BREEDING BIRD RESPONSE TO A SECOND-STAGE SHELTERWOOD HARVEST IN AN UPLAND HARDWOOD FOREST

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Abstract—Post-logging sites were historically assumed to provide unfavorable habitat for songbirds. Timber harvests have always been important for species that require disturbances, but while most studies focus on clearcuts, few examine the harvesting methods ranging between clearcutting and undisturbed forests; such as those created with shelterwood prescriptions. We studied breeding bird community response to different basal area retention levels during the second stage of a two-stage shelterwood harvest, 12 and 13 years post-initial harvest. Study sites were located in an upland hardwood forest in northern Alabama on the southern end of the mid-Cumberland Plateau through territory mapping. This study examined how different retention cuts affect bird species with varying habitat requirements. Bird diversity (calculated using the Brillouin Index) was compared among treatments using analysis of variance with a post-hoc LSD test. The relationship between habitat features and bird diversity were examined using correlation analysis. Breeding bird diversity was significantly lower in the control stands than the 50 percent retention stands (2013 $p = 0.002$ – 2014 $p = 0.007$) in both years. Breeding bird diversity was positively correlated with sapling density in 2013 ($r = 0.65$); showed a quadratic correlation with sapling density in 2014 ($r = 0.85$), and canopy cover in both years (2013 $r = 0.96$; – 2014 $r = 0.96$). Breeding bird diversity was similar across all four shelterwood treatments in both years, although these treatments had structural differences among them. These finding suggest that breeding bird diversity is dynamic and temporally dependent upon timber harvest and subsequent succession.

INTRODUCTION

Neotropical songbird conservation continues to be a topic receiving considerable focus and attention due to habitat degradation and/or transformation over the past century (Augenfeld and others 2008, Schlossberg and King 2007). Neotropical songbirds are primarily habitat specialists, each requiring a specific habitat during the breeding period (Perry and Thill 2013). MacArthur (1964) stated that the vegetation structure of an area can affect the abundance, richness and diversity of the breeding songbird community. Due to entire bird communities' wide array of habitat preferences, it is difficult for managers to create suitable habitat for all species. Regenerating clearcuts are considered detrimental to mature/interior forest birds, but beneficial for early-successional/disturbance dependent species immediately following harvest (Gram and others 2003). Silviculture practices differ in their effects on bird communities, primarily shelterwood prescriptions. Because shelterwood harvests are a two stage process, where the initial disturbance or harvest reduces overstory to create favorable light conditions for understory regeneration and reproduction, some favorable habitats are retained by the remaining canopy trees (Newell and Rodewald 2012). Over the course of 10 years, the understory is allowed to grow under the protection of the overstory; thus, creating a vertically stratified forest structure. The shift in plant communities can alter bird communities due to birds' preferences associated with vegetation complexity (Brawn and others 2001). The habitat heterogeneity created through varying levels of structural complexity provides viable habitat for a large suite of bird species that require differing habitat (Twedt and Somershoe 2009). With shelterwood prescriptions, we can manage for a myriad of songbird species that vary in their habitat preferences. We seek to explore the specific habitat associations driving bird species composition changes across various levels of shelterwood harvest.

METHODOLOGY

Study Site and Design

Study sites were located in northern Jackson County, AL on the southern end of the mid-Cumberland Plateau. Three block replications at 2 different sites (1 at Miller Mountain (MM) and 2 at Jack Gap (JG)) with 5 stands each comprise the study areas (totaling 3 block replications and 15 stands). Miller Mountain has a mean elevation of 500 m with a southwestern aspect, and Jack Gap has elevations of 450 and 360 m respectively with both having northern aspects. Study sites were mainly composed of oaks (*Quercus velutina, Q. rubra, Q. alba, Q, prinus*), yellow-poplar

