Springtime bird diversity on the Domain of the University of the South: an investigation of exurbanization and its impact on the University's avian population

A Thesis Submitted to the Department of Biology

The University of the South

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by

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Certified by: _____**Thesis Advisor**

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ABSTRACT

The focus of this two-year project was to uncover a relationship between exurbanization and the avian population on the Domain of the University of the South in Sewanee, Tennessee. Exurbanization involves the movement of housing developments into areas that were previously undeveloped. Often this involves the destruction of native forests, which are common along the Cumberland Plateau, where Sewanee, Tennessee is located. This study utilized various statistical methods to interpret data from the spring seasons of 2008 and 2009. The goal of this data analysis was to better understand our hypothesis that exurban regions will witness higher species richness, greater evenness, and that both exurban and forested regions will exhibit community similarities. Additionally, data provided by local colleagues allowed us to hypothesize that spring and summertime bird species richness will have some degree of correlation. By comparing the alpha diversity of exurban and forested habitats in spring of 2008 and 2009, the results indicate that exurban environments have higher per point diversity. Further data analysis of the species accumulation curves in exurban versus forested environments reveals that the curve for forested environments rise faster. Neither curve, however, levels off suggesting that the forested and exurban regions were not fully sampled resulting in no definitive conclusion to be reached. This study did find that forested environments exhibit higher species evenness. There was no specific bird species that dominated the region. In exurban areas, several species, such as the Northern Cardinal, American Crow, Common Grackle, and Tufted Titmouse constituted a large portion of the recorded species. Detrended correspondence analyses (DCA) of the 2008 and 2009 springtime data displayed a clustering of species in exurban and forested habitats with only small areas of overlap showing a community relationship between exurban and forested habitats. The last part of our hypothesis,

attempting to reveal a relationship between spring and summertime birds, revealed no significant correlation.

INTRODUCTION

The University of the South Domain, along the southern Cumberland Plateau, is approximately 13,000 acres in area and comprises oak-hickory forests on a nutrient-poor sandstone cap. This area has been described in previous literature as an "area of high conservation priority – one of the 'Global 200' biodiversity hotspots" (Haskell 2006). Native forests along the Cumberland Plateau are shrinking, which results in declining "biodiversity and degradation of ecosystem services formerly provided by the forests" (Haskell 2006). Sewanee, Tennessee, located within The University of the South Domain, is an exurban community witnessing a reduction in native forest space. Exurbanization by definition is "the migration of urban residents to rural environments" (Egan 2000). Egan states that this process has increased rapidly "over the past two decades often motivated by the perception of an improved quality of life in rural locations." The University Domain typifies the forest loss commonly seen throughout the United States in similar cases of native forest loss (Haskell 2006). Nelson *et. al.* (1990) finds that the "risks of ignoring the nature causes, consequences, and policy implications of exurbanization are great." Nelson relates an immediate need to better understand how exurbanization might effect local community biodiversity. The areas immediately surrounding Sewanee, Tennessee contain many spaces that are available for exurban growth. Development of these lands could negatively impact biodiversity.

Wooded patches remaining after development are important wildlife habitat (Dickman 1987). Dickman adds that the chief concern dominating the study of these wooded areas is to find "conservation value" in terms of "species richness [and] diversity of the habitat."

Haskell *et al.* (2006) asserted "the Cumberland Plateau and Southern Appalachian region in which the Plateau sits harbor very high levels of biological diversity." Melles *et al.* (2003) surveyed bird diversity in urban environments in Vancouver and Burnaby, British Columbia, Canda. They studied "tree cover, composition, and number of tree species along different spacial scales" and related these factors to "urban bird species richness and abundance." These scientists originally hypothesized that urban habitats would decrease the available food to bird species and cause a significant decline in the number of species found in a given area. Their data supported this hypothesis and they concluded that areas of increasing development serve to decrease species richness and abundance. Ortega and MacGregor (2009) found that cities and other large urban environments account as an "important threat to biodiversity at different scales." They surveyed bird communities in an urban setting and found that urbanization was negatively correlated with bird species richness and positively correlated with abundance. Further, functional homogenization of the bird communities is positively correlated with urbanization.

Kwok *et al* (1999) concluded that deforestation, such as the process that occurs consecutively with exurbanization, threatens global bird diversity but establishes a secondary forest habitat with rich bird density. In a 1996 field study analyzing the effect of urban areas on bird diversity, Blair found that urban, populated areas exhibit increased bird diversity compared to areas of undeveloped forest. (Blair 1996). Birds typically consume snails as a primary resource for eggshell development during reproduction (Graveland 1996). Snails utilize calcium as a primary means to form a shell (Graveland 1996). Urban development in Sewanee might increase food sources for snails relative to the acidic, cation-poor soils of undeveloped forests. The growth of these food sources will inevitably cause a rise in the population of invertebrates in developed regions of the University Domain. As a result of

this increase, the number and variety of bird species will be higher than lesser-developed regions.

