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# Local Scale Comparisons of Avian and Woody Vegetation Communities within Four Arkansas State Parks

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Running Title: Comparison of Biotic Communities in 4 Arkansas State Parks

## Abstract

Measuring the spatial distribution of biotic communities can provide useful data to wildlife managers on how and why species assemblages differ across a landscape. During 18 May – 7 August 2015, we conducted avian point counts and collected vegetation data in nested subplots at 4 Arkansas state parks. We then used a series of one-way ANOVAs and Kruskal-Wallis tests to examine differences in species richness, Simpson's evenness, Simpson's diversity, and Bray-Curtis similarity across the 4 parks. Mount Magazine State Park had the lowest avian evenness ($F_{3,22} = 9.57$ $P = 0.003$) and diversity ($F_{3,22} = 17.8$ $P \leq 0.001$). Mount Magazine also had the lowest understory vegetation evenness ($F_{3,22} = 9.41$ $P \leq 0.001$) and diversity ($F_{3,22} = 17.8$ $P \leq 0.001$). Our analyses provided weak evidence supporting a possible relationship between avian and understory woody vegetation communities at Mount Magazine; however, this relationship was not observed in the remaining parks. Comparing biotic communities across 4 local state parks may aid park managers by providing a baseline of biotic data that can be used to better understand the collective effects acting on a specific park's flora and fauna.

## Introduction

Biodiversity can be measured within a mosaic of spatial scales, with biotic communities often governed by a mix of both local and regional processes (Turner *et al*. 1989; Noss 1990; Huston 1999; Atauri and de Lucio 2001; Agrawal *et al*. 2007; Harrison and Cornell 2008). Patterns of biodiversity may also differ depending on the spatial scale of observation (Scrosati and Heaven 2007; Marsh and Trenham 2008). Understanding the influences acting on biotic community structure and how those communities and influences change across spatial scales is imperative for the management of flora and fauna in protected areas.

Research on the influence of external factors on biotic communities has been conducted primarily at 2 spatial perspectives: the regional scale and the local scale (Caley and Schluter 1997; Hillebrand and Bleckner 2002; Harrison and Cornell 2008; Hillebrand *et al*. 2008). Studies at the regional scale typically research species populations across states, biogeographic regions, or continents (Ricklefs 2004; Harrison and Cornwell 2008). Studies at the local scale focus on community influences to the extent of an individual site or cluster of sites (Huston 1999; Harrison and Cornell 2008). Biotic community structure at the regional scale is shaped by long-term, historic changes in habitat (i.e., geology, climate, historic land use), while local scale structure can be attributed to daily changes in weather, availability of resources, and alterations to habitat structure and use by protected area managers (Böhning-Gaese 1997; Ricklefs 2004; Harrison and Cornwell 2008).

State parks serve as a primary setting for local scale studies, in that biotic communities within state parks may differ from neighboring parks due to local differences in habitat structure and resource availability due to differing park management strategies. The likelihood of human-wildlife interaction changes throughout state parks, depending on the location and frequency of human activities and the distribution of wildlife (Cole 1993; Leung and Marion 2000). For example, parks that offer longer hiking trails that bisect a greater variety of natural habitats may have increased human-wildlife interactions compared to parks that have shorter trails or that have stronger restrictions on park use (Torn *et al*. 2009). Differences in vegetation structure and resource availability may further change depending on the habitat structure within the park as well as what the conservation objectives are for each park (Cueto and Casenave 1999). By focusing research among clusters of neighboring state parks, there is a potential to examine the influences shaping local community biodiversity within those state parks.

Our goal was to quantify and compare local avian and woody vegetation communities across 4 state parks in central Arkansas. Providing baseline community metrics for state park flora and fauna while simultaneously observing how these communities differ across neighboring parks may aid managers in mitigating the effects of human recreation and park management that have shaped the species composition and communities within those parks.

