

# **Analysis of Vegetative Structure in the Choice of Nesting Habitat by Midwestern Songbirds**

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## **ABSTRACT:**

Habitat destruction is one of the major problems affecting the diversity, abundance and species richness of passerines around the world, and much of the remaining habitat is degraded and highly fragmented. To understand what habitat types are necessary for passerines to thrive, a working knowledge of the vegetative structural factors that make up habitats is necessary. Our study analyzed the differentiation in the choice of vegetative structure by breeding passerines and additionally determined how complex vegetative structure affects passerine species diversity. Using 45 point count sites, we analyzed bird species associated with each of nine vegetative structure variables. Passerine vegetative structural choices were much more complex than is often reported. We created habitat space maps for 27 species to address habitat preferences. We also found that overall, horizontal, and vertical vegetative structure complexity is correlated with greater bird diversity.

**KEYWORDS:** Breeding birds, vegetative structure, habitat character space

## **INTRODUCTION**

### **Habitat Destruction**

Habitat destruction is one of the major problems affecting the diversity, abundance and species richness of passerines around the world, and much of the remaining habitat is considered degraded and highly fragmented (Noss et al. 1995, Baile et al. 2004). In the Midwest, habitat important to species of birds is being destroyed for a number of reasons, the top reason being conversion to agriculture (Robbins et al. 1986, Warner 1994, Rich et al. 2004). Because of this, it is important to study how birds select their habitat, especially during the reproductive season.

### **Habitat Selection**

Birds will primarily select habitat based on large-scale geographical factors, vegetative factors, instinct and previous experiences (Hilden 1965, Huto 1985). It is believed that birds recognize available resources, primarily food and nesting location, by examining vegetative factors. The specific set of resources needed and recognized by each individual bird species is unique (Mengel 1964, Cody 1974). It is likely vegetative factors allow birds to recognize necessary resources and that these factors vary within and between bird species (Willson 1974).

The most common way to determine how birds select habitat is by measuring bird numbers to determine the habitat they prefer (Johnson 2007). This is the general method that we employed in our study. In doing this, researchers have studied the relationship of birds to different aspects of vegetation in a number of ways. For example, Mills et al. (1991) found that total vegetation volume was strongly correlated with the density of breeding birds. Pearman (2002) found that species composition is related to differences in the forest cover for birds in Amazonian Ecuador. Rice et al. (1984) examined specific bird species' responses to the number of a particular tree species and found that tree species composition was important.

## **Vegetative Structure**

Lack (1933) was the first to propose that birds select habitats based on structural features of the vegetation that allow the bird to recognize its ancestral habitat. After this idea was proposed by Lack, other researchers have discovered correlations between vegetative structure and breeding bird abundance and diversity, and it is now generally held that structural features of vegetation are the most important variables affecting the selection of habitat by birds (MacArthur & MacArthur 1961, Hildan 1965, Willson 1974). DeGraaf et al. (1998) tested which aspect of vegetation is most effective in predicting bird abundances. They found stand structure was the best predictor of bird abundance for 25 of 31 bird species and that cover type was the best predictor of 5 species, but size class was not the best predictor of any species.

Some birds select specialized habitat. For example, Baril et al. (2011) found that Wilson's Warbler (*Wilsonia pusilla*) specialized in tall dense willows. As willows that had been suppressed began to grow, populations of Wilson's Warbler and other willow dependent species increased. Other birds, such as the Ovenbird (*Seiurus aurocapillus*), are not specialized to a certain species of tree but require mature stands of deciduous forests (Titterington et al. 1979). Changes in habitat composition or structure can have a disproportional effect on species that have a specialized habitat niche such as the ones described above. Because of this, it is necessary to understand the specific needs of each bird species.

## **Diversity**

Numerous studies have been performed on the interaction between bird diversity and vegetative structure. MacArthur and MacArthur (1961) found that in deciduous forests the diversity of birds can be determined from the density of foliage in a vertical height profile. Erdelen (1984) found that vegetation structure diversity was correlated with bird diversity. Erdelen also found that foliage height diversity was correlated with bird diversity only in certain

habitat types. Karr & Roth (1971) found that bird diversity was linearly correlated to foliage height diversity and that in certain cases vegetation volume can be an important predictor of diversity.

Although a large amount of research has been conducted to understand the process of habitat selection by birds, the results of some studies do not agree (Willson 1974, Burke 1998), and selection can be location and species specific. In order to manage bird abundance and species composition it is important to understand the needs of each bird species, and that is primarily what we studied. More research is also called for to augment general understandings of the use of structure in habitat selection (Willson 1974, Rice et al. 1984).

## **Hypotheses**

We hypothesized 1) that there will be differentiation in the choice of vegetative structure by breeding passerines based on vegetative structure. Additionally, we hypothesized 2) that areas with a complex vertical structure will contain the greatest diversity of species.

## **METHODS**

### **Study Area**

The research was conducted in Barry County, Michigan at the Pierce Cedar Creek Institute (PCCI), Otis Bird Sanctuary (OTIS), Barry State Game Area (BSGA) and Yankee Springs Recreation Area (YSRA). The research focused on the mixed woodlands, wetlands, and prairies throughout the study sites. Forty-five sites were selected based on a continuum of horizontal and vertical vegetative structure (Appendix A).