Using this logic, exurban areas of Sewanee should witness greater bird species diversity than forested regions, where no significant development has occurred. We hypothesize that we will witness: (1) higher species richness and greater evenness in exurban environments, (2) community similarities in exurban and forested habitats, and (3) a correlation between spring and summer species richness.

METHODS

This experiment utilized data from sites on the Domain of The University of the South in Sewanee, Tennessee. The information in this study was collected in two time periods, one in the spring of 2008 and one in the spring of 2009. In the spring 2008 study, the experiment utilized sites on the Domain of The University of the South in Sewanee, Tennessee. Areas of particular emphasis were central campus and along the Brakefield Road. In each of these regions, two, four-part transects were conducted. In the case of central campus, the first site was Manigault Park, and the second site originated from the parking lot behind Elliot dormitory. Similar extremities were tested in the forest along Brakefield Road. In the first test, transects were centered on fire gate number five. During the second test, trials were conducted at the end of Brakefield Road originating at fire gate ten. Each region, therefore, has data representing eight, 300 meter transects. Transect starting points were separated by a minimum distance of 300 meters. At each starting point, 4 transects were performed in each of the cardinal directions. Each transect consisted of six, sampling point counts evenly spaced over a distance of 300 meters. At each point, the number of bird species seen or heard was recorded over a five minute period. Sampling was conducted by Laura Morris, Kit Deppe, Carey Donald, and Chase Spurlock. To eliminate

observer bias, all members of the team collected data in both regions. Sampling occurred between the hours of 0600 and 0900 from February 28 – March 27, 2008. On days experiencing fog, rain, or signs of inclement weather, no data was collected

The spring 2009 study recorded the number of different bird species, whether seen or heard for a series of thirty randomized GPS points on the University Domain that were used by Marie Wilson and Jordan Casey in their 2008 summertime bird survey. Jake Sberna, Katie Royer, and Chase Spurlock conducted sampling in 2009. The group inputted coordinate data into an eTrax GPS device and the team walked or drove to each randomized point. GPS cover typically utilized six or more satellites with an accuracy of no less than 100 feet on most sunny or partly cloudy days. To eliminate observer bias, all members of the 2009 springtime team collected data at each of the thirty points. Sampling occurred between the hours of 0600 and 1000 from February 26 – April 14, 2009. As with the 2008 springtime data, on days experiencing fog, rain, or signs of inclement weather, no data was collected. Each sample site depended upon the ability of the listener, or group of listeners, to visually or acoustically detect bird and their songs. There were no distance limitations at any of the points.

Data from the 2009 samples was compared to that collected by Casey, Wilson, and Haskell in the 2008 summertime bird-breeding season. They sampled the same points as our study, allowing a direct point-to-point comparison. In the 2008 and 2009 springtime study, we first ranked each species according to habitat in terms of numbers of individuals sampled. In order to compare the alpha diversity between habitats, we used a t-test, which compares the difference between the means of the two data sets. In order to assess the gamma diversity (overall diversity) in the 2008 study, we then graphed how the number of species accumulates as we sample more points in each habitat. We ranked the species in each habitat

and plotted how many individuals were present in each category so that evenness and number of the types of species could be displayed for each habitat. For the 2008 and 2009 springtime data, a Multivariate Statistical Package was used to generate detrended correspondence analysis graphs (DCA).

RESULTS

Central campus has greater alpha diversity or species richness than the forest habitat (Figure 1; $P<0.0001$). The cumulative number of species detected plotted against the number of points sampled (Figure 2) shows a marked difference between the slope of the Brakefield Road data and the data from central campus. The slope of the Brakefield Road data is higher meaning that we are more likely to see new species as we continue to make observations in the forest. The habitat is not fully sampled because it does not appear to level off with the tangent line slope-nearing zero. The accumulation curve rises faster for the forest but neither curve levels off. Therefore, there is no definite conclusion that can be drawn. If the trend continued and the forest curve continued to rise, it might suggest that the forest will accumulate more species. In the final graph utilizing spring 2008 data (Figure 3), we are relating the evenness of the number and types of species found in each habitat. The forest exhibited higher evenness; there is no real dominant species (Figure 3).

In the data tables from 2009, the number of springtime species is slightly higher with thirty species being detected in exurban environments compared to the previous year's sampling of twenty-five. Additionally the forested areas also saw a slight increase with fourteen sampled in 2008 and eighteen sampled in 2009. Alpha diversity differed between forested and exurban (Figure 4; $P=0.0073$).

We found a clustering of specific species in exurban and forested habitats with a small area of overlap found in the figure (Figure 5 for 2008, Figure 6 for 2009).

