplands. Our analysis of the 2017 data illustrated community-level differences between upland and riparian plots along the same stream reaches. There is nothing to suggest an incompatibility between increased use of prescribed fire in uplands of the Ozark WMAs we sampled and maintenance of evidently high-quality habitat provisioning for multiple riparian songbirds closer to the streams. Should they continue to support tall trees and deep canopies, riparian forests within the larger forested Ozark landscapes will likely increase in importance as refugia for birds during times of stress from heat and drought.

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F. PREPARED BY: Timothy O'Connell and Samantha Cady,
Department of Natural Resource Ecology and Management
Oklahoma State University Stillwater, Oklahoma

G. DATE: February 13, 2019

H. APPROVED BY: ______________________
Wildlife Division Administration,
Oklahoma Department of Wildlife Conservation

Andrea Crews, Federal Aid Coordinator,
Oklahoma Department of Wildlife Conservation

I. LITERATURE CITED:

Blair, W. F., and T. H. Hubbell. 1938. The biotic districts of Oklahoma. *American Midland Naturalist* **20**: 425–454.

Conner, R. N., J. G. Dickson, B. A. Locke, and C. A. Segelquist. 1983. Vegetation characteristics important to common songbirds in east Texas. *The Wilson Bulletin* **95**: 349–361.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. *BioScience* **41**: 540–551.

Hoagland, B. 2000. The vegetation of Oklahoma: A classification for landscape mapping and conservation planning. *The Southwestern Naturalist* **45**: 385–420.

Kelsey, K. A. and S. D. West. 1998. Riparian wildlife. Pages 235–258 in: River ecology and management: lessons from the Pacific coastal ecoregion. R. J. Naiman and R. E. Bilby, editors. Springer-Verlag, New York, New York, USA.

Lowrance, R., R. Todd, J. Fail Jr, O. Hendrickson Jr, R. Leonard, and L. Asmussen. 1984. Riparian forests as nutrient filters in agricultural watersheds. *BioScience* **34**: 374–377.

Moore, R., D. L. Spittlehouse, and A. Story. 2005. Riparian microclimate and stream temperature response to forest harvesting: a review. *Journal of the American Water Resources Association* **41**: 813–834.

Naiman, R. J., J. S. Bechtold, D. C. Drake, J. J. Latterell, T. C. O'Keefe, and E. V. Balian. 2005a. Origins, patterns, and importance of heterogeneity in riparian systems. Pages 279–309 in G. M. Lovett, M. G. Turner, C, G. Jones, and K. C. Weathers, editors. Ecosystem function in heterogeneous landscapes. Springer, New York, New York, USA.

Naiman, R. J. and H. Decamps. 1997. The ecology of interfaces: riparian zones. *Annual Review of Ecology and Systematics* **28**: 621–658.

Naiman, R. J., H. Decamps, and M. E. McClain. 2005b. Riparia: ecology, conservation, and management of streamside communities. Pages 1–418. Elsevier, Amsterdam.

Naiman, R. J., H. Decamps, and M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. *Ecological Applications* **3**: 209–212.

O'Connell, T. J., R. P. Brooks, D. J. Prosser, M. T. Gaudette, J. P. Gyekis, K. C. Farrell, and M. J. Casalena. 2013. Wetland-riparian birds of the Mid-Atlantic Region *in* R. P. Brooks and D. H. Wardrop (Eds.) Mid-Atlantic Freshwater Wetlands: Advances in Wetlands Science, Management, Policy, and Practice. Springer Ecological Studies Series.

Oklahoma Department of Wildlife Conservation. 2015. Oklahoma Comprehensive Wildlife Conservation Strategy: A Strategic Conservation Plan for Oklahoma's Rare and Declining Wildlife. Oklahoma Department of Wildlife Conservation, 422 pp.

PRISM Climate Group. 2004. Oregon State University. http://prism.oregonstate.edu.

Selwood, K. E., J. R. Thomson, R. H. Clarke, M. A. McGeoch, and R. MacNally. 2015. Resistance and resilience of terrestrial birds in drying climates: do floodplains provide drought refugia? *Global Ecology and Biogeography* **24**: 838–848.

Ter Braak, C. J. F. and P. Šmilauer. 2012. Canoco reference manual and user's guide: software for ordination, version 5.0. Microcomputer Power, Ithaca, New York, USA.

Woinarski, J. C. Z., C. Brock, M. Armstrong, C. Hempel, D. Cheal, and K. Brennan. 2000. Bird distribution in riparian vegetation in the extensive natural landscape of Australia's tropical savanna: a broad-scale survey and analysis of a distributional data base. *Journal of Biogeography* **27**: 843–868.

FIGURES AND TABLES

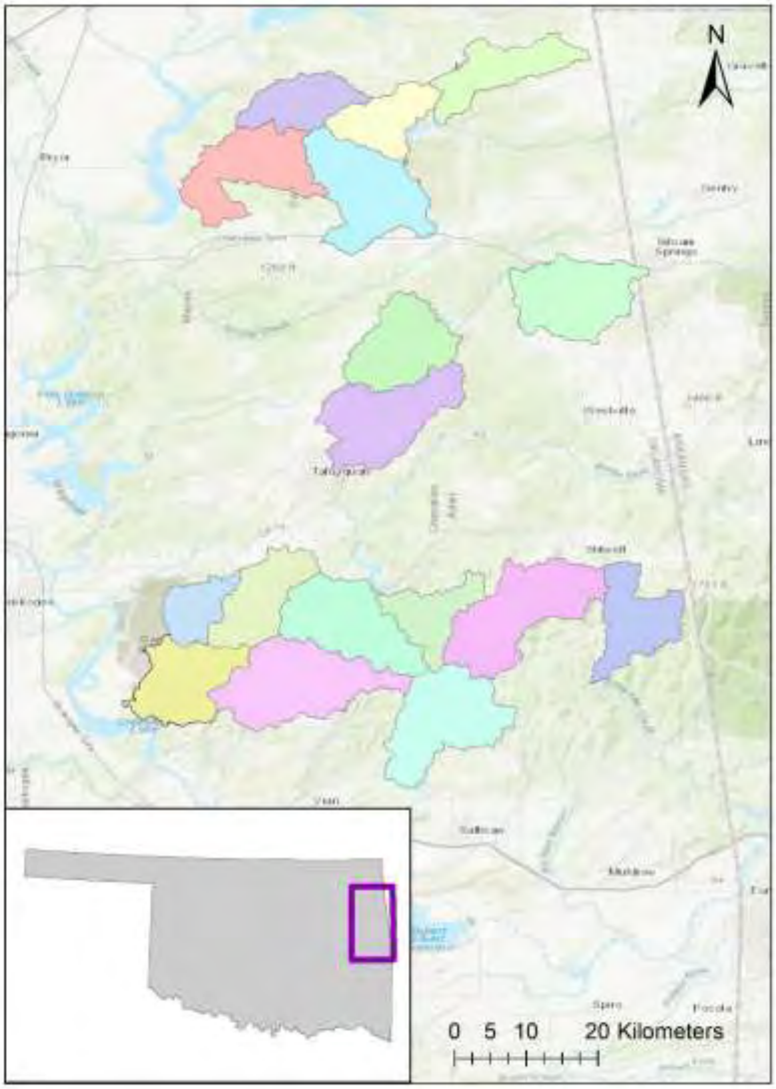


Figure 1: Study area with the 17, 12-digit Hydrologic Unit Code watersheds sampled in 2016 and 2017.

Figure 2: Typical Ozark Plateau headwater stream sampled in 2016 and 2017

Figure 3: Cover board technique for quantifying understory density (i.e. horizontal cover) in a forested system. Understory density measured as percent visual obstruction of a standardized cover board.

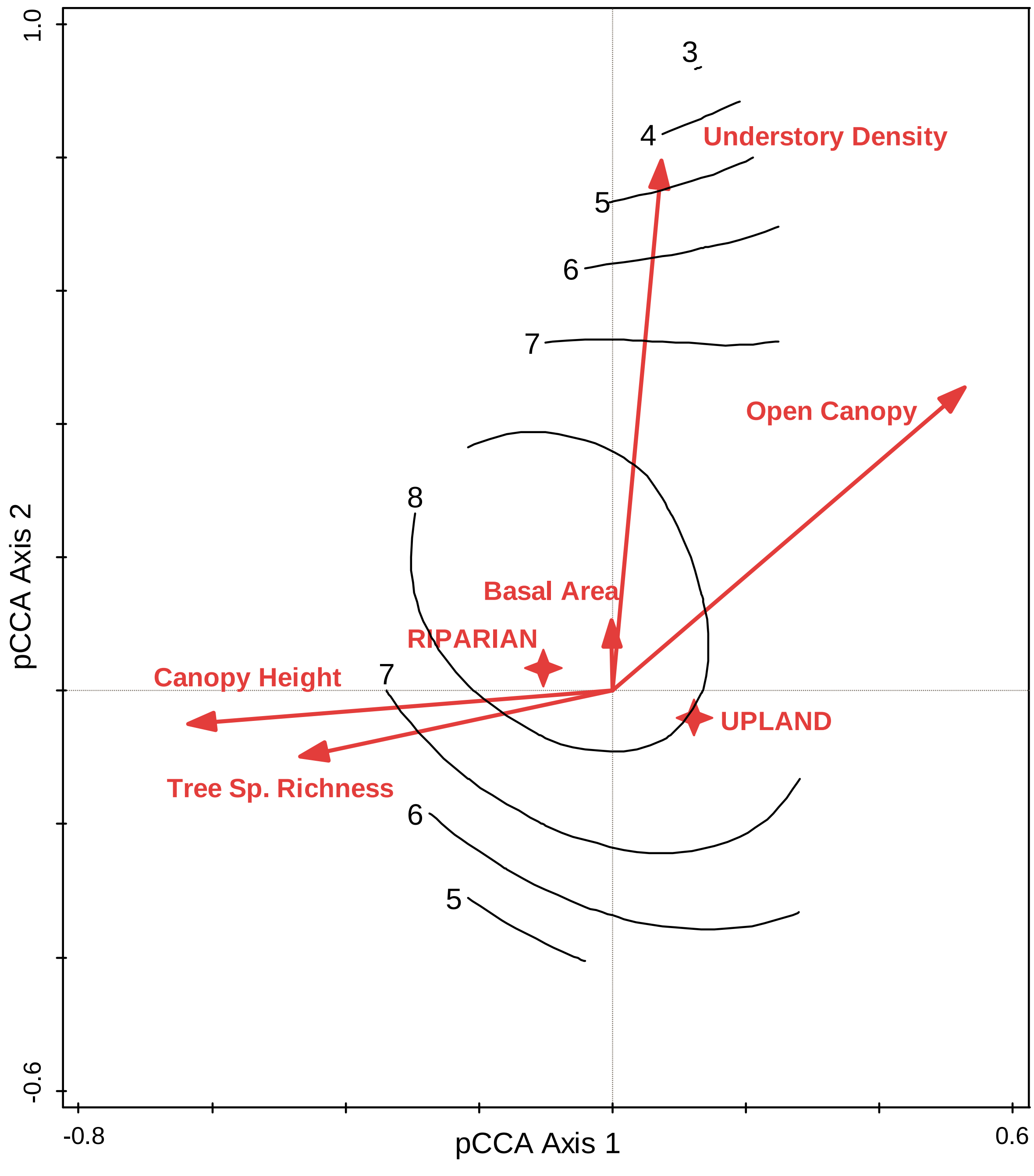


Figure 4: Biplot of environmental gradients for upland and riparian forest in the Ozark Plateau ecoregion of Oklahoma, USA. Isolines indicate bird species richness at the sampling locations from which the environmental data were obtained.