### **Bird Point Counts**

To document current abundance, distribution, and diversity of breeding songbirds on Pierce Cedar Creek Institute property we used the point count method based in the Handbook of Field Methods for Monitoring Landbirds (Ralph et al. 1993). We stood at a designated point

count site for 5 minutes and recorded all seen and heard passerine birds within 75 m. When possible, the sex was recorded. Other conditions such as time of day and weather were also documented. Data collection in the field took place weekly from mid-May to July. We observed all point count sites (45 sites) once a week for six weeks during the breeding and nesting season, giving a total of 22.5 hours of bird survey time.

### **Vegetative Sampling**

*Horizontal Vegetative Sampling.* For the horizontal vegetative sampling, we analyzed percent cover of both the canopy and herbaceous layers. Canopy cover was evaluated using Gap Light Analysis software (Simon Fraser University, Institute of Ecosystem Studies 1999). A photograph of the canopy was taken using a Panasonic DMC-FZ150 with an Opteka High Definition 0.20x AF Fisheye Lens. The camera was mounted to a 5 m pole for the photograph to minimize the influence of mid-layer vegetation on the canopy cover. The pole was equipped with a level to ensure straight images. Images were input into Gap Light Analyzer and standardized using fiber optic points from each image. The images were then analyzed for percentage of cover based on light gaps in the canopy. Horizontal ground cover was examined using a 1m<sup>2</sup> quadrat and a Canon PowerShot D10. At each of the forty-five sites three separate quadrant samples were photographed. The pictures were taken with the camera squared above the quadrat on a wooden frame. The pictures were then uploaded and a 10x10 grid was superimposed on the image. Squares composed of  $\geq 50\%$  vegetation were counted towards the percent cover.

*Vertical Vegetative Sampling.* Vertical vegetative sampling was conducted to create a cross-section plane that showed the area of ground occupied by trunks and stems, as well as to be able to compare how many trunks and stems were present in relation to the percent cover observed in the vertical vegetative sampling. In the herbaceous layer, vertical vegetation was examined by conducting a stem density count with meter quadrats. Three samples were taken at each site, and

stems within the plot counted. The mean of the three plots determined overall stem-density at the point count site. Trunk density counts within a 10 m radius were performed to determine the density of shrubs and canopy layer trees. A plant was deemed a shrub or tree based on its Diameter Breast Height (DBH). Shrubs, a plant with a DBH of < 2.5 cm, were split into two categories < 5 m and >5 m. Trees were separated into four categories based on increasing DBH (Table 1) (Smith & Shugart 1987).

Table 1. Vertical and horizontal vegetative structure categories measured at point count sites at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan, 21 May – 27 June 2012.

Variable	Description	Axis
GRCV	Percent ground cover	Horizontal
CNPY	Percent canopy cover	Horizontal
SHL5	Shrubs < 5m/100 m <sup>2</sup>	Vertical
SHG5	Shrubs >5m/100 m <sup>2</sup>	Vertical
TR1A	DBH = 2.5-7.5cm/100 m <sup>2</sup>	Vertical
TR1B	Tree < 5m; DBH = 7.6-15.2 cm/100 m <sup>2</sup>	Vertical
TR2	Tree > 5m; DBH = 7.6-15.2 cm/100 m <sup>2</sup>	Vertical
TR3	Tree > 5m; DBH = 15.3-22.9 cm/100 m <sup>2</sup>	Vertical
TR4	Tree > 5m; DBH > 22.9 cm/100 m <sup>2</sup>	Vertical

## Analysis

*Bird Vegetative Structure Choices.* We compared birds with more than 20 observations with the nine vegetative structure components using ANOVA with a Tukey pairwise comparison. We subsequently used distribution fitting models to create habitat character space maps that visually show the preferences of bird species during the breeding season at these sites.

*Diversity vs. Complexity.* We defined complexity as having vegetative structure spread out across vertical and horizontal planes at a point count site, so a site with high complexity had high values in multiple vegetation indices. In order to establish a single numerical value for complexity we took the sum of the log value of each of the vegetative matrices. We chose to analyze bird diversity against vegetation complexity instead of other possible overall structural measures such as density or volume. This is because complexity is calculated with normalized data from

multiple different vegetative factors. In contrast, density or volume can be skewed by mass or volume of vegetation on only one of the vegetative layers. Bird species diversity was calculated using an inverse Shannon-Wiener Species Diversity Index.

## RESULTS

### General Findings

Over the course of the sampling period we detected 1,771 birds, representing 65 species (Appendix B) between the 45 point count sites. Of the 65 species observed, 27 species had sufficient numbers of observations from which to test our hypotheses ( $N > 20$ ).

### Hypothesis 1: Breeding Birds and Vegetative Structure

We used ANOVA to test the variation between the 27 bird species based on each of the vegetative structure variables. Significant differences among bird species were found on all of the nine vegetative structure variables (Table 2).