We then compared species richness in the summer of 2008 with richness in the spring of 2009 and found that there is no real relationship between the spring and summer datasets (Figure 7; P=0.257).

Appendices one through four show the raw data points for the 2008 and 2009 springtime sampling.

Figure 1:
Mean and standard error of the number of species detected in the central campus and Brakefield road habitat measured in Sewanee, Tennessee from February-March, 2008. ($P=2.28*10^{-11}$; n=16)

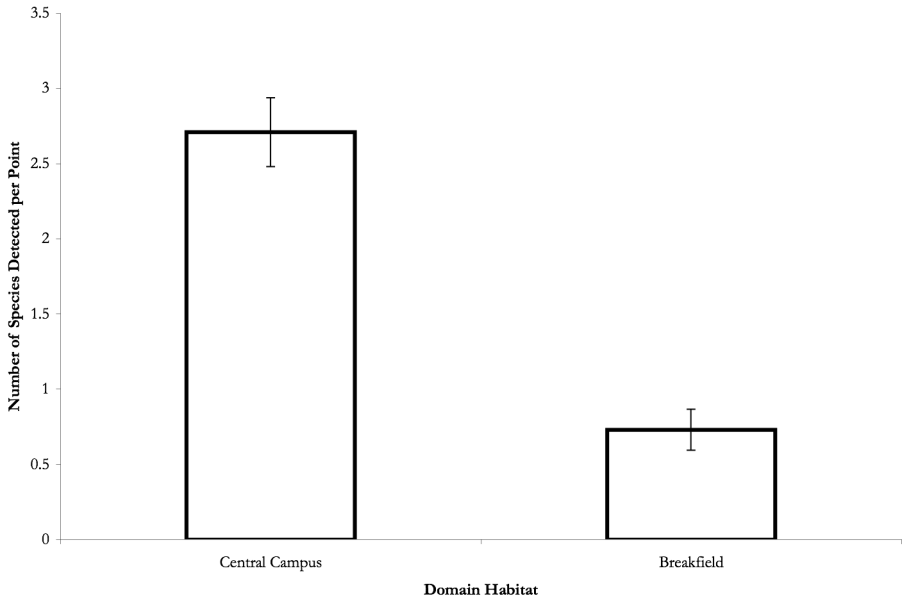


Figure 2:
Cumulative number of species detected in both habitats over the course of the study in Sewanee, Tennessee from February-March, 2008.

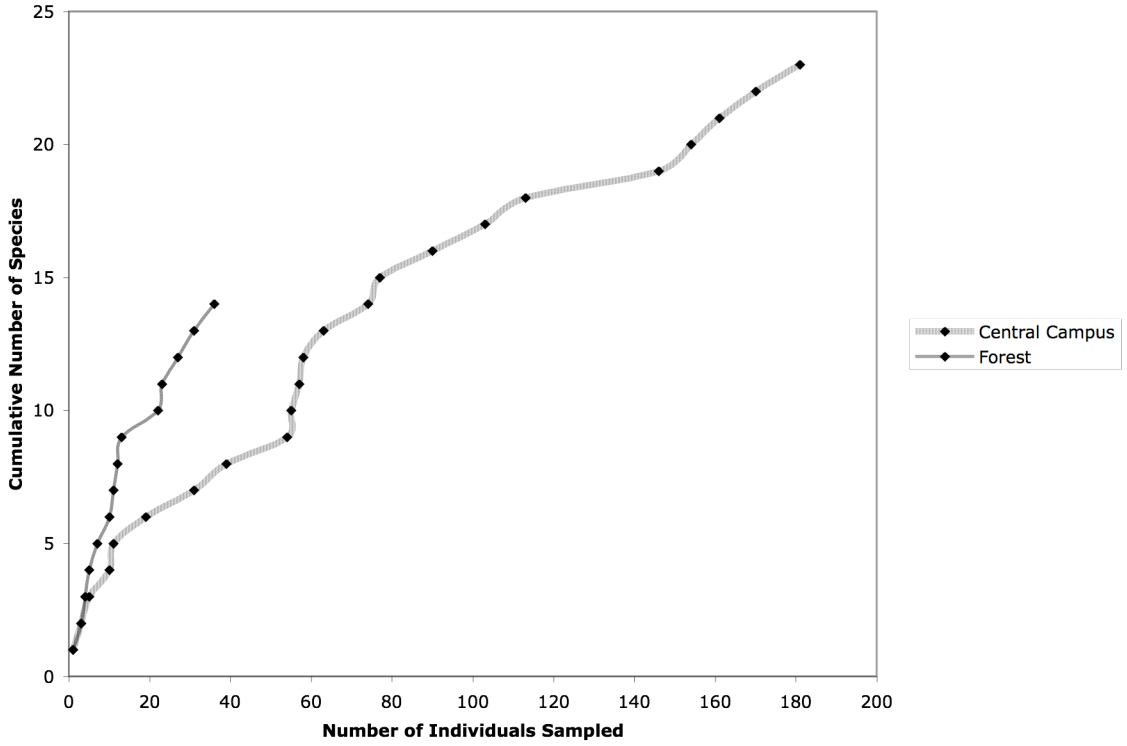


Figure 3:
Species abundance according to species rank for all individuals sampled in the central campus and Brakefield road habitats measured in Sewanee, Tennessee from February-March, 2008.