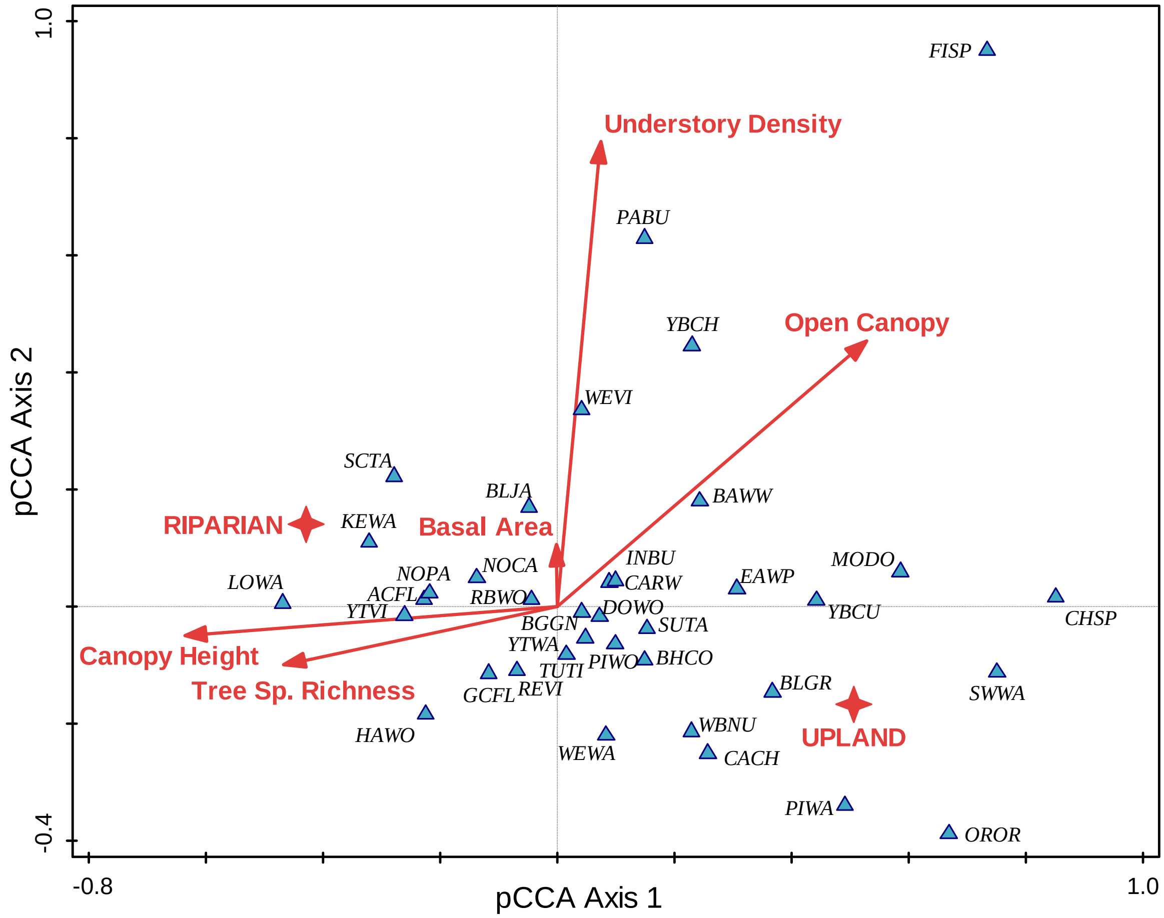


Figure 5: Biplot and associated environmental axes of bird species assemblages in upland and riparian forests of the Ozark Plateau ecoregion in Oklahoma, USA.

Species Codes

Acadian Flycatcher (ACFL)
Black & White Warbler (BAWW)
Blue-gray Gnatcatcher (BGGN)
Brown-headed Cowbird (BHCO)
Blue Grosbeak (BLGR)
Blue Jay (BLJA)
Carolina Chickadee (CACH)
Carolina Wren (CARW)
Chipping Sparrow (CHSP)
Downy Woodpecker (DOWO)
Eastern Wood-pewee (EAWP)
Field Sparrow (FISP)
Great Crested Flycatcher (GCFL)
Hairy Woodpecker (HAWO)
Indigo Bunting (INBU)
Kentucky Warbler (KEWA)
Louisiana Waterthrush (LOWA)
Mourning Dove (MODO
Northern Cardinal (NOCA)
Northern Parula (NOPA)
Orchard Oriole (OROR)
Painted Bunting (PABU)
Pine Warbler (PIWA)
Pileated Woodpecker (PIWO)
Red-bellied Woodpecker (RBWO)
Red-eyed Vireo (REVI)
Scarlet Tanager (SCTA)
Summer Tanager (SUTA)
Swainson's Warbler (SWWA)
Tufted Titmouse (TUTI)
White-breasted Nuthatch (WBNU)
White-eyed Vireo (WEVI)
Worm-eating Warbler (WEWA)
Yellow-billed Cuckoo (YBCU)
Yellow-breasted Chat (YBCH)
Yellow-throated Vireo (TYVI)
Yellow-throated Warbler (TYWA)

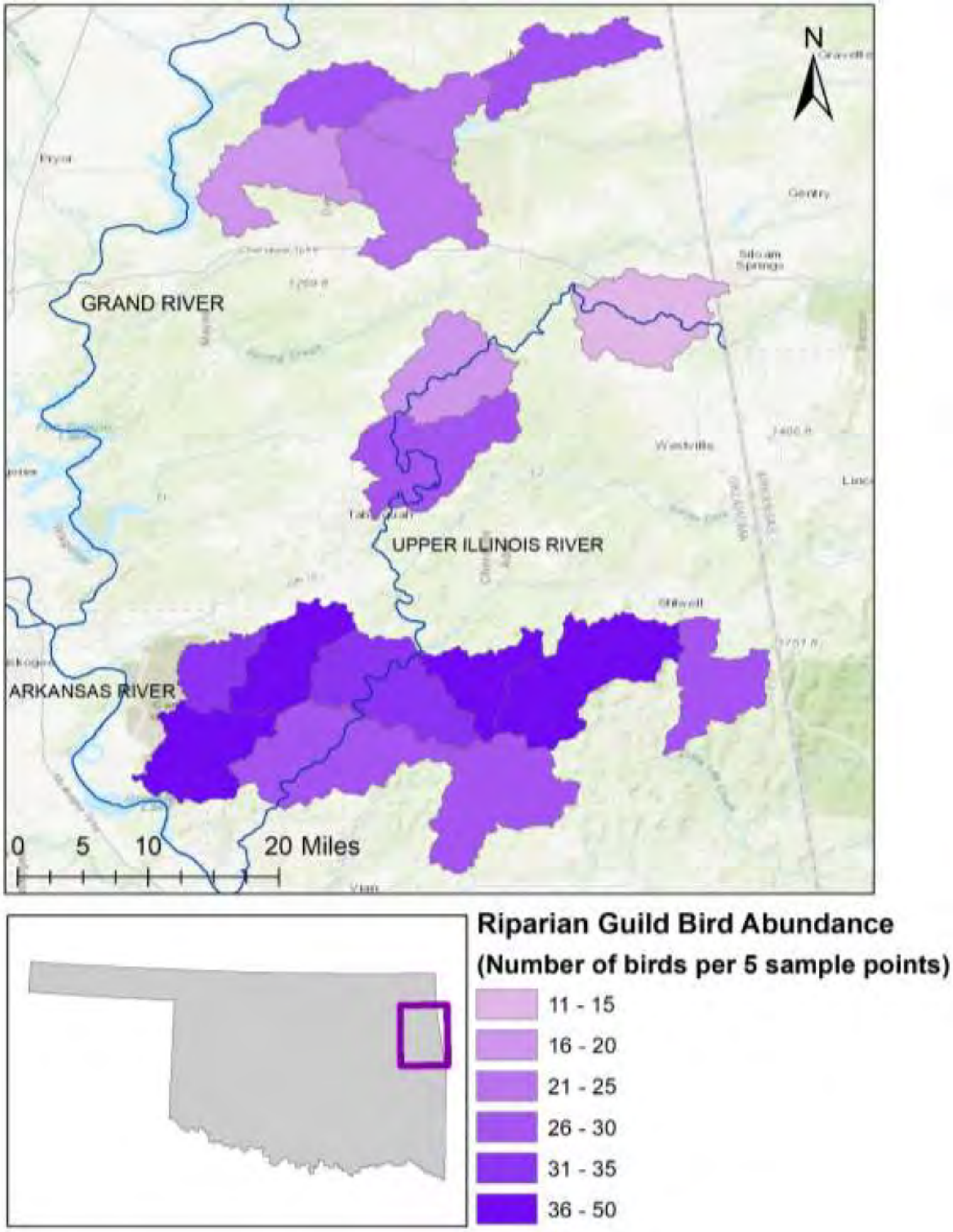


Figure 6: Relative watershed health in the Oklahoma Ozarks as determined by abundance of Acadian Flycatcher, Black and White Warbler, Blue Grosbeak, Carolina Wren, Indigo Bunting, Kentucky Warbler, Louisiana Waterthrush, Northern Parula, Pine Warbler, Red-eyed Vireo, Scarlet Tanager, Summer Tanager, Swainson’s Warbler, White-eyed Vireo, Worm-eating Warbler, Yellow-throated Vireo, and Yellow-throated Warbler.