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(*Liriodendron tulipifera*), hickories (*Carya* spp.), and sugar maple (*Acer saccharum*) (Schweitzer 2004). The study was established in 2001, with each stand within a block randomly receiving one of five possible basal area retention treatments (0, 25, 50, 75, and 100 percent retention). Trees in the 0, 25, and 50 percent retention stands were harvested by chain saw felling and grapple skidding. Stands receiving the 75 percent retention treatments had the midstory removed by means of the hack-and-squirt technique using an herbicide (Arsenal®, active ingredient imazapyr) in order to mimic overstory removal. Stands within the 100 percent retention category were undisturbed. All fifteen stands were allowed to grow for ten years, prior to final harvest in 2011. Canopies in the 25, 50, 75, and 100 percent retention treatments were removed while the 0 percent retention treatments were left undisturbed; three new control stands (one each per block replication) were put in place for bird community surveying purposes. This created five forest cohorts: (1) ten-year old regeneration clearcut ("old clearcut") (consisted of 0 percent retention stands), (2) released regeneration 1, with more vertical structure due to understory/midstory persistence through the second harvest and new sprouts from midstory and overstory trees (consisted of 25 and 50 percent retention stands), (3) released regeneration 2, with less vertical structure due to lack of midstory from herbicide during the initial harvest which subdued resprouting (consisted of 75 percent retention stands), (4) "new clearcut" or "old control", due to the lack of treatment during the initial phase, this was essentially a clearcut ten years after the first clearcut (consisted of 100 percent retention stands), and (5) mature or "new control", a forest that had not been disturbed for greater than 40 years (herein referred to as "2011 control stands") (Personal communication. Callie J. Schweitzer. 2014. Research Forester, Southern Research Station, 730-D Cook Avenue, Huntsville, AL 35801).

Bird Community Assessment

The spot-mapping technique was used to determine territory densities of breeding songbirds during the 2013 and 2014 season (May 1 – June 30). The spot-mapping method allows for robust estimators of species diversity, richness, and evenness because sites are visited 10 times throughout the survey period, which accounts for temporal variation within the breeding period. This technique is superior to single-visit point counts and line transects for observing behavioral patterns during the breeding period (Ralph and others 1993). Surveys were conducted beginning around 0500-0530 (CST) and lasted about five hours, with each stand taking 45-60 minutes. During surveys, territorial behaviors (songs, calls, and/or displays) were recorded on a topographic map with each stand visit being recorded on its own separate map. After the breeding season finished, maps were digitally transferred into ArcMAP v. 10.1. For a species to register a territory, it must have met the following requirements: (1) individuals must be detected on three or more visits, with two detections being at least ten days apart, (2) territories in one stand must be evaluated simultaneously with territories of an adjacent stand, and (3) if there are multiple territories of the same species within a single stand, one of the following requirements must be met: a minimum of one simultaneous interaction with a conspecific or at least two pairs of non-simultaneous registrations (Lesak 2004).

Vegetation Assessment

Habitat was assessed using a modified James and Shugart method (1970) 0.4 ha circular plot method. Each stand had three vegetation plots that were randomly generated in ArcMap v. 10.1. Percent canopy cover was recorded using a hand-held spherical densitometer at the center of each plot and at 11.3 m from the plot center in the 4 cardinal directions. Understory sapling density was measured by walking along transects that were 11.3 m from the plot center in the 4 cardinal directions and counting all woody stems less than 30 mm in diameter at 0.25 m above the ground and were within 0.85 m on each side of the transect. Percent canopy cover and understory density were grouped and averaged for each stand.

Statistical Analysis

Spot-mapping assumes a census of the entire songbird community for a study site (Pielou 1975). As such, the Brillouin diversity index was used to describe the songbird community for each treatment based on territories of each species (Zar 1996). A one-way analysis of variance (ANOVA) of the Brillouin diversity index was used with a post-hoc least squared difference test (LSD) to test for differences between treatments. A correlation analysis was used to determine the relationship between songbird diversity and habitat features (canopy cover and understory density), with an R value being reported for goodness of fit. Each season (2013 and 2014) was analyzed individually. All statistical analyses were computed in SPSS v. 20. All statistical tests were deemed significant at $p \leq 0.05$, unless otherwise stated.

RESULTS

Vegetation varied depending on whether a treatment had canopy removal during the second phase of this study. Treatments subjected to canopy removal during the second phase had greater understory vegetation density and less canopy closure than treatments that were left undisturbed during the second phase harvest (table 1). Understory density in the 25, 50, 75, and 100 percent retention stands were significantly greater than in the 2011 control stands in 2013 ($F = 6.40$, $p = 0.000$) and 2014 ($F = 6.12$, $p = 0.005$). Canopy cover was

Table 1—Percent canopy cover and understory sapling density for 2013 and 2014 seasons. Letters denote significant differences at p ≤ 0.050. Table depicts mean ± standard error