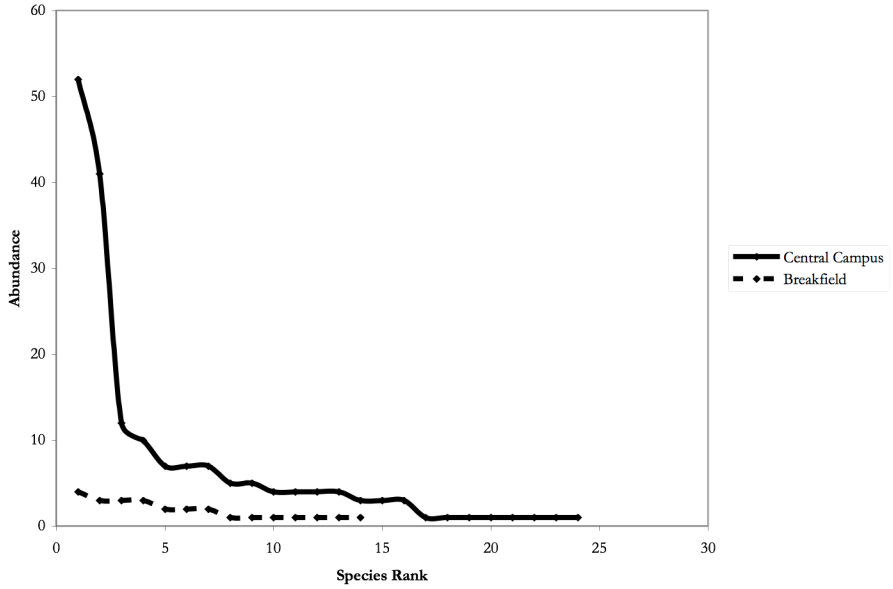


Figure 4:
Mean and standard error of the number of species detected in the exurban and forested habitat measured in Sewanee, Tennessee from February-April, 2009.
(P=0.0073; n=30)

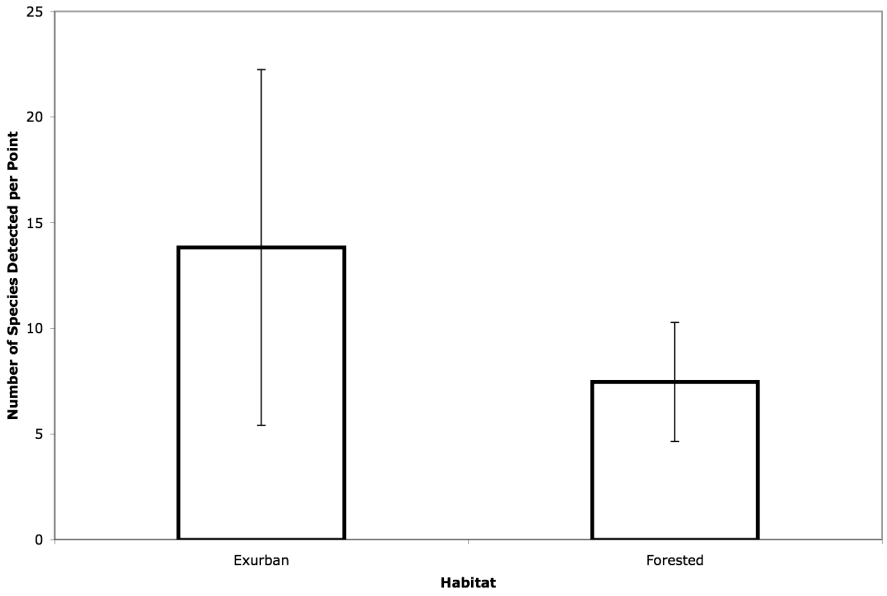


Figure 5:
Detrended correspondence analysis for Spring 2009 data measured in exurban and forested habitats in Sewanee, Tennesseee from February-April, 2009.