Table 1: Top 20 most common birds identified during point count surveys (years 2016 and 2017 compiled)

Common Name	**Species Code**	**Total Count**
Blue-gray Gnatcatcher	BGGN	289
Red-eyed Vireo	REVI	173
Indigo Bunting	INBU	158
Acadian Flycatcher	ACFL	153
Tufted Titmouse	TUTI	151
Northern Parula	NOPA	134
Summer Tanager	SUTA	94
Carolina Wren	CARW	91
Carolina Chickadee	CACH	75
White-eyed Vireo	WEVI	72
Louisiana Waterthrush	LOWA	63
Northern Cardinal	NOCA	62
Black-and-white Warbler	BAWW	61
Kentucky Warbler	KEWA	58
Brown-headed Cowbird	BHCO	54
Red-bellied Woodpecker	RBWO	47
Eastern Wood Pewee	EAWP	38
Yellow-throated Vireo	YTVI	31
Yellow-throated Warbler	YTWA	26
White-breasted Nuthatch	WBNU	25

Table 2: Top 20 most common identified during fixed plot surveys (years 2016 and 2017 compiled)

Common Name	**Scientific Name**	**Total Count**
Black Hickory	*Carya texana*	268
American Sycamore	*Platanus occidentalis*	217
Eastern Hophornbeam	*Ostrya virginiana*	210
Winged Elm	*Ulmus alata*	207
Post Oak	*Quercus stellata*	205
Bitternut Hickory	*Carya cordiformis*	156
Slippery Elm	*Ulmus rubra*	154
Chinkapin Oak	*Quercus muehlenbergii*	111
Ash	*Fraxinus sp.*	107
Shumard Oak	*Quercus shumardii*	101
Flowering Dogwood	*Cornus florida*	99
Sugarberry	*Celtis lavaegata*	91
Eastern Black Oak	*Quercus velutina*	87
Southern Red Oak	*Quercus falcata*	79
Carolina Buckthorn	*Frangula caroliniana*	78
Northern Red Oak	*Quercus rubra*	73
Black Walnut	*Juglans nigra*	67
White Oak	*Quercus alba*	63
Eastern Redcedar	*Juniperus virginiana*	57
Eastern Redbud	*Cercis canadensis*	54

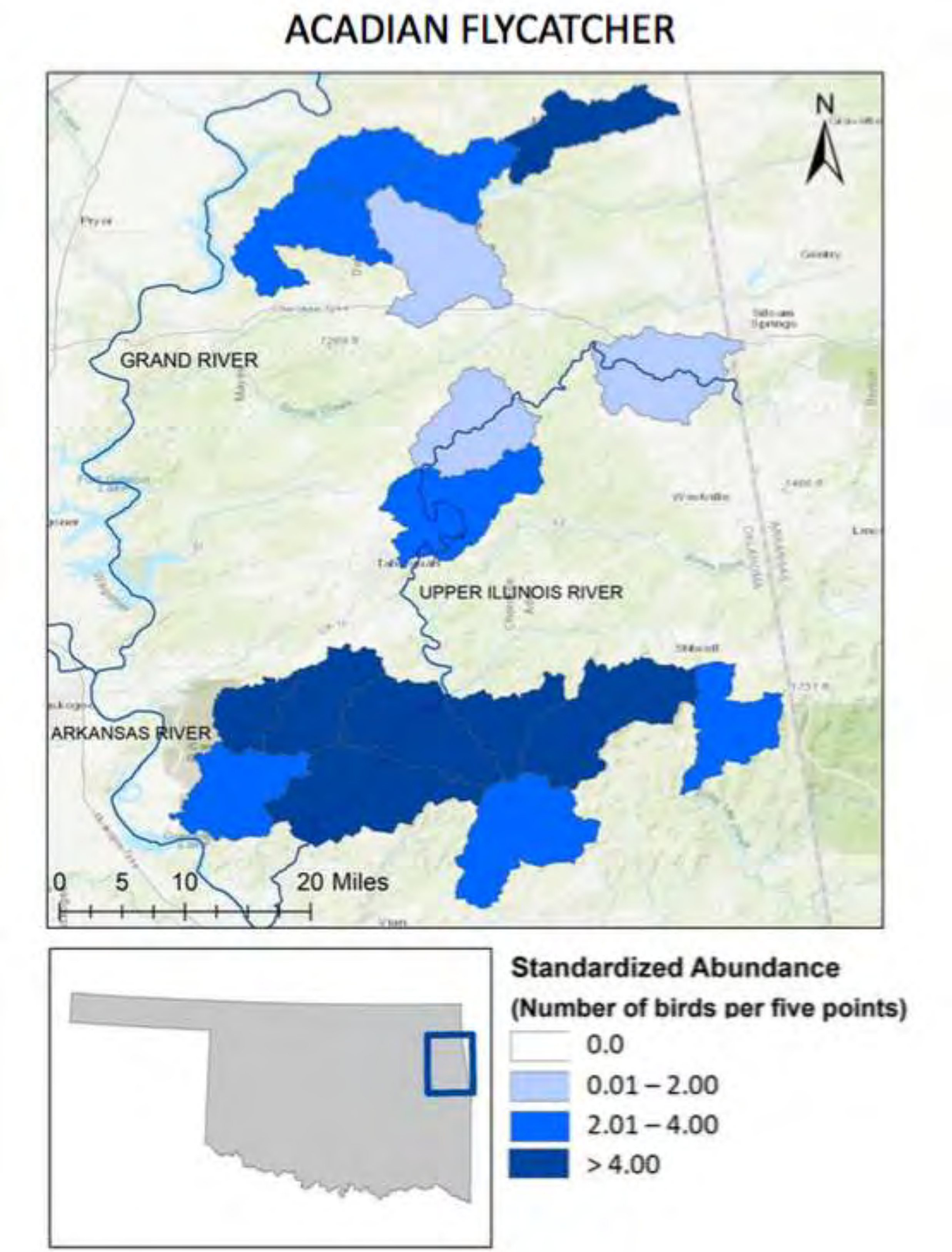
Table 3: Vegetation structure of upland and riparian plots in the Ozark Plateau (surveyed in 2017). Difference between vegetation structure attributes are significant between riparian and upland areas at $p < 0.05$.

	OZARK PLATEAU								
	Riparian (n=52)				**Upland (n=52)**				
	Min	Max	Mean	SE	Min	Max	Mean	SE	p
canopy height (m)	8	30	18	0.70	6	23	13	0.70	<0.001
canopy cover (%)	75	99	94	1.00	51	99	91	1.00	0.030
tree species richness	3	15	9	0.07	2	11	6	0.07	<0.001
understory density (%)	6	61	22	1.90	1	62	16	1.90	0.050
basal area (m^2/ha)	8	302	35	8.70	11	444	41	8.70	0.600

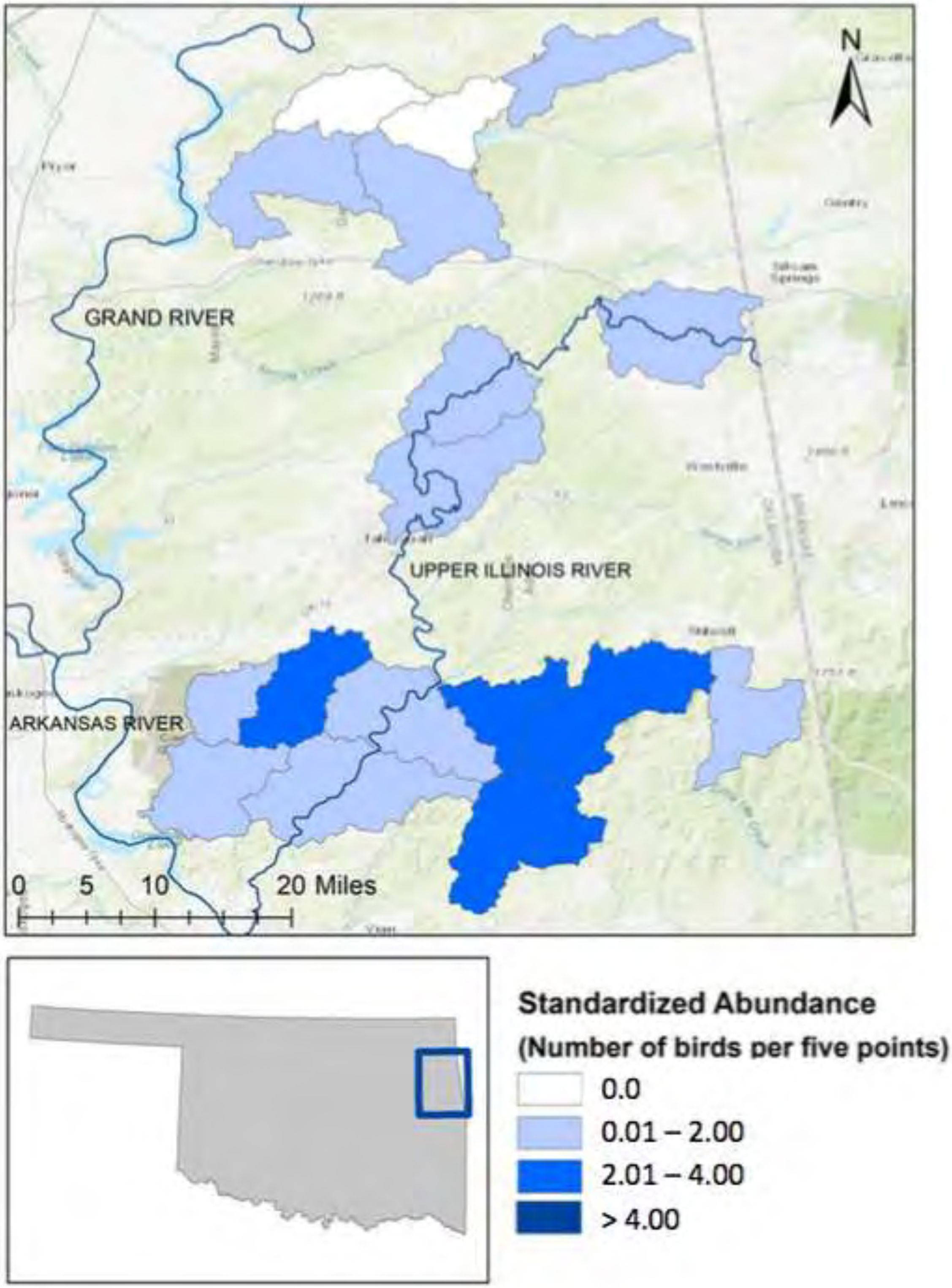
Table 4: Model selection results for variables that best explain high numbers of riparian obligate or facultative riparian birds at a given sample point. Response variable was number of species present (species richness) from the following list: Acadian Flycatcher, Black and White Warbler, Blue Grosbeak, Carolina Wren, Indigo Bunting, Kentucky Warbler, Louisiana Waterthrush, Northern Parula, Pine Warbler, Red-eyed Vireo, Scarlet Tanager, Summer Tanager, Swainson's Warbler, White-eyed Vireo, Worm-eating Warbler, Yellow-throated Vireo, and Yellow-throated Warbler. Results indicate that riparian bird communities increase species richness as canopy height increases.