## Methods and Materials

Four state parks located in close proximity to the Arkansas River in central and west-central Arkansas served as the focus for our study: Mount Magazine State Park, Petit Jean State Park, Mount Nebo State Park, and Pinnacle Mountain State Park. Mount Magazine, Mount Nebo, and Petit Jean State Parks are located in the Arkansas River Valley ecoregion and Pinnacle Mountain State Park is located in the Ouachita Mountain ecoregion (USEPA 2016).

Mount Magazine State Park is located in Logan County, south of Paris, AR (15 S 442199, 38952229) and encompasses 904ha surrounded by the Ozark National Forest. The park is positioned on top of Mount Magazine (839m), a flat-topped plateau rimmed by sandstone bluffs. Compared to the other parks in this study with smaller elevations, Mount Magazine is locally considered "montane" and the diverse collection of wildlife and vegetation species reflects this habitat description. Average temperature for Mount Magazine during the study was 23.0°C with a mean precipitation of 7.26mm.

Mount Nebo State Park is located in Yell County, west of Dardanelle, Arkansas (15 S 476945, 3897552) and encompasses 1,246ha of habitat. The park is centered on top of Mount Nebo, which measures 411m in elevation. The habitat is mostly comprised of thick oak (*Quercus* spp.) and hickory (*Carya* spp.) dominated forests, characteristic of the Ozark Plateau region, with mixes of sweetgum (*Liquidambar styraciflua*) and red maple (*Acer rubra*) stands throughout the park. Average temperature for Mount Nebo during the study was 26.7°C with a mean precipitation of 8.33mm.

Petit Jean State Park is located in Conway County, west of Oppelo, Arkansas (15 S 505957, 3886563). Petit Jean mountain (368m) lies between the Ozark and Ouachita mountain ranges in the Arkansas River Valley and serves as the midpoint for the 1,416ha park. The habitat is comprised mostly of forests dominated by a mix of oak, hickory, and pine (*Pinus* spp.) stands within a series of ponds, streams, and glades, also characteristic of the Ozark mountain ecoregion (USEPA 2016). Average temperature for Petit Jean during the study was 26.4°C with a mean precipitation of 1.87mm.

Pinnacle Mountain State Park is located in Pulaski County, Northwest of Little Rock, Arkansas (15 S 547062, 3855665) and encompasses 809ha surrounding Pinnacle Mountain (308m). The park is composed of a mosaic of habitats including boulder fields, bald cypress (*Taxodium distichum*) swamps, bottomland hardwood forests, and upland forests composed of mixes of oak, hickory, and pine stands. The park's habitat includes an Arboretum that contains woody vegetation from across the state and the Big and Little Maumelle rivers that transect the park. Average temperature for Pinnacle Mountain during the study was 28.9°C with a mean precipitation of 0.49mm.

During 18 May – 7 August 2015, we sampled avifaunal and woody vegetation communities in cyclic 1-week increments. We rotated among the 4 parks so that each park was sampled 3 times during the study. Sampling took place on trails chosen within each park based on total trail length, diversity of habitat types that a trail traversed, and the total area each trail encompassed within the park. We included all trails measuring ≤ 16km in length and split trails measuring 8 – 16km into 2 equal portions to accommodate temporal limitations. We used ArcGIS (Environmental Systems Research Institute, Inc., Redlands, CA) to assess the diversity of habitat types represented along each trail (USEPA 2016) and the total area of the trails within each park. Applying these criteria resulted in 26 trails included in the study, with 6 trails each at Mount Magazine State Park, Mount Nebo State Park, and Petit Jean State Park and 8 trails at Pinnacle Mountain State Park. Initial sampling locations for avian point counts and vegetation subplots along trails were located randomly within the first 250m of each trail's trailhead. Subsequent sampling locations were then systematically located every 250m to ensure independence of bird count data (Ralph *et al*. 1995; Torn *et al*. 2009).