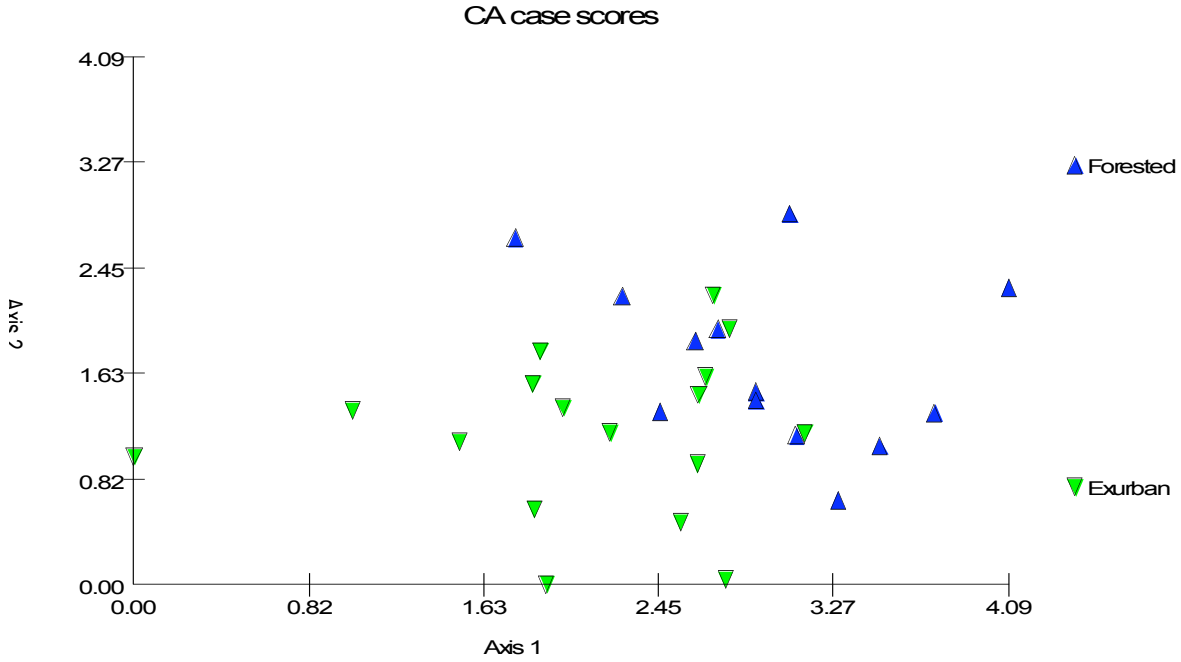


Figure 6:
Detrended correspondence analysis for Spring 2008 data measured in exurban and forested habitats in Sewanee, Tennesseee from February-March, 2008.