Explanatory Variable	**AIC**	**dAIC**	**Weight**	**Beta (slope)**
Canopy Height*	827.3	0.0	1	0.033
Canopy Cover	842.9	15.6	<0.01	
Tree Species Richness	843.0	15.7	<0.01	
Null Model	845.3	18.0	<0.01	
Horizontal Cover	453.3	18.0	<0.01	

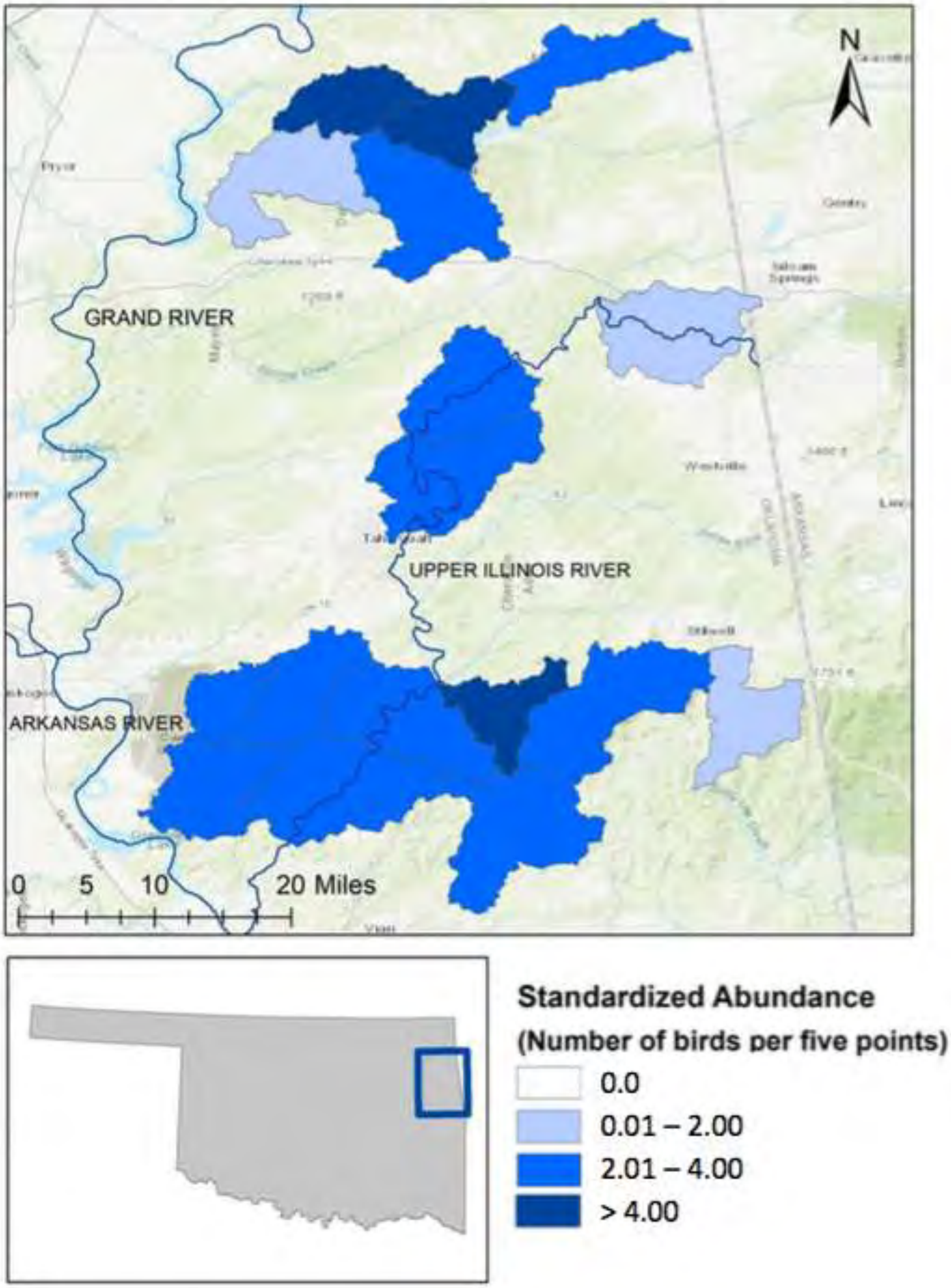
Appendix 1 – Watershed Occurrence Maps for Select Species