Avian point counts began ≤15min of sunrise each weekday and lasted approximately until 5 hours after sunrise. Point counts lasted 5-min each with birds sighted/heard at each 50m-radius point identified to species level and specified in their location to the study point, their distance from the study point, and whether the record was visual or auditory via symbols established by Ralph *et al*. (1993). We conducted point counts only during suitable weather conditions for avian activity defined as mornings with no rain or fog (Cyr *et al*. 1995; Martin *et al*. 1997); wind speeds <13km/hr (Freedmark and Rogers 1995; Petit *et al*. 1995); and temperatures ranging 18 – 23°C (Buskirk and McDonald 1995; Martin *et al*. 1997).

Each avian point was sampled independently 3 times per week, once each by 3 observers (Petit *et al.* 1995). This methodology resulted in 9 visits for each of the 227 points (i.e., 3 times/week at each point during 3 independent weeks), with 45 minutes of total observation time collected per point. By utilizing 3 observers throughout the week rather than 1, as is common in many avian surveys, we were able to diminish repeated observer bias and increase the detection probability at each point (Ralph *et al*. 1995, MacKenzie and Royle 2005). Point counts along each trail were scheduled to prevent any point being visited at the same time throughout the week by any of the 3 observers.

We sampled woody vegetation subplots once at each sampling location during the study using a nested subplot method similar to James and Shugart (1970). Sampling occurred on adjusted points 16.3m off trail to establish a 5-m buffer between each trail edge and vegetation plot to avoid immediate edge effects (Brown *et al*. 2009). Subplots consisted of a 5-m radius plot, where we identified and counted all understory vegetation (saplings measuring ≤1.4m tall), nested in an 11.3-m radius plot, where we identified and counted all overstory vegetation (trees measuring >1.4m tall; Geldenhuys 1997, Rodewald and Brittingham 2004, Brown *et al*. 2009).

We calculated species richness (recorded as S), Simpson's Evenness Index, $E_{1/D} = \frac{(1/D)}{S}$ (recorded as E), and Simpson's Diversity Index, $D = \sum p_i^2$ (recorded as 1 – D; Magurran 2004) at each sample location for each biotic community. We used the averaged community metric data from sampling points along each trail as replicates for comparisons among the parks. We investigated if metric values for each biotic community differed across the parks using a series of one-way ANOVAs (α = 0.05 for all statistical analyses; SAS/STAT software Version 9.3) or Kruskal-Wallis tests (R Version 3.1.2.) with Tukey's and Dunn's post hoc tests, respectively. Additionally, we used the Bray-Curtis similarity Index (R Version 3.1.2.) to investigate differences in species composition among parks (Su *et al*. 2004).

## Results

We recorded 70 avian species, 65 understory vegetation species, and 83 overstory vegetation species using 2,043 avian point counts and 227 vegetation subplots. Species richness did not differ for avifauna ($F_{3,22} = 0.50$ $P = 0.685$), understory vegetation ($F_{3,22} = 2.85$ $P = 0.060$), or overstory vegetation communities ($F_{3,22} = 1.67$ $P = 0.202$) across the 4 parks (Table 1). Diversity and evenness values for avifauna ($F_{3,22} = 17.8$ $P \leq 0.001$; $F_{3,22} = 9.57$ $P = 0.003$) and understory vegetation communities ($F_{3,22} = 7.38$ $P = 0.001$; $F_{3,22} = 9.41$ $P \leq 0.001$) were lowest at Mount Magazine (Table 1). Overstory vegetation evenness ($F_{3,22} = 0.71$ $P = 0.559$) and diversity values ($F_{3,22} = 1.61$ $P = 0.242$) did not differ among the parks (Table 1).