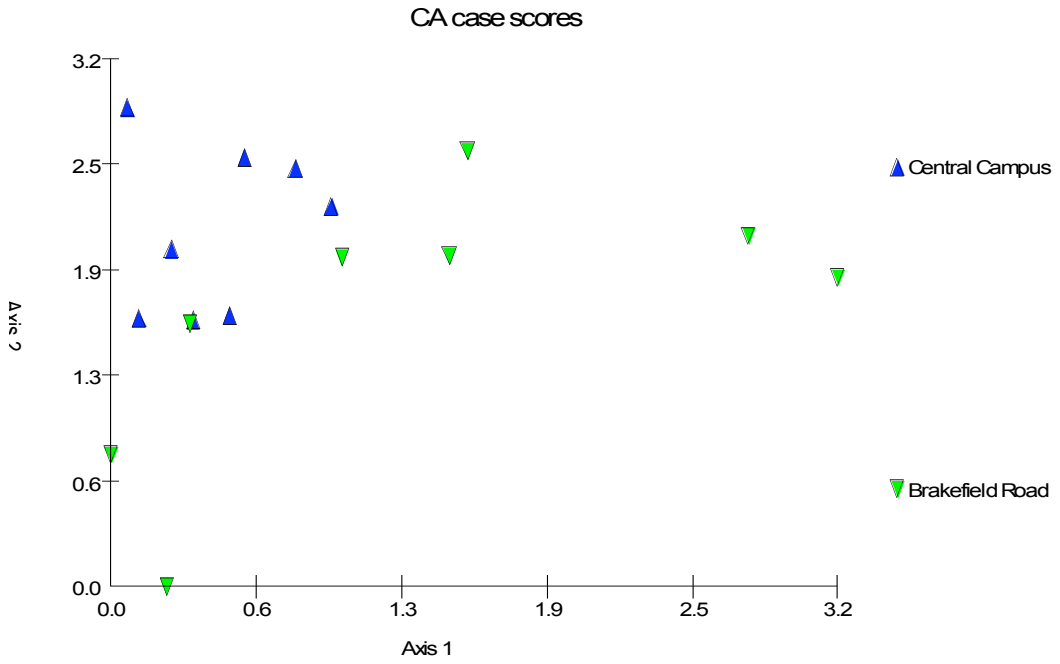
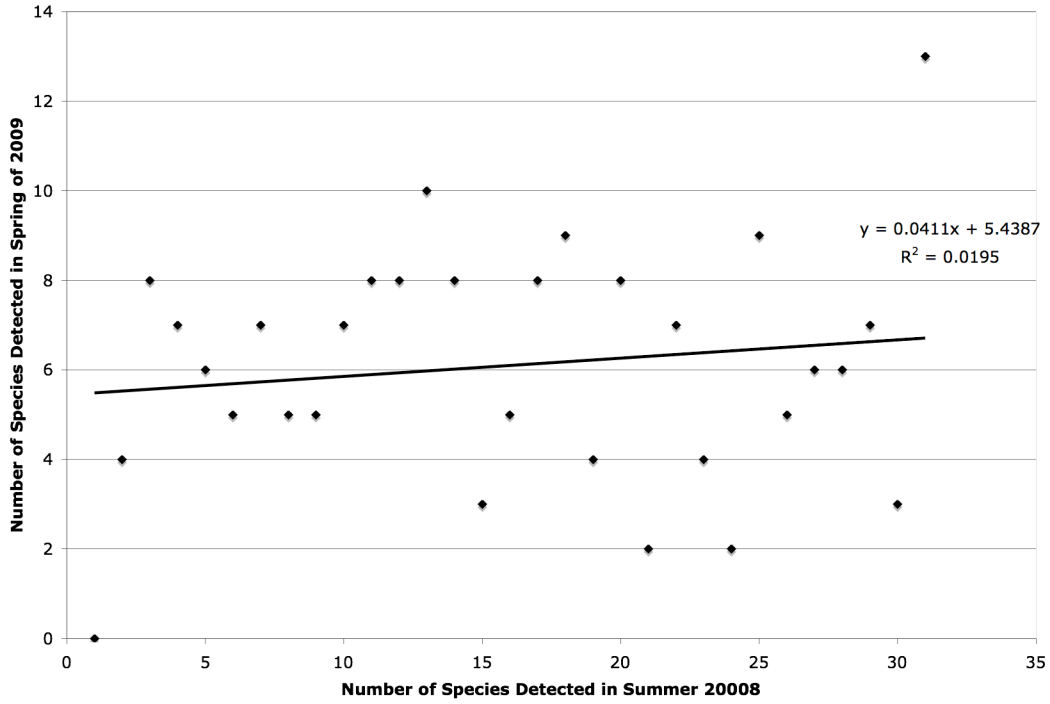


Figure 7:
Per point comparison of bird species richness in the 2008 summer study and 2009 springtime bird survey utilizing the same data points in Sewanee, Tennessee. (P=0.257)



DISCUSSION

In the spring of 2008, our original hypothesis sought to investigate a relationship between bird diversity and habitat. Evidence leading up to this 2008 study indicated that we should witness greater bird diversity in urban areas and fewer species outside of this urban environment, such as the habitat supported by the native forest of Brakefield Road (Clergeau, *et. al.* 1998).

The data collected during this experiment displays several trends. Figure 1 represents alpha diversity on central campus as well as along Brakefield Road. As evidenced by this graph, central campus has greater alpha diversity. Alpha diversity measures the species diversity at a small spatial scale within a given habitat. However, Figure 2 shows that as we continue to sample individuals in the areas along the Brakefield Road habitat, there is a higher probability that we will encounter new species. The alpha diversity graph includes numbers of individuals and number of species, but the rarefaction curve shows richness with density factored out but neither curve levels off, therefore definitive conclusions are not possible. Figure 3 also suggests that there is greater species evenness in the Brakefield Road region as compared to central campus. Central campus seemed to be dominated by American Crow and Northern Cardinal, whereas the areas along Brakefield Road were more uniform with no clear species majority.

One possible source of error in this experiment is its length. This experiment was conducted over the course of two months. As we witnessed during the experiment, new species of birds were migrating into the region, thus constantly changing the numbers and species of birds on the Domain at any given time. In future studies it might be beneficial to avoid times of the year that witness changing seasons, and to compress this study into a more compact timeframe.

The 2008 data may be flawed based upon the observer's proficiency with bird identification. Each of the four team members had relatively little experience with bird identification at the start of the experiment. However, over the course of the two months, each experimenter became more proficient with sight and auditory recognition of bird species. The 2009 dataset would have been less affected by this problem, as each experimenter was more confident with identifying each encountered species. No species was marked unknown during the survey. Additionally, three members present at each point allowed for the collective identification of each encountered bird.