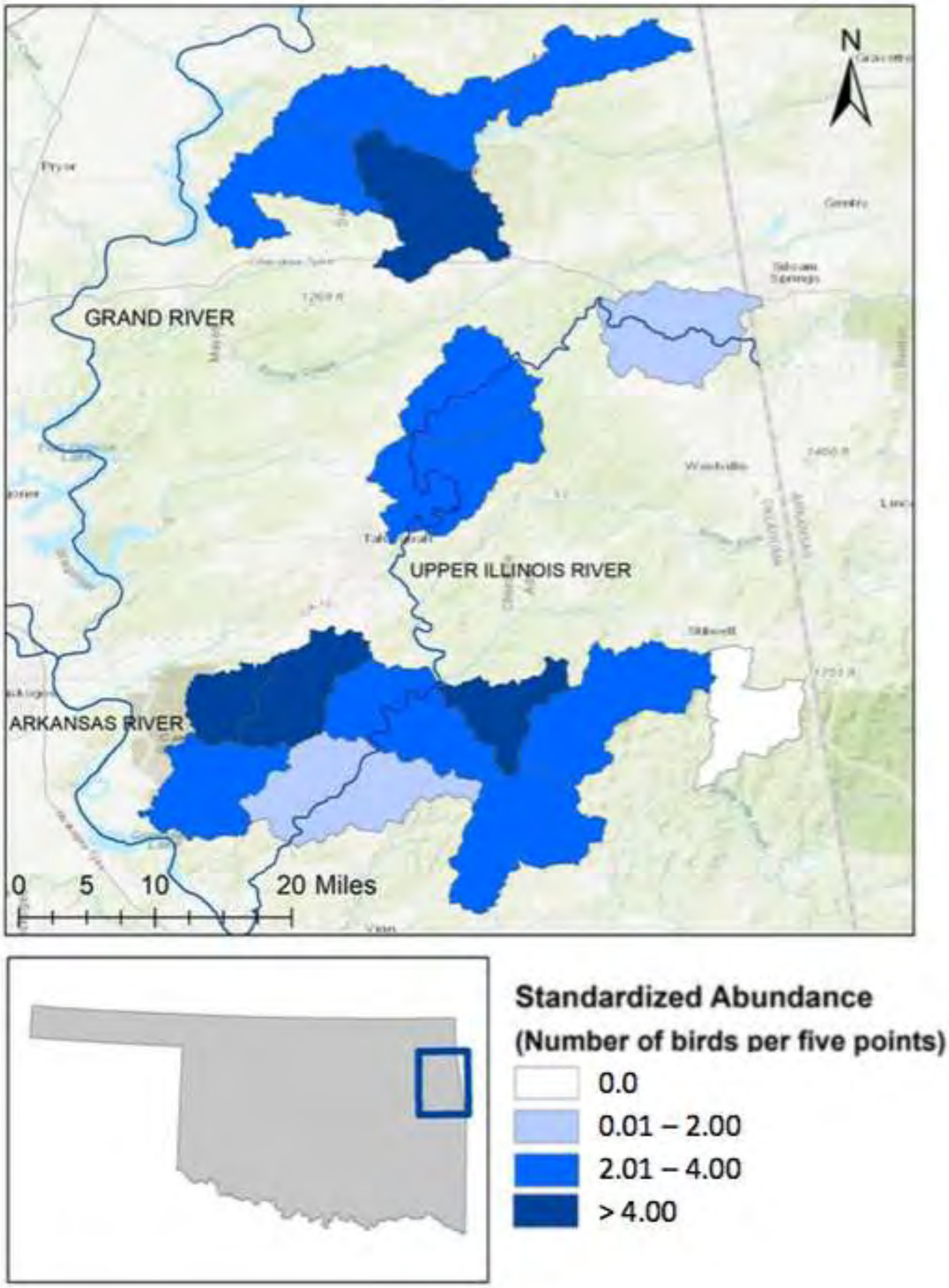
BLACK AND WHITE WARBLER



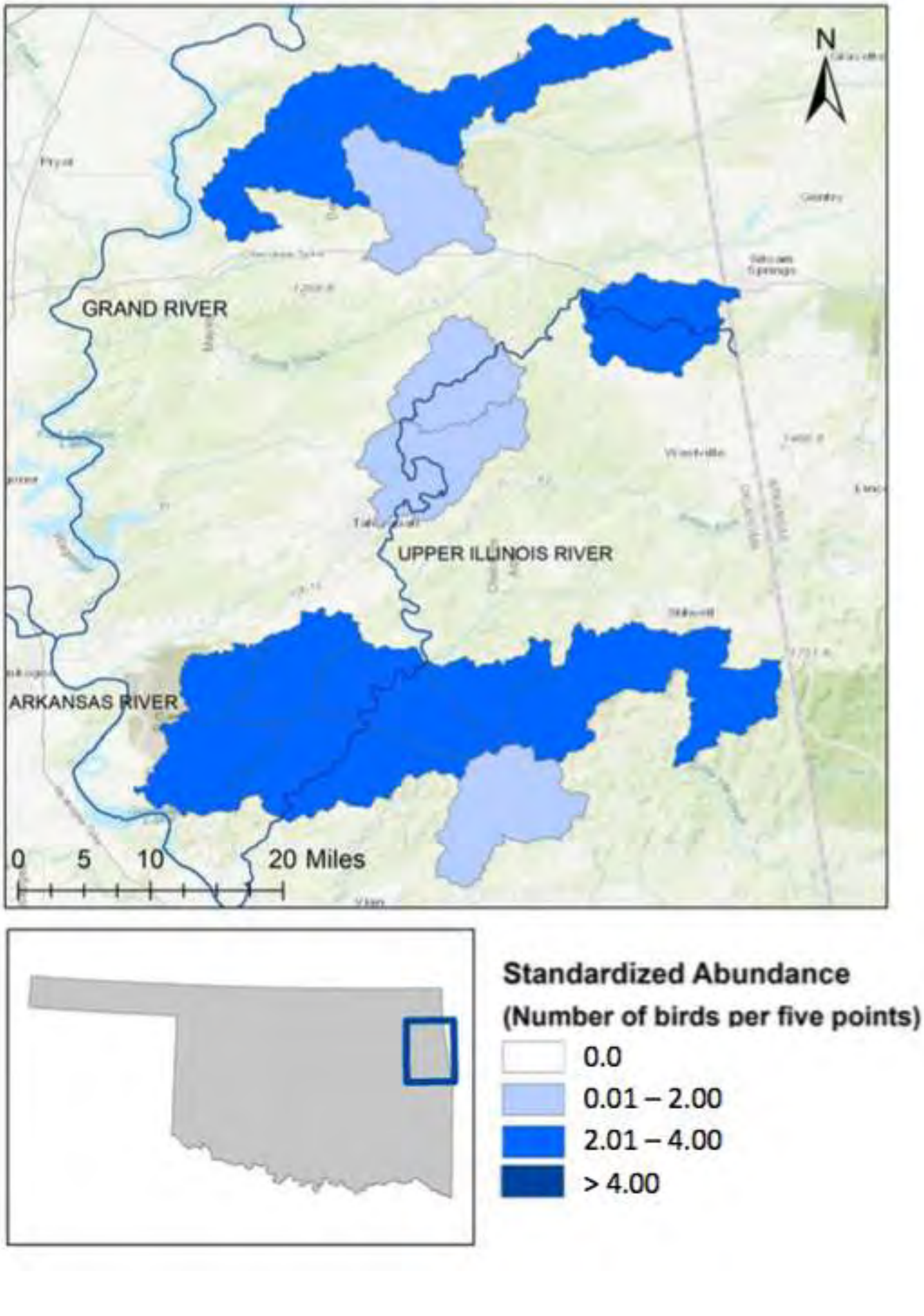
CAROLINA WREN



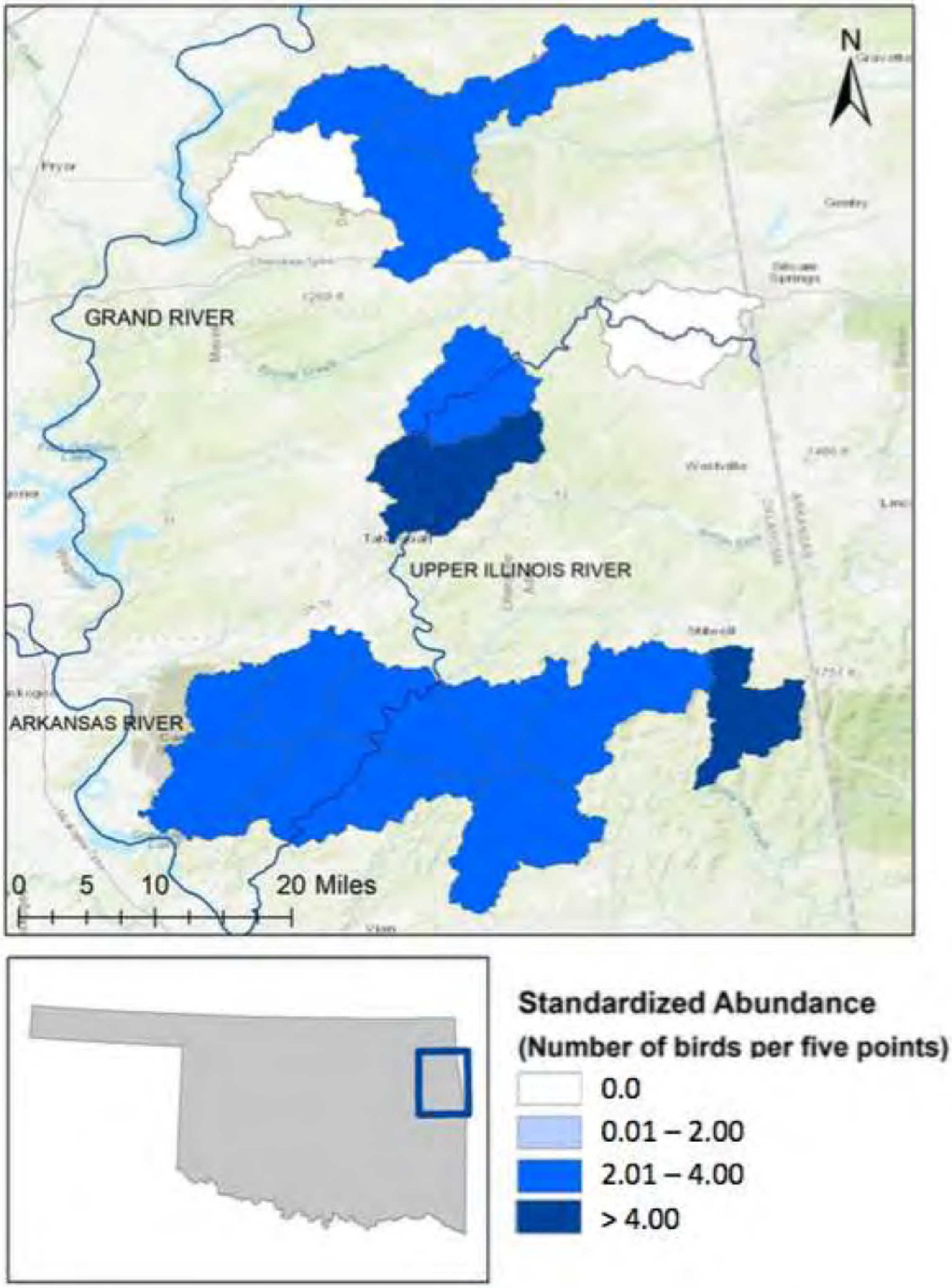
INDIGO BUNTING



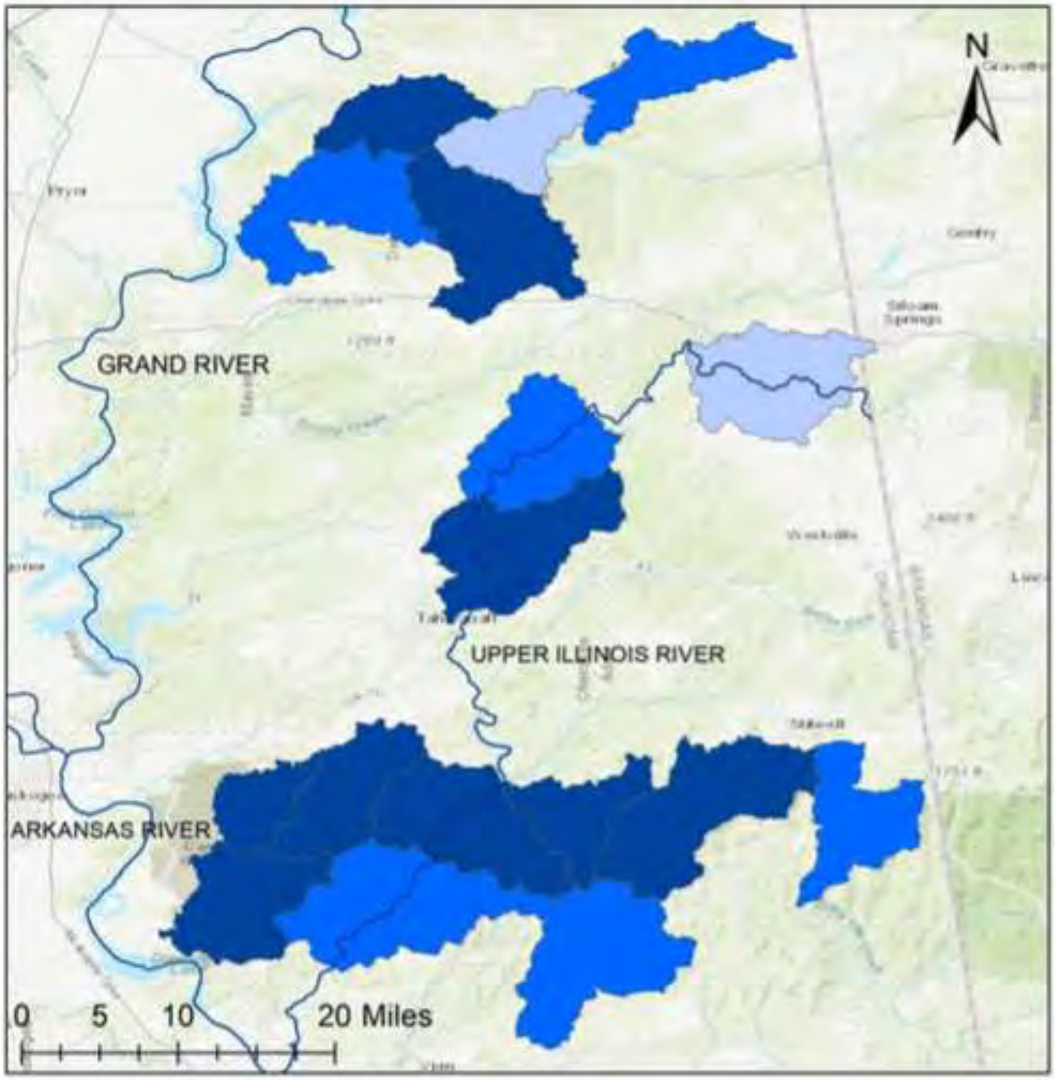