Table 1. Community metrics (± 1 SD) for avian, understory woody vegetation, and overstory woody vegetation communities in Mount Magazine, Mount Nebo, Petit Jean, and Pinnacle Mountain State Parks, Arkansas, 2015. Within each community metric and taxon, different letters indicate differences among parks ($P < 0.05$).

| Taxon and parks | Richness | Evenness | Diversity |
|---|---|---|---|
| *Avian* | | | |
| Mount Magazine | 26.0 ± 3.63[a] | 0.49 ± 0.08[a] | 0.92 ± 0.01[a] |
| Mount Nebo | 29.0 ± 6.94[a] | 0.69 ± 0.11[b] | 0.95 ± 0.01[b] |
| Petit Jean | 30.0 ± 7.19[a] | 0.65 ± 0.06[b] | 0.95 ± 0.01[b] |
| Pinnacle Mountain | 29.0 ± 6.14[a] | 0.74 ± 0.10[b] | 0.95 ± 0.01[b] |
| *Understory vegetation* | | | |
| Mount Magazine | 25.0 ± 4.80[a] | 0.10 ± 0.03[a] | 0.55 ± 0.16[a] |
| Mount Nebo | 20.0 ± 6.50[a] | 0.27 ± 0.10[b] | 0.77 ± 0.10[b] |
| Petit Jean | 23.0 ± 3.33[a] | 0.27 ± 0.11[b] | 0.81 ± 0.08[b] |
| Pinnacle Mountain | 18.0 ± 5.54[a] | 0.28 ± 0.14[b] | 0.76 ± 0.07[b] |
| *Overstory vegetation* | | | |
| Mount Magazine | 27.0 ± 6.12[a] | 0.35 ± 0.14[a] | 0.88 ± 0.04[a] |
| Mount Nebo | 23.0 ± 6.56[a] | 0.43 ± 0.14[a] | 0.89 ± 0.02[a] |
| Petit Jean | 23.0 ± 2.83[a] | 0.32 ± 0.14[a] | 0.83 ± 0.08[a] |
| Pinnacle Mountain | 21.0 ± 5.13[a] | 0.35 ± 0.15[a] | 0.84 ± 0.07[a] |

Among the 4 parks, avian species composition was most similar between Petit Jean and Pinnacle Mountain state parks (Tables 2 and 3). Understory vegetation species composition was most similar between Mount Nebo and Petit Jean (Tables 2 and 4) and overstory vegetation species composition was most similar between Mount Nebo and Mount Magazine (Tables 2 and 5). Species composition was most dissimilar between Mount Magazine and Pinnacle Mountain State Parks for all biotic communities.

Table 2. Bray-Curtis similarity values (%) for regional avian (A), understory vegetation (UV), and overstory vegetation (OV) species composition in Mount Magazine, Mount Nebo, Petit Jean, and Pinnacle Mountain State Parks, Arkansas, 2015.

| Parks | Magazine | Nebo | Petit Jean | Pinnacle |
|---|---|---|---|---|
| Magazine A, UV, OV | | 64.8, 36.3, 52.9 | 53.8, 41.3, 44.2 | 51.3, 26.4, 41.5 |
| Nebo A, UV, OV | 64.8, 36.3, 52.9 | | 77.6, 72.1, 45.7 | 78.8, 43.2, 52.6 |
| Petit Jean A, UV, OV | 53.8, 41.3, 44.2 | 77.6, 72.1, 45.7 | | 79.5, 50.0, 45.5 |
| Pinnacle A, UV, OV | 51.3, 26.4, 41.5 | 78.8, 43.2, 52.6 | 79.5, 50.0, 45.5 | |

Table 3. Point count totals for the 10 most abundant avian species observed in Mount Magazine, Mount Nebo, Petit Jean, and Pinnacle Mountain State Parks, Arkansas, 2015.