Treatment	Brillouin Diversity-2013	Canopy Cover-2013	Sapling Density-2013	Brillouin Diversity-2014	Canopy Cover-2014	Sapling Density-2014
0 % Retention	0.96 ± 0.07[bc]	94.08 ± 2.99[b]	21.69 ± 5.82[abc]	0.89 ± 0.12[bc]	93.41 ± 2.06[a]	27.61 ± 8.47[ab]
25 % Retention	1.07 ± 0.06[ab]	73.21 ± 5.09[ab]	36.19 ± 3.73[c]	1.06 ± 0.05[ab]	78.24 ± 10.76[a]	44.89 ± 8.82[bc]
50 % Retention	1.13 ± 0.01[a]	68.63 ± 6.02[ab]	17.17 ± 3.99[ab]	1.13 ± 0.03[a]	80.22 ± 5.06[a]	43.36 ± 6.68[b]
75 % Retention	1.07 ± 0.05[ab]	41.19 ± 7.87[a]	34.97 ± 7.51[bc]	1.05 ± 0.03[ab]	60.42 ± 11.68[a]	68.64 ± 13.44[c]
100 % Retention	1.13 ± 0.02[a]	54.28 ± 7.74[ab]	35.06 ± 7.55[bc]	1.11 ± 0.01[a]	65.98 ± 13.04[a]	48.53 ± 4.36[bc]
2011 Control	0.89 ± 0.02[c]	92.62 ± 2.89[ab]	8.86 ± 1.22[a]	0.87 ± 0.01[c]	92.51 ± 1.74[a]	9.39 ± 1.25[a]

significantly different between the 0 percent retention stands and the 75 percent retention stands in 2013 (F = 7.98, p = 0.000); 0 percent retention and 2011 control stands were significantly different from the 75 and 100 percent retention stands in 2014 (F = 2.39, p = 0.101).

Brillouin diversity was significantly different across treatments in both 2013 (F = 5.23, p = 0.009) (fig. 1) and 2014 (F = 3.84, p = 0.026) (fig. 2) seasons, with treatments subjected to the second stage canopy release having higher diversity values than treatments not receiving any second-stage harvest for both 2013 and 2014. In 2013, diversity showed a quadratic relationship with canopy cover (r = 0.96) (fig. 3) and a positive linear relationship with understory sapling density (r = 0.65) (fig. 4). In 2014, diversity showed a quadratic relationship with canopy cover (r = 0.96) (fig. 5) and understory density (r = 0.85) (fig. 6).

Songbird species were mainly composed of early-successional and edge habitat breeders (table 2); with the Indigo Bunting (*Passerina cyanea*) (2013-34 territories, 2014-26 territories), Prairie Warbler (*Setophaga discolor*) (2013-26 territories, 2014-29 territories), and Yellow-breasted Chat (*Icteria virens*) (2013-30 territories, 2014-30 territories) having the greatest territory abundances for both years, though abundances varied from year-to-year. Birds associated with mature/interior forest habitat had lower abundances (White-breasted Nuthatch: 2 and 6 territories in 2013 and 2014, Worm-eating Warbler: 10 and 12 territories in 2013 and 2014, Wood Thrush: 4 and 4 territories in 2013 and 2014) and fewer mature forest species were present (8 mature forest species were detected in both 2013 and 2014) than early-successional species (10 species and 11 species in 2013 and 2014 respectively) and edge habitat species (12 species in both 2013 and 2014).

DISCUSSION

Treatments that showed minimal vertical complexity (0 percent retention and 2011 control) had lower breeding bird diversity. Treatments that were subjected to canopy removal during the second stage of the shelterwood harvest (25, 50, 75, and 100 percent retention) showed a greater amount of vertical structure, and had greater songbird diversity within their treatments. Because of this study's implementation, we were able to manage for an entire songbird community that has varying habitat requirements. The staggered levels of canopy removal at the beginning of the study allowed us to mimic different stages of forest succession, thus meet the breeding needs of species from early-successional to mature forests immediately following implementation and 10+ years after. Yahner (2003) stated that managing for early-successional habitats in forested landscapes can benefit the long term conservation of both early-successional and mature forest bird species. While clearcutting may not provide immediate benefit for some songbird species, it is an integral part of the system that should remain in management plans to increase habitat heterogeneity and improve habitat suitability for Neotropical migrants. This study shows that with time habitats created by differing regeneration methods change in their desirability to an array of wildlife species that shift in time from birds that prefer open environments to those who prefer mature forests. In other words, regenerated stands progress through a sequence of preferred habitat depending on the bird species requirements for nesting or survival and growth in certain life stages. Therefore, we must be careful not to associate a specific treatment type with certain songbird species or community indices (diversity, richness, and evenness), and with the stage of stand development following regeneration.