KENTUCKY WARBLER

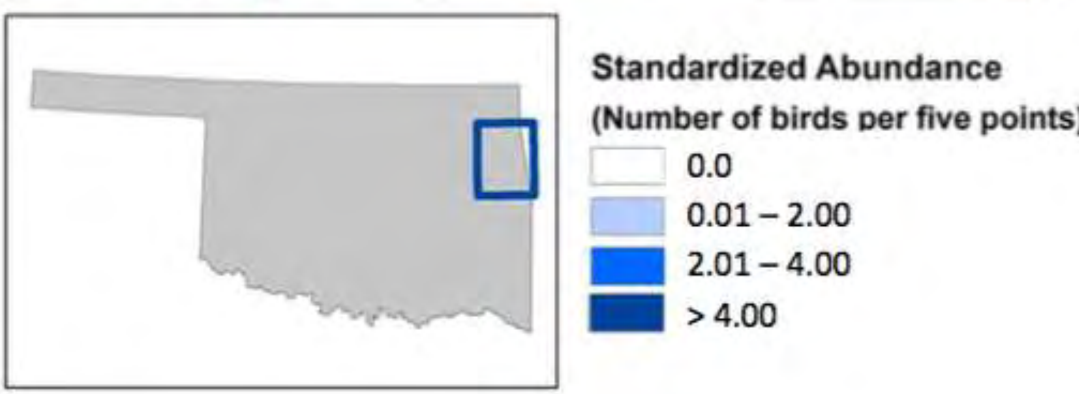


LOUISIANA WATERTHRUSH

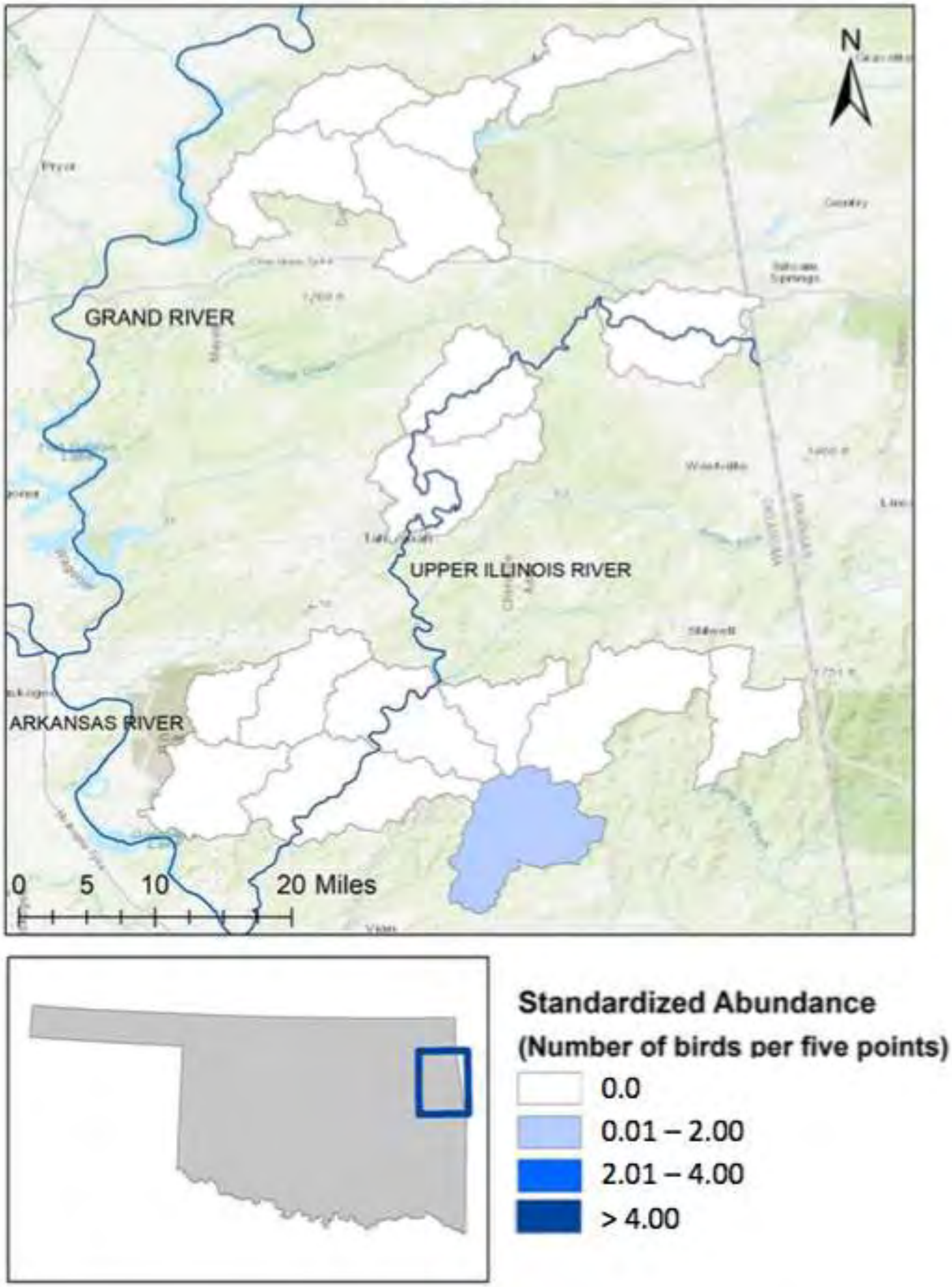


NORTHERN PARULA

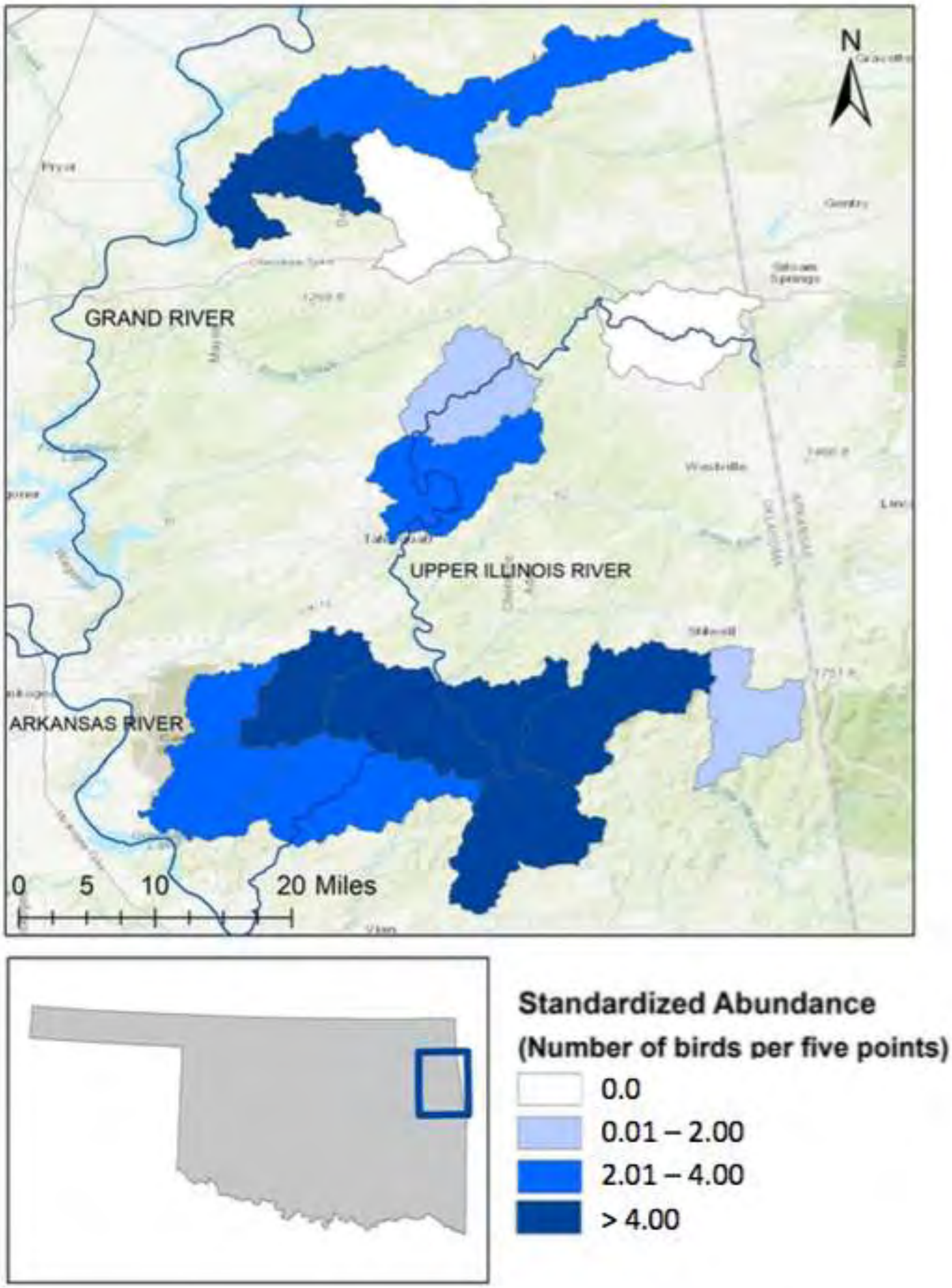