| Mount Magazine | | Mount Nebo | | Petit Jean | | Pinnacle Mtn. | |
|---|---|---|---|---|---|---|---|
| Species | Count | Species | Count | Species | Count | Species | Count |
| Ovenbird | 115 | Red-Eyed Vireo | 77 | Red-Eyed Vireo | 61 | Carolina Wren | 51 |
| Indigo Bunting | 84 | Indigo Bunting | 53 | Carolina Wren | 58 | Tufted Titmouse | 50 |
| Red-Eyed Vireo | 76 | Carolina Chickadee | 51 | Carolina Chickadee | 54 | Red-Eyed Vireo | 48 |
| Black & White Warbler | 55 | Black & White Warbler | 49 | Tufted Titmouse | 51 | Carolina Chickadee | 46 |
| Eastern Wood Pewee | 42 | Northern Cardinal | 46 | Northern Cardinal | 47 | Northern Cardinal | 44 |
| Carolina Chickadee | 35 | Carolina Wren | 44 | Indigo Bunting | 46 | Pine Warbler | 41 |
| Summer Tanager | 26 | Tufted Titmouse | 42 | American Crow | 44 | Indigo Bunting | 40 |
| Hooded Warbler | 23 | Summer Tanager | 41 | Blue Gray Gnatcatcher | 40 | Summer Tanager | 40 |
| Scarlet Tanager | 23 | Eastern Wood Pewee | 35 | Black & White Warbler | 37 | Blue Jay | 39 |
| Blue Jay | 22 | Blue Gray Gnatcatcher | 32 | Pine Warbler | 32 | Blue Gray Gnatcatcher | 27 |

Table 4. Count totals for the 10 most abundant understory woody vegetation species observed in Mount Magazine, Mount Nebo, Petit Jean, and Pinnacle Mountain State Parks, Arkansas, 2015.

| Mount Magazine | | Mount Nebo | | Petit Jean | | Pinnacle Mtn. | |
|---|---|---|---|---|---|---|---|
| Species | Count | Species | Count | Species | Count | Species | Count |
| Virginia Creeper | 8894 | Virginia Creeper | 1470 | Virginia Creeper | 1614 | Blueberry *spp.* | 1070 |
| Blackberry *spp.* | 1233 | Northern Red Oak | 541 | Blueberry *spp.* | 482 | White Oak | 767 |
| Blueberry *spp.* | 728 | White Oak | 365 | Pignut Hickory | 400 | Virginia Creeper | 359 |
| Northern Red Oak | 476 | Blackberry *spp.* | 233 | Northern Red Oak | 327 | Shortleaf Pine | 334 |
| White Oak | 391 | Blackgum | 209 | Blackberry *spp.* | 320 | Blackberry *spp.* | 217 |
| Pignut Hickory | 316 | Flowering Dogwood | 205 | White Oak | 254 | Northern Red Oak | 168 |
| Black Locust | 269 | Silver Maple | 193 | Flowering Dogwood | 105 | Blackjack Oak | 161 |
| Rose *spp.* | 226 | Pignut Hickory | 192 | Blackgum | 92 | Pignut Hickory | 139 |
| Sassafras | 129 | Paw Paw | 159 | Silver Maple | 84 | Blackgum | 137 |
| Privet *spp.* | 123 | Blueberry *spp.* | 132 | American Beautyberry | 83 | American Beautyberry | 91 |

Table 5. Point count totals for the 10 most abundant overstory woody vegetation species observed in Mount Magazine, Mount Nebo, Petit Jean, and Pinnacle Mountain State Parks, Arkansas, 2015.

| Mount Magazine | | Mount Nebo | | Petit Jean | | Pinnacle Mtn. | |
|---|---|---|---|---|---|---|---|
| Species | Count | Species | Count | Species | Count | Species | Count |
| Pignut Hickory | 732 | Pignut Hickory | 382 | Shortleaf Pine | 2053 | Shortleaf Pine | 375 |
| White Oak | 388 | Blackgum | 261 | Pignut Hickory | 747 | Pignut Hickory | 352 |
| Northern Red Oak | 369 | Eastern Red Cedar | 255 | Winged Elm | 382 | Sweet Gum | 222 |
| Mockernut Hickory | 225 | Northern Red Oak | 188 | Northern Red Oak | 299 | White Oak | 165 |
| Blackgum | 168 | White Oak | 188 | American Elm | 250 | Post Oak | 152 |
| Persimmon | 153 | Paw Paw | 148 | Sweet Gum | 225 | American Elm | 132 |
| Black Cherry | 148 | American Elm | 129 | Eastern Red Cedar | 194 | Blackgum | 91 |
| American Elm | 126 | Post Oak | 125 | White Oak | 186 | Northern Red Oak | 83 |
| Downey Serviceberry | 126 | Flowering Dogwood | 117 | Downey Serviceberry | 185 | Mockernut Hickory | 81 |
| Sassafras | 120 | Silver Maple | 75 | Blackgum | 177 | Shumard Oak | 72 |