Rather, we can look at direct effects (vegetation features) which might explain what drives the bird community. Songbird diversity showed a quadratic relationship with percent canopy cover, with an optimal canopy range between 40-80 percent canopy cover. Beyond 80 percent canopy closure we began to see a sharp decrease in songbird diversity, most likely due to a lack of sunlight penetrating through the canopy into

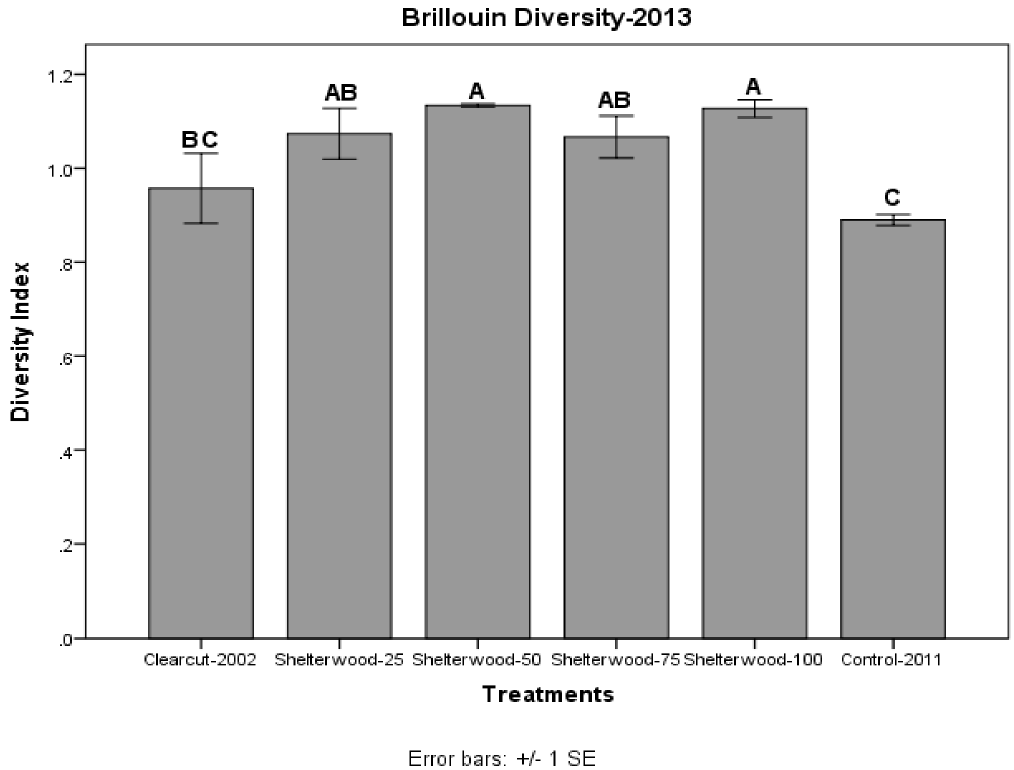

Figure 1—Brillouin diversity of treatments for the 2013 season. Letters denote significant differences at the 0.05 level. Graph depicts mean and standard error.