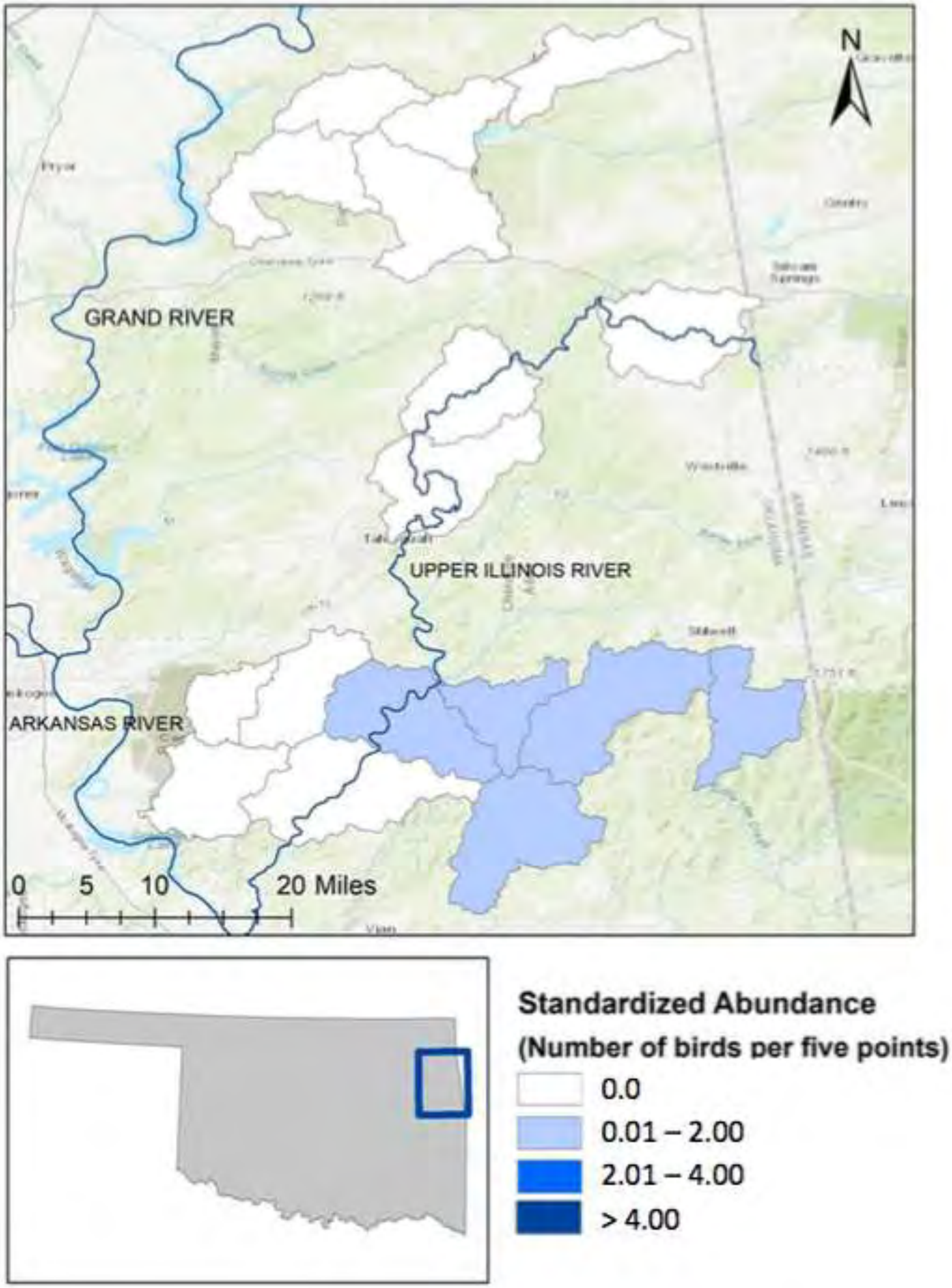
PINE WARBLER



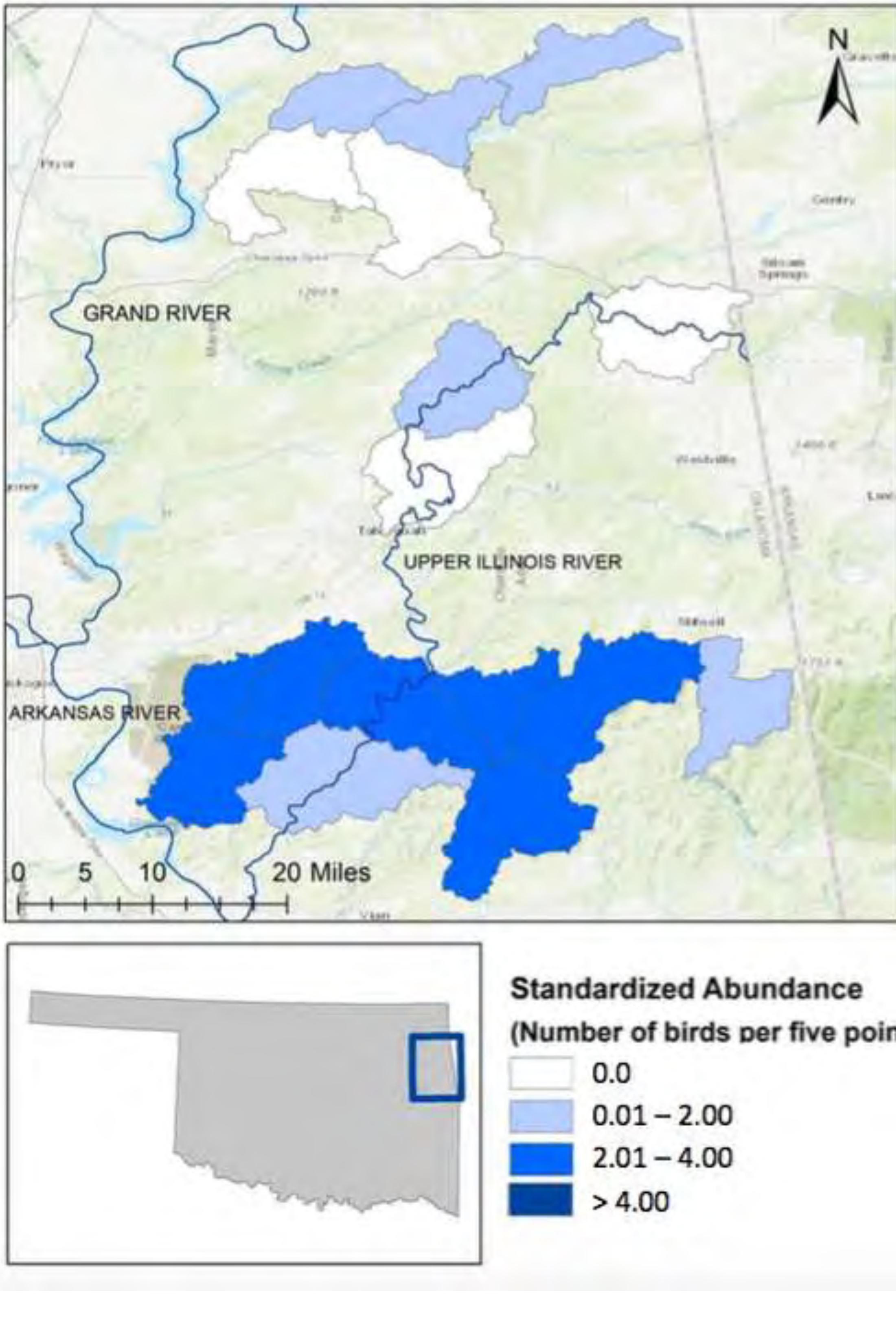
RED-EYED VIREO



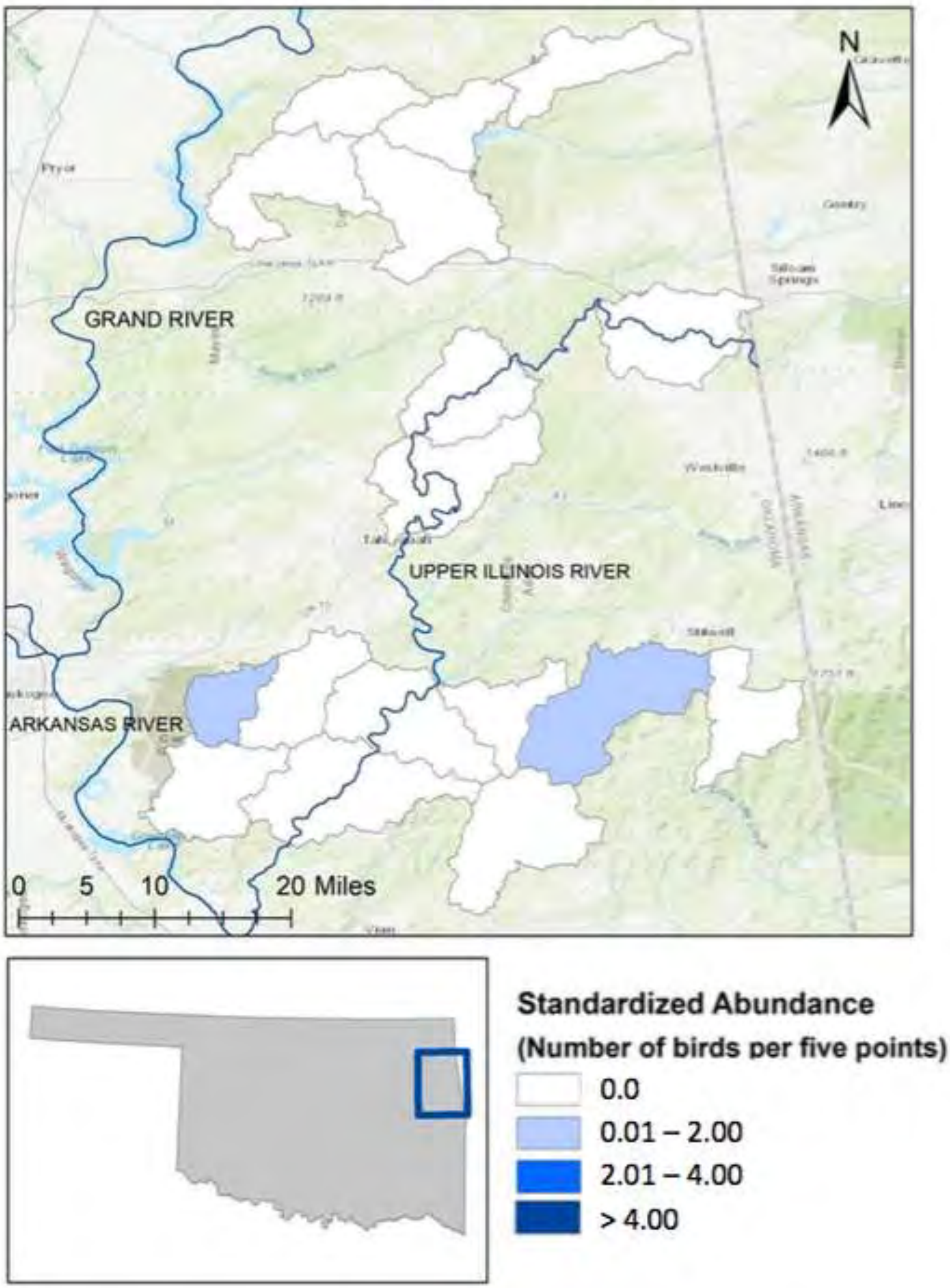
SCARLET TANAGER



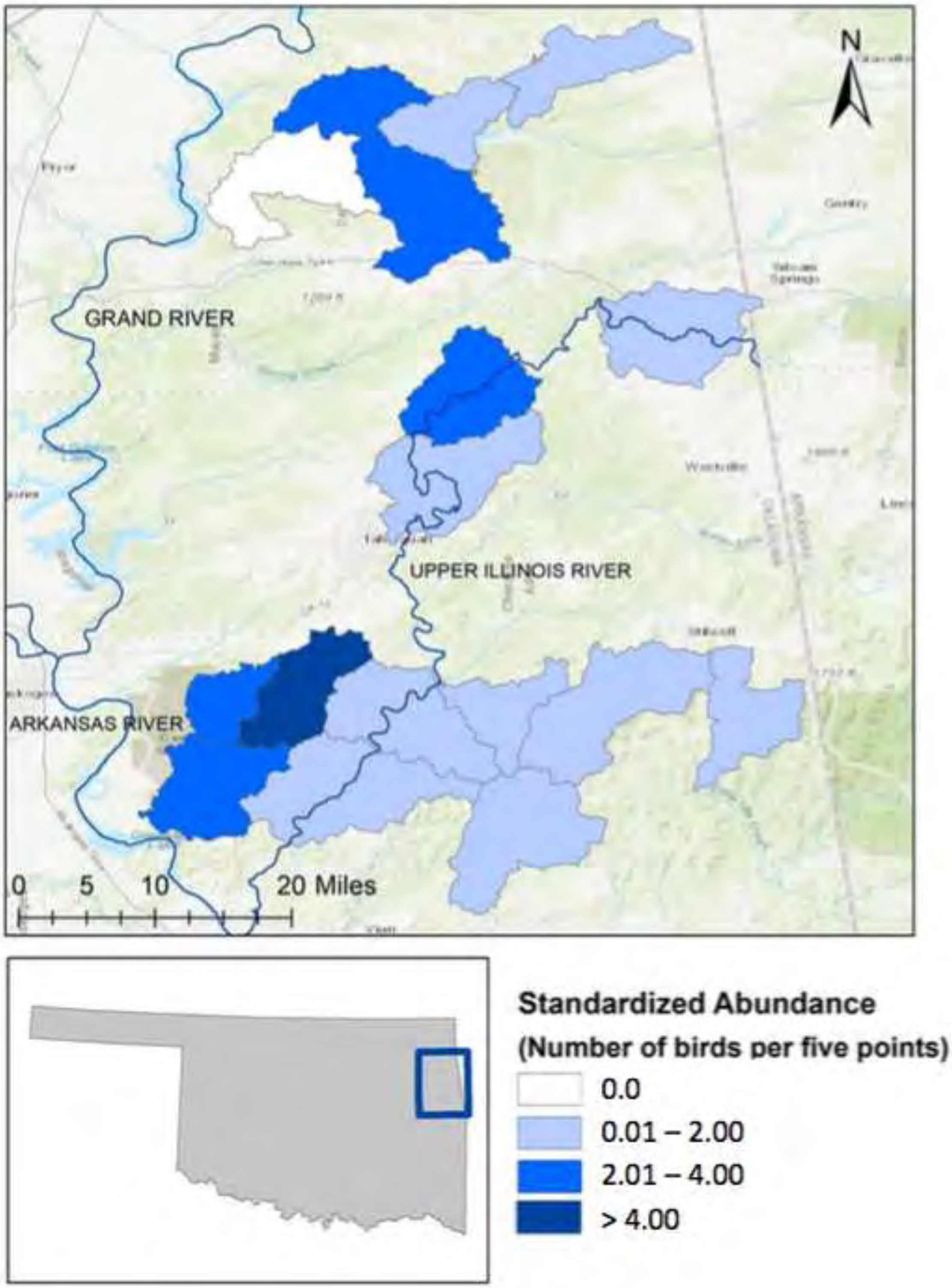