## Discussion

We observed no differences in species richness for avian or woody vegetation communities across the 4 parks. Prior research suggests that species richness at the local scale is partly influenced by regional and geological processes such as historic land use, climate, topography, and soil conditions (Harrison *et al*. 2006). Considering that all 4 study sites were mountainous parks of similar latitude and regional habitat condition, the lack of differences in species richness then is unsurprising. Similarities in community richness may have reflected species present that have adapted to the same historical patterns of temperature, precipitation, and topography in west-central Arkansas.

A positive relationship exists between vegetation community structure and avian communities at local scales via the availability of resources and the amount of protective vegetation cover (Böhning-Gaese 1997; Cueto and Casenave 1999; Gill *et al*. 2001; Rahbek and Graves 2001). Given that park management decisions can affect vegetation communities within state parks through vegetation removal and trail upkeep, the lower values of avian and understory vegetation community evenness and diversity we observed at Mount Magazine compared to the other parks could be related to their management practices. For example, daily decisions on trail upkeep, design, and the clearing of debris within state parks can promote unevenness in woody vegetation through the removal of disturbance-intolerant species. To promote recreation in state parks, park managers will alter trail structure and vegetation with respect to the desired purpose of the trail (Marion *et al.* 2011). This may explain why Mount Magazine had some of the lowest levels understory vegetation and avian evenness among the parks. Many trails within Mount Magazine had primarily grassy substrates and led to major tourism structures (i.e., the lodge, visitor center, and picnic areas). Consequently, trails in Mount Magazine were regularly mowed and had branch trimming to allow for greater ease of travel to these structures compared to trails within the other parks that did not lead to major structures of interest. Thus, these modifications to understory woody vegetation communities from recreational use and park management may have led to cascading effects on the surrounding avian communities in Mount Magazine that depend on trailside vegetation for visual cover and resources (Gill *et al*. 2001).

The lack of differences in overstory woody vegetation communities among the 4 parks may also be attributed to park management decisions. State parks often do not allow for major timber removal within park boundaries and typically alter woody vegetation only in conjunction with park management decisions. Overstory woody vegetation communities were also likely influenced by long-term patterns of climate, human land use, and topography within the region.

Similarities in species composition were primarily observed between the 3 parks located within the Arkansas River Valley, likely due to similarities in historic topography and land use among the parks in that ecoregion. Ecoregions are identified based on similarities in abiotic and biotic factors such as soil type, historic land use, and geology (USEPA 2016). Given that Mount Magazine, Mount Nebo, and Petit Jean occurred in the same ecoregion, it was expected that the biotic community compositions would be highly similar. Of the 4 parks, Mount Magazine and Pinnacle Mountain were of greatest geographical distance from each other and existed in 2 different ecoregions. This distance may have translated into differing abiotic pressures acting on park flora and fauna, resulting in the dissimilarities in biotic community composition between the 2 parks that we observed (USEPA 2016).

## Conclusions

Biotic communities within protected areas may respond differently to anthropogenic and natural influences depending on the specific management objectives and habitat structures within each park. We observed no differences in species richness for any of the communities studied. However, there was slight evidence for a possible relationship between avian and understory vegetation evenness and diversity in Mount Magazine, which had the lowest values of both metrics for both communities. These results underscore the importance of researching how local scale changes in park management strategies and habitat structure can influence biotic communities across a landscape. Future research extending the comparisons of biotic communities at a larger scale may benefit protected area managers by providing baseline sets of biotic community data which could then be used to develop holistic management strategies that encompass the collective anthropogenic and environmental effects shaping local state park flora and fauna.

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