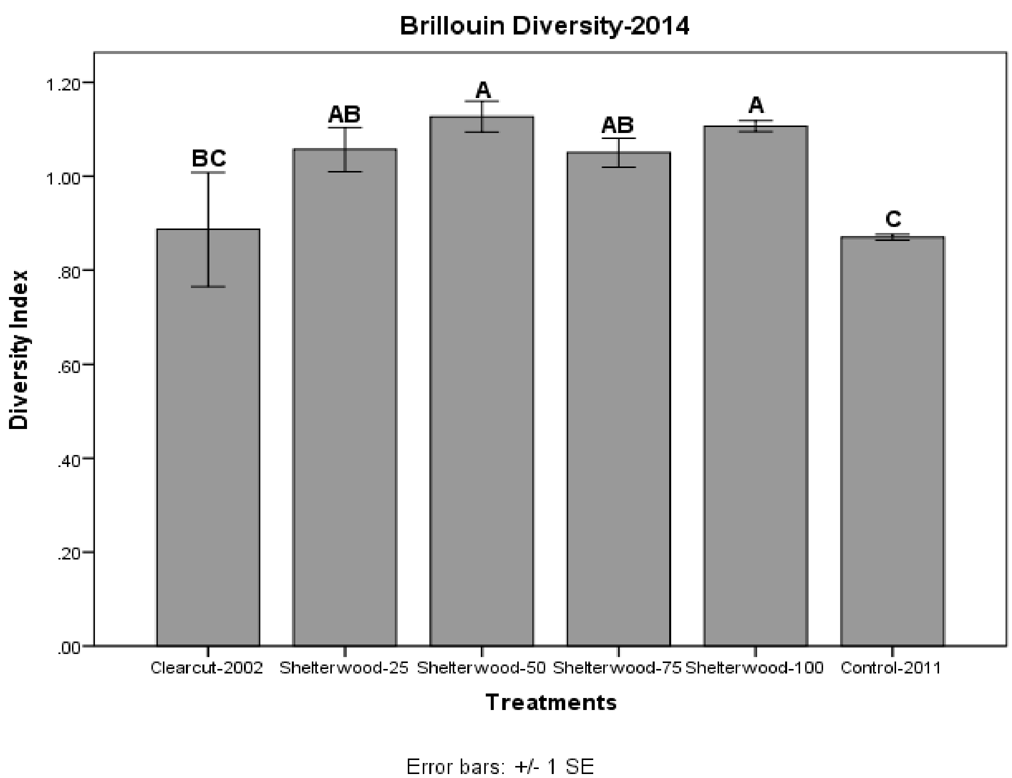

Figure 2—Brillouin diversity of treatments for the 2014 season. Letters denote significant differences at the 0.05 level. Graph depicts mean and standard error.

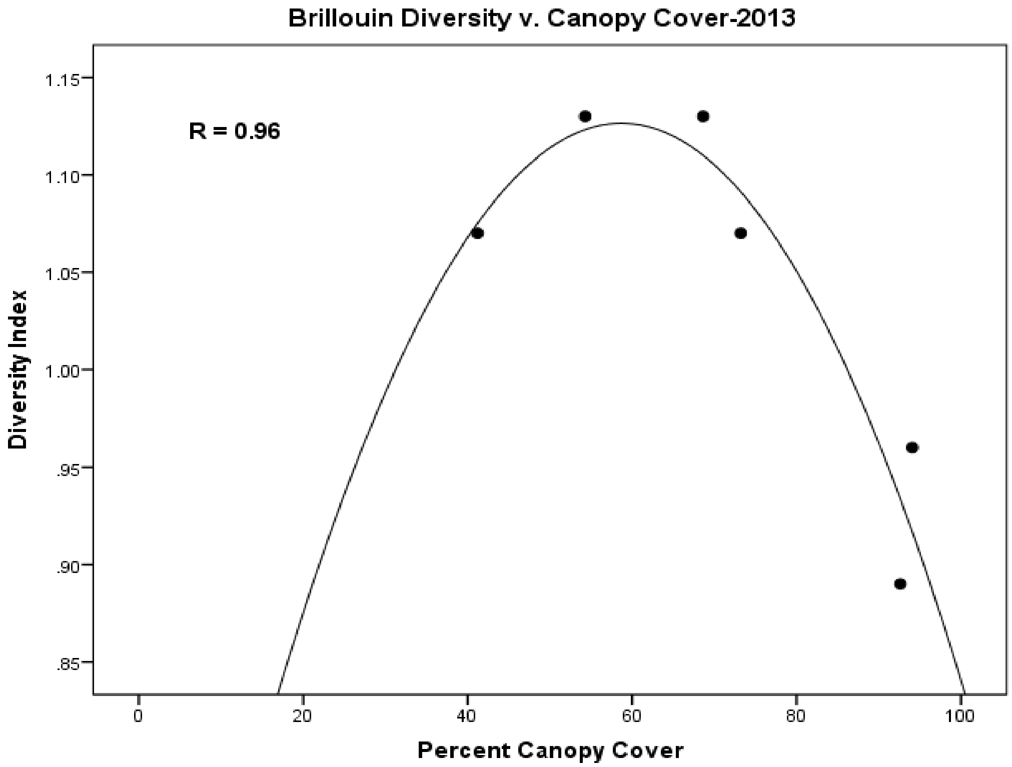

Figure 3—Brillouin diversity in relation to canopy cover for the 2013 season.