SUMMER TANAGER



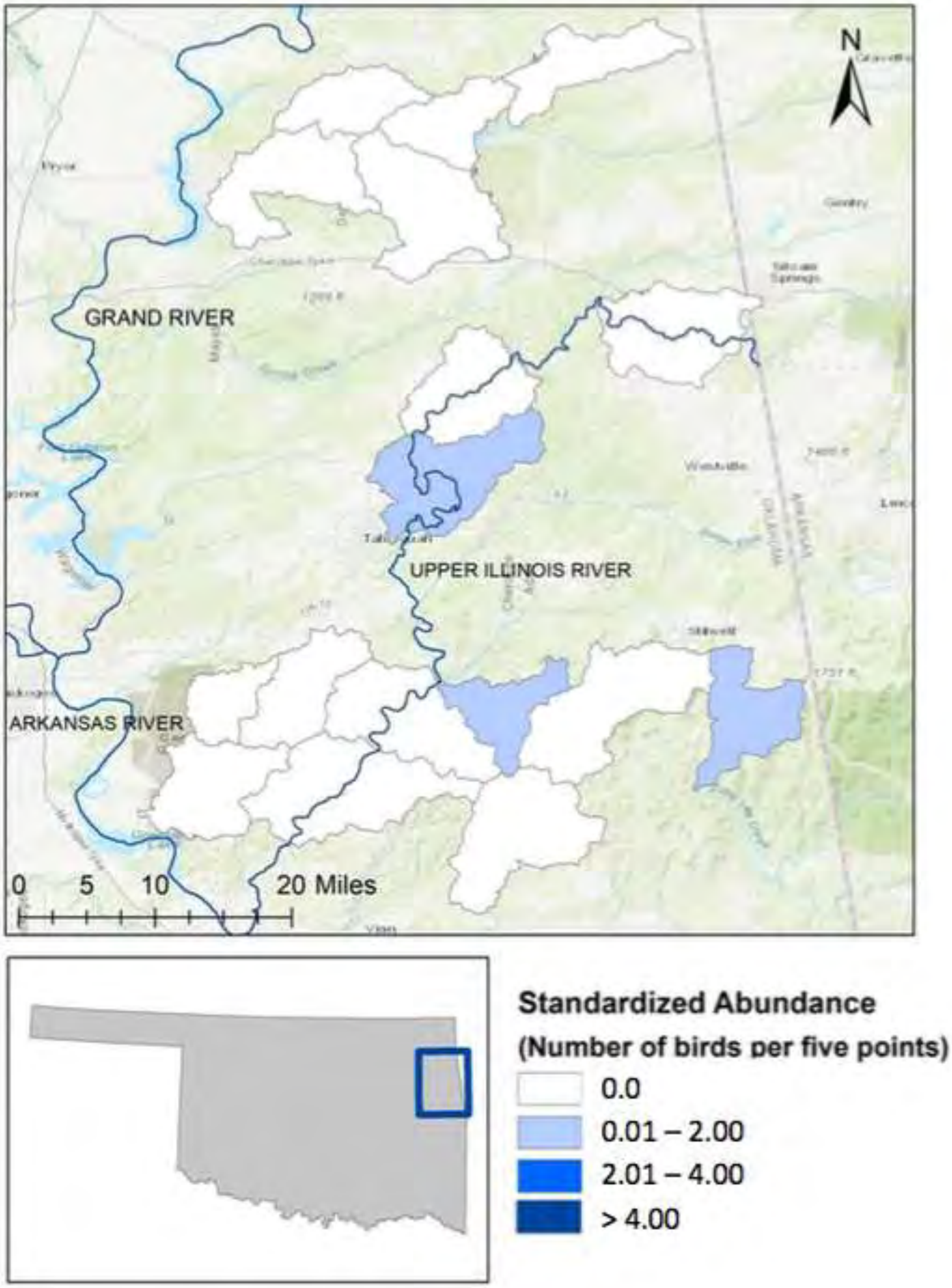
SWAINSON'S WARBLER



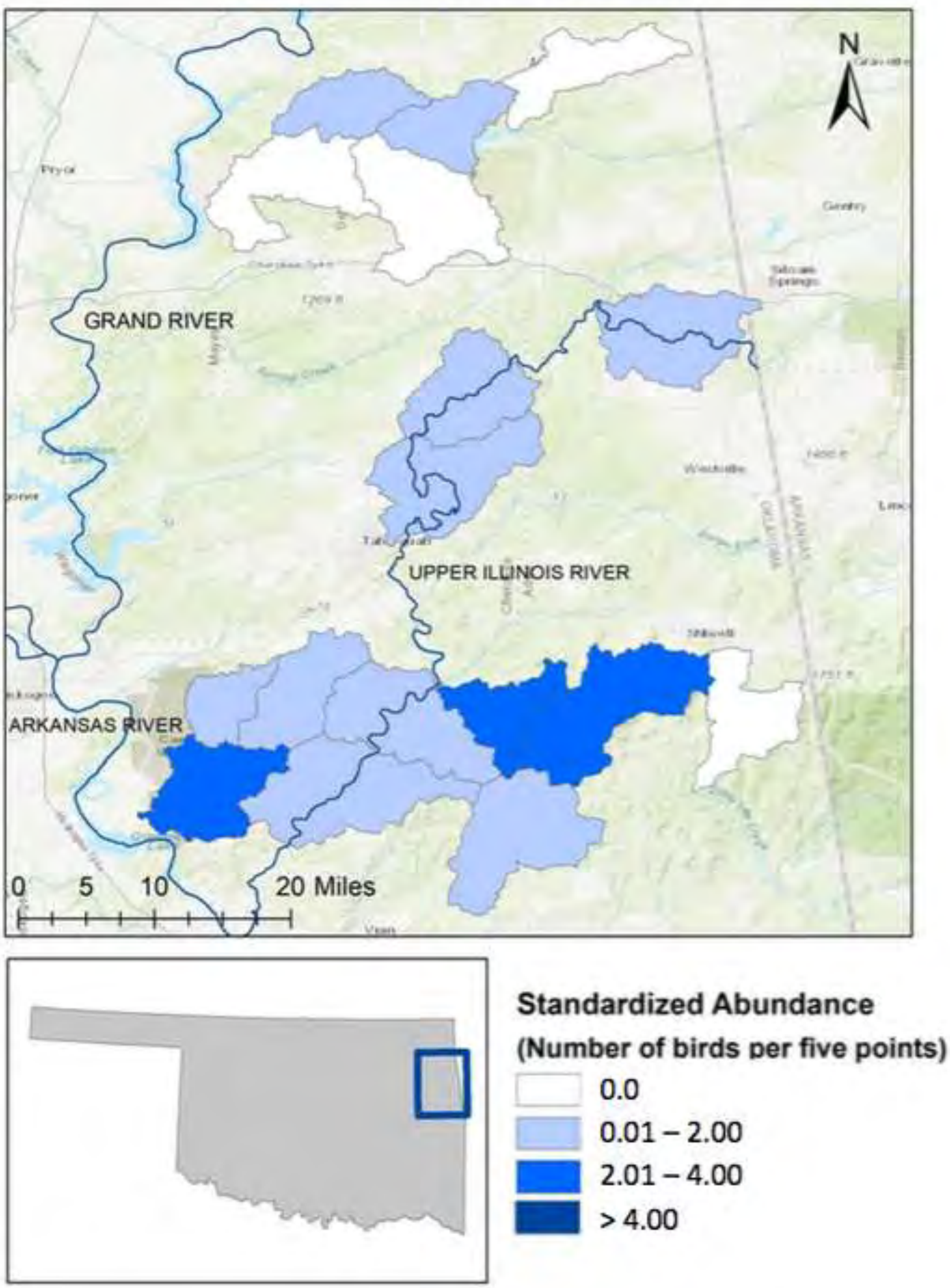
WHITE-EYED VIREO



WORM-EATING WARBLER



YELLOW-THROATED VIREO



YELLOW-THROATED WARBLER