In Figure 4, the graph illustrating alpha diversity for the 2009 dataset reveals significant results with a p-value of 0.0073. Even while a large standard error was present, this graph illustrates that greater point diversity exists in exurban environments when compared to forested regions of the University Domain. When comparing the alpha diversity graph for 2008 (Figure 1) to the graph for 2009 (Figure 4), there is a noticeable increase in variation. In the 2008 study, the bird surveys were fixed in regions that were clearly exurban or forested, such as the sandstone-building habitat of central campus and the strictly native forest habitat along Brakefield Road. In the 2009 study, there was a greater range of geography included in the study. Points that were labeled as exurban could have been along the edges of the forested regions of the Domain. Analysis of previous literature sources did not indicate a codified rubric for determining exurban versus forested areas. For labeling purposes, the 2009 dataset utilized Marie Wilson and Jordan Casey's scheme for identifying exurban versus forested environments, which was that any "exurban" site had greater than five percent impervious cover within 200 meters.

Figure 6 models the detrended correspondence analysis (DCA) for the 2008 dataset. This analysis relates how the species are spread across the study area. In Figure 6 and Figure

7, the two differing regions have species found only in exurban and forested areas. However, there is an overlap between the exurban and forested areas characterized by two bird species common to both studies, the American crow and northern cardinal.

Figure 7 displaying data from Jordan Casey, Marie Wilson, and David Haskell combined with the 2009 springtime data analyzes springtime and breeding season avian species richness. This scatter plot series shows no relationship between richness at points in the spring and in the summer. This indicates that ecological processes such as food supply, predation or competition for space may differ between spring and summer.

Given the data collected in the springtime of two years, the original hypothesis seems to be supported when interpreted closely. The alpha diversities of both seasons find a greater point diversity and higher number of species present in exurban environments than in forested environments. Additionally, Figure 2 shows that both number of species and individuals is higher in exurban environments than in forested regions. While both regions exhibit similar stratification (Figures 5 and 6), the level of bird species diversity in exurban areas is still higher. Further data collection should be performed across multiple seasons both springtime and summertime for multiple years to see if this trend perpetuates. For now, the data presented seems to support the original hypothesis set forward in this study.

Previous studies yield data that can be used to explain these results. One study, analyzing exurban housing developments along the southwestern United States, found that richness and abundance of bird species was higher in exurban environments when compared to landscapes similar to the native forests commonly found in Sewanee, Tennessee (Bock *et al.*, 2008). The study found that areas favorable for nesting were typically present in exurban environments, along the edges of home sites (Bock *et al.*, 2008). Birds are able to use these points as supply centers for "shade, nectar, nest sites, and water" (Bock *et al.* 2008). This

information helps to explain why greater point diversity was seen in the exurban areas sampled. The exurban points exhibited greater species diversity because the environment enabled easy access to necessary resources.

While one study suggests that bird species will diversify when land development occurs, another looks at forest bird species richness and analyzes how landscape development patterns across the United States may negatively impact short-range migrant bird species or cavity nesters (Pidgeon *et al.*, 2007). This study concludes that some species may be eradicated when urbanization is intensified. Some species may be favored in urban environments while others are forced out their habitat by commercial development. This research indicates that housing developments constitute a significant variable in avian richness and often negatively impact the native bird population. The creation of broad land use policies will not be sufficient to correct an imbalance caused by development (Pidgeon *et al.* 2007). Instead, thorough research of each avian community is necessary so that the policies can be conditioned to regional bird species (Pidgeon *et al.*, 2007). While our study found greater evenness in forested environments, this study states it is impossible to define how one region of the United States or any country will compare to another. It is important to adequately define and describe the different habitat types and characteristics that create positive and negative relationships between forested and exurban habitats.

Future studies of the Cumberland Plateau need to gather additional data points in exurban and forested environments. This data should be used to confirm if the conclusions presented in this study are supported. While greater species diversity was found in exurban environments and greater evenness was noticed in the forest habitat, additional data may reveal the contrary. Once the conclusions presented in this study are confirmed or refuted, the characteristics of this region should be documented and analyzed in other geographic

locations that exhibit shared traits. A pattern may emerge showing shared regional characteristics and their positive and negative correlation to bird diversity. It is important to understand how development may cause a decline in avian biodiversity. Supplementary research will provide better tools to diagnose the threat of development to regional avian species diversity, abundance, and community development.

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2008 Field Partners: Kit Deppe, Carey Donald, and Laura Morris

2009 Field Partners: Jake Sberna and Katie Royer

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APPENDIX

Appendix 1:
Species of birds found along each transect of the University Domain in Sewanee, Tennessee from February-March, 2008.