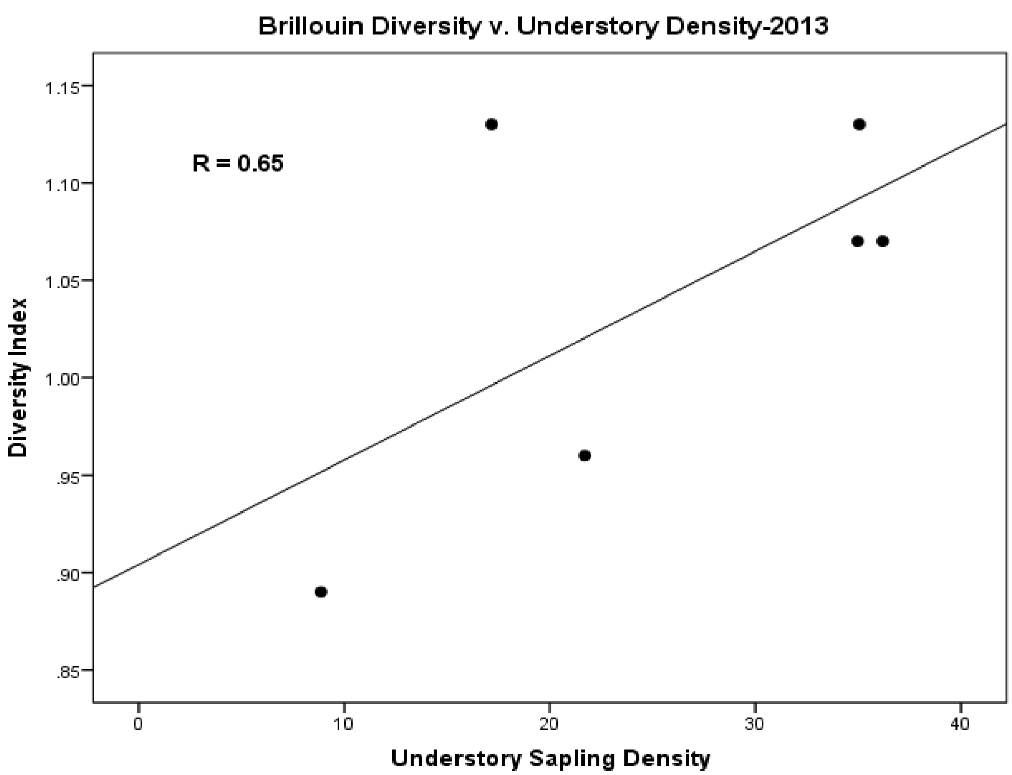

Figure 4—Brillouin diversity in relation to understory sapling density for the 2013 season.

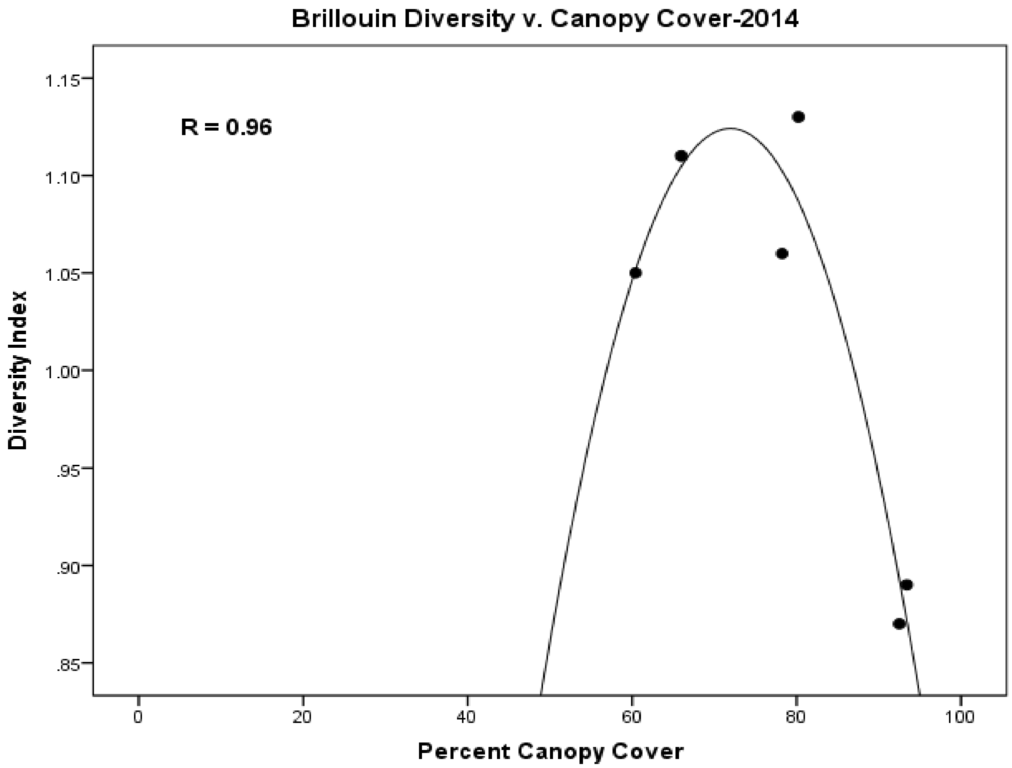

Figure 5—Brillouin diversity in relation to canopy cover for the 2014 season.

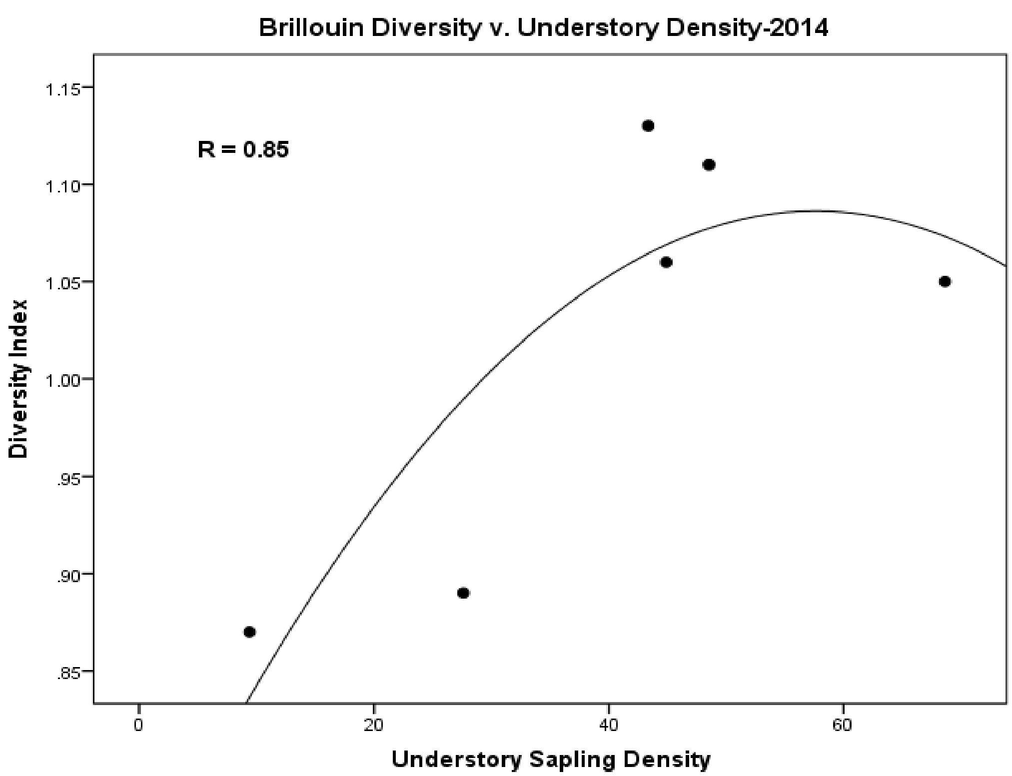

Figure 6—Brillouin diversity in relation to understory sapling density for the 2014 season.

Table 2—Territory abundances of songbird species for the 2013 and 2014 seasons. Habitat categories for individual species are as follows: O/E-open/edge habitat, I/E-interior/edge habitat, I-interior forest

2013			2014		
Species	Habitat	Territories	Species	Habitat	Territories
Indigo Bunting	O/E	34	Yellow-breasted Chat	O/E	30
Yellow-breasted Chat	O/E	30	Prairie Warbler	O/E	29
Prairie Warbler	O/E	26	Indigo Bunting	O/E	26
Northern Cardinal	I/E	25	White-eyed Vireo	O/E	23
Eastern Towhee	I/E	23	Eastern Towhee	I/E	19
Kentucky Warbler	I/E	21	Red-eyed Vireo	I/E	19
Red-eyed Vireo	I/E	18	Hooded Warbler	I	18
Tufted Titmouse	I/E	17	Tufted Titmouse	I/E	17
Carolina Wren	O/E	16	Northern Cardinal	I/E	17
White-eyed Vireo	O/E	16	Kentucky Warbler	I/E	16
Yellow-throated Vireo	I/E	16	Carolina Wren	O/E	14
Hooded Warbler	I	14	Worm-eating Warbler	I	12
Scarlet Tanager	I	13	Scarlet Tanager	I	12
Red-bellied Woodpecker	I/E	13	Summer Tanager	I/E	11
Summer Tanager	I/E	12	American Goldfinch	O/E	10
Eastern Wood-pewee	I/E	10	Blue-gray Gnatcatcher	I/E	10
Worm-eating Warbler	I	10	Red-bellied Woodpecker	I/E	9
Carolina Chickadee	I/E	9	Eastern Wood-pewee	I/E	7
Black-and-white Warbler	I	8	Carolina Chickadee	I/E	7
Hairy Woodpecker	I	7	White-breasted Nuthatch	I	6
American Goldfinch	O/E	7	Black-and-white Warbler	I	6
Blue-gray Gnatcatcher	I/E	6	Wood Thrush	I	4
Downy Woodpecker	I/E	5	Pileated Woodpecker	I	4
Pileated Woodpecker	I	4	Downy Woodpecker	I/E	4
Wood Thrush	I	4	Hairy Woodpecker	I	4
Field Sparrow	O/E	3	Yellow-throated Vireo	I/E	3
Orchard Oriole	O/E	3	Blue Jay	I/E	3
Chipping Sparrow	O/E	3	Orchard Oriole	O/E	3
White-breasted Nuthatch	I	2	Common Yellowthroat	O/E	2
Eastern Bluebird	O/E	1	Field Sparrow	O/E	1
American Redstart	I	1			
Blue Jay	I/E	1			