Campus (Common Name)	TR1	TR2	TR3	TR4	TR5	TR6	TR7	TR8	Totals
American Crow	19	14	5	8	6	5	1	5	63
American Robin			2				1	1	4
Blue Jay				3			3	1	7
Carolina Wren	1	1					1		3
Downy Woodpecker	1	1	1	1					4
Eastern Towhee		1							1
European Starling		3					2		5
Hairy Woodpecker				1	1				2
House Finch		1							1
House Sparrow	2		1				1	3	7
Killdeer				1					1
Mourning Dove		2					1	1	4
Northern Cardinal	9	14	6	6	1	3	4	2	45
Northern Flicker				3					3
Northern Mockingbird			1						1
Pileated Woodpecker				1					1
Red-bellied Woodpecker			1						1
Rock Dove		3						1	4
Song Sparrow	3	1			3	1	3	3	14
Tufted Titmouse	4	3	3					2	12
Unknown	3	5	20	23	14	20	6	2	93
White-breasted Nuthatch		6				2		1	9
Eastern Bluebird						3			3
Eastern Phoebe						5			5
Number of species = 25									
Brakefield (Common Name)	TR1	TR2	TR3	TR4	TR5	TR6	TR7	TR8	Totals
American Crow		1			3		1		5
American Robin	1								1
Blue Jay								1	1
Carolina Chickadee	2								2
Carolina Wren							1		1
Downy Woodpecker	2		1	1	2				6
Hairy Woodpecker			1						1
House Sparrow						1	1	1	3
House Wren				1					1

Northern Cardinal		1			2		1	1	5
Northern Oriole				1					1
Pileated Woodpecker	1			1	2			1	5
Tufted Titmouse	1		1	1					3
Unknown	1		3		3			2	9
Dark-Eyed Junco					1				1
Number of species = 14									

Appendix 2:
Species of birds found at each point count of exurban habitats on the University Domain in Sewanee, Tennessee from February-April 2009.

Exurban (Common Name)	**2**	**3**	**7**	**8**	**10**	**11**	**12**	**15**	**16**	**17**	**18**	**21**	**24**	**25**	**28**	**29**	**30**	**TOTAL**
American Crow	7					1	3		3		1	2				1	1	19
American Goldfinch	1						8	1				2	3					15
American Robin		4		1	1			1		1							3	11
Blue Jay		2	1			2				1							2	8
Brown Thrasher					1					3							1	5
Brown-headed Cowbird													1					1
Canada Goose																	2	2
Carolina Chickadee			2						3	1		3	2	4			1	16
Carolina Wren	2			1	1	1		1		1	1		1		2			11
Chipping Sparrow	1												1		1			3
Common Grackle		23				5												28
Downy Woodpecker												1			1			2
Easter Towhee					1				1	2					1		2	7
Eastern Bluebird									1									1
European Starling	1				6		1	3				2	2	1				16
Hairy Woodpecker	1																	1
House Finch							4										1	5
House Sparrow						1												1
Mourning Dove															1		1	2
Northern Cardinal	2	3	1	1	3	1	2		2	3	1	2		1	2		4	28
Northern Flicker					1													1
Pileated Woodpecker		2																2
Purple Finch							1											1
Red-Bellied			2	1			2			2			2	2			1	12
Red-shoulder Hawk									1									1
Song Sparrow		2				1	1										1	5
Tufted Titmouse	1		6	1		3	2		2	1	1	6	4	4		1		32
White-breasted Nuthatch					1		1		1							1	1	5

White-throated Sparrow		1						1										2
Yellow-bellied Sapsucker													1					1
Yellow-throated Warbler															1			1
TOTAL	**16**	**37**	**12**	**5**	**15**	**15**	**25**	**7**	**14**	**15**	**4**	**18**	**17**	**12**	**9**	**3**	**21**	**245**
Number of Species= 30																		

Appendix 3:
Species of birds found at each point count in forested habitats on the University Domain in Sewanee, Tennessee from February-April 2009.

Forested	**1**	**4**	**5**	**6**	**9**	**13**	**14**	**19**	**20**	**22**	**23**	**26**	**27**	**TOTALS**
American Crow												2		2
American Goldfinch		1	1	2		1			3				1	9
Black and White Warbler			1	1								1	1	4
Blue Jay	3							1					1	5
Brown-headed Cowbird			2	2	1			1						6
Carolina Chickadee		1		1		1							1	4
Carolina Wren		1	2	1	1	1		2		1	1			10
Chipping Sparrow												2		2
Downy Woodpecker							2			1			1	4
Eastern Bluebird					1			1						2
European Starling						1								1
Northern Cardinal						1		3				1	2	7
Northern Flicker	1				1			1			1			4
Pileated Woodpecker										1				1
Red-Bellied	3	2	1			2						3		11
Red-eyed Vireo				1	3		1	1						6
Red-tailed Hawk					1									1
Tufted Titmouse	2	2		1	1	2	2	2	2	1		1		16
White-breasted Nuthatch		1				1								2
TOTAL	**9**	**8**	**7**	**9**	**9**	**10**	**5**	**12**	**5**	**4**	**2**	**10**	**7**	**97**
Number of Species= 18														