the understory and subsequent decline in vegetation structure in the ground and lower canopy positions. These canopy values themselves might be somewhat misleading because values were obtained at 1.5 m above ground level and reflect any canopy above that height. Productivity at these study sites is high, and we see noticeable changes in the habitat from year-to-year. From 2013 to 2014, the amount of canopy closure increased 5-20 percent in the shelterwood treatments, but these treatments had only been subjected to this increase overstory for a short period of time. The understory had not yet been affected by the decreased amount of light for us to see any concurrent detrimental effects on the bird community. Songbird diversity showed a positive relationship with the amount of understory sapling density. As the understory becomes denser, the amount of foraging and nesting opportunities increases for a large portion of these species. Foraging is increased with the amount of resources immediately available, which becomes important during the breeding and post-breeding season (Chandler and others 2012). As many of these species are Neotropical migrants and must prepare for trans-continental migration, areas where food is immediately available and in high amounts is important for successful travel (Marshall and others 2003). Areas with dense understory also provide nesting opportunities for a variety of species, which can use different types of vegetation to their benefit (Vitz and Rodewald 2011). Predator avoidance is also an important component with which dense vegetation can offer cover or protection. During the post-breeding period, when juveniles are beginning to dispersal but do not have the mobility that adults do can be a period where foliage from vegetation can increase survivability (King and others 2006).

Canopy cover seemed to be a factor that indirectly affects diversity of the songbird community through influence on understory sapling density, which in turn directly affects bird community diversity. With increasing light penetration to the understory, early-successional plant species are stimulated. This creates a dense level of understory vegetation, which can benefit the foraging and breeding for songbirds and influence community diversity. Understory sapling density showed a strong positive relationship with community diversity. Due to the creation of habitat that met the needs of many bird species and for different periods during the summer (breeding, post-breeding, pre-migration preparation), we believe dense understory habitat with herbaceous vegetation to be a good habitat driver of the bird community. Measures of the amount of herbaceous and forb material associated with each treatment may have improved our ability to detect changes in bird diversity among treatments. Sapling density only tells a portion of the story, as we observed an increase in herbaceous growth following the final harvests. To truly understand the relationships that birds have with their habitat, we would have to account for non-woody species as well. For example, *Rubus* spp. is a key nesting substrate for Yellow-breasted Chats and offers substantial foraging opportunities for many bird species (Ricketts and Ritchison 2000), but is difficult to quantify in early-successional systems due in part to dense thickets associated with early-successional habitat. We noted thickets of *Rubus* spp. and other dense herbaceous areas that colonized the stands following the second harvest, particularly in the 75 percent retention stands. These areas were also where we found the greatest activity of Yellow-breasted Chats and other early-successional bird species. This research, which documented habitat and concurrent bird community usage, showed that these disturbance-dependent birds responded to disturbance caused by tree harvesting. The unique vegetation structure created using a two-stage shelterwood prescription allowed for higher bird diversity compared to less-frequently disturbed sites. Also of interest is the loss of suitable habitat due to vegetation regrowth. The 11-year old clearcut has now reached the stem exclusion stage, and no longer provides suitable habitat for early-successional bird species, but is now beginning to be used by mature forest bird species. The creation of habitat has also been seen to be beneficial for not only early-successional species immediately following harvest, but beneficial to mature forest species years later.

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