We then used a Tukey pairwise comparison to analyze species-species comparisons looking for non-significant differences between individual species. The Tukey pairwise comparison was not based on all vegetative structure variables. Instead, groupings were created for each of the individual vegetative structure variables (Tables 3-10). Groupings ranged from one distinct group for TR1B to eight distinct groupings for CNPY.

Table 2: Correlation and ANOVA for mean vegetative structure related to observed birds species ( $N > 20$ ) at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan, 21 May – 27 June 2012.

Variable	<i>N</i>	Mean	<i>SD</i>	$R^2$	<i>F</i>	<i>P</i>
GRCV	1534	63.75	30.65	0.20	14.41	< 0.0001
CNPY	1534	38.71	32.09	0.50	57.14	< 0.0001
SHL5	1534	17.35	23.43	0.11	6.94	< 0.0001
SHG5	1534	34.59	78.90	0.12	7.84	< 0.0001
TR1A	1534	6.27	12.45	0.08	5.22	< 0.0001
TR1B	1534	0.24	0.52	0.03	1.88	0.005
TR2	1534	1.65	2.35	0.12	7.97	< 0.0001
TR3	1534	0.96	1.27	0.12	7.66	< 0.0001
TR4	1534	1.45	2.15	0.08	5.26	< 0.0001

Ground cover analysis showed that Common Yellowthroat ( $\bar{x} = 79.6\%$ ) was the only species grouped in one distinct grouping in its preference for a high percentage of ground cover. The Ovenbird ( $\bar{x} = 21.8\%$ ) was the only species grouped in one distinct grouping with a preference for minimal ground cover in its habitat (Table 3).

Four species showed significant preferences in one distinct grouping for dense canopy cover over other species. Eastern Wood-pewee ( $\bar{x} = 73.4\%$ ) preferred the most dense canopy cover of all bird species analyzed. Red-bellied woodpeckers, Ovenbirds and Acadian Flycatchers ( $\bar{x} = 72 - 72.9\%$ ) also selected significantly more canopy cover than other passerines. Similarly, Red-winged Blackbirds ( $\bar{x} = 5\%$ ) and Tree Swallows ( $\bar{x} = 2.8\%$ ) both selected significantly less canopy cover than other species (Table 4).

Small shrubs (< 5 m) were distinctly important for Swamp Sparrows ( $\bar{x} = 36/100 \text{ m}^2$ ) and Yellow Warblers ( $\bar{x} = 34/100 \text{ m}^2$ ), but while small shrubs were present, they were not significant for Field Sparrows ( $\bar{x} = 4.9/100 \text{ m}^2$ ) (Table 5).

For most species observed, larger shrubs were not a significant separating factor in their habitat selection with the exception of the Swamp Sparrow ( $\bar{x} = 118.4/100 \text{ m}^2$ ) for which they are a significant part of the habitat character space. (Table 6)



Table 3. Tukey pair-wise analysis grouping of 27 species of passerines based on the percentage of ground cover (GRCV) at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan, 21 May – 27 June 2012.

Species	Mean		Groups				
	GRCV						
COYE	79.55	A					
GRCA	78.47	A	B				
BWWA	77.19	A	B				
EATO	76.94	A	B				
SOSP	76.41	A	B				
CEWA	71.28	A	B	C			
BHCO	70.42	A	B	C			
TUTI	70.41	A	B	C			
YEWA	70.38	A	B	C			
SWSP	69.99	A	B	C			
FISP	69.48	A	B	C			
RWBL	66.73		B	C			
TRSW	65.97		B	C	D		
INBU	65.64		B	C	D		
AMRO	63.18		B	C	D		
BTBW	62.44		B	C	D		
WBNU	62.39		B	C	D		
NOCA	62.20		B	C	D		
GCFL	56.33		B	C	D	E	
CHSP	54.96		B	C	D	E	
BCCH	54.94			C	D	E	
REVI	48.34				D	E	
RBWO	48.04				D	E	
WOTH	47.63				D	E	
EAWP	44.67				D	E	
ACFL	40.88					E	F
OVEN	21.85						F

Table 4. Tukey pair-wise analysis grouping of 27 species of passerines based on the percentage of canopy cover at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan, 21 May – 27 June 2012.

Species	Mean		Groups								
	CNPY										
EAWP	73.44	A									
RBWO	72.89	A									
OVEN	72.68	A									
ACFL	72.03	A									
WOTH	64.48	A	B								
REVI	63.04	A	B								
WBNU	62.00	A	B								
GCFL	61.99	A	B								
NOCA	54.08		B	C							
TUTI	53.58		B	C							
BTBW	51.40		B	C							
AMRO	51.09		B	C							
CEWA	49.61		B	C	D						
BCCH	47.65		B	C	D						
INBU	38.47			C	D	E					
BHCO	35.69				D	E					
EATO	29.02					E	F				
BWWA	28.86					E	F				
GRCA	26.14					E	F				
SOSP	20.34						F	G			
CHSP	20.08						F	G			
YEWA	19.29						F	G			
COYE	18.32						F	G			
FISP	13.65						F	G	H		
SWSP	7.42							G	H		
RWBL	5.00								H		
TRSW	2.83								H		

Table 5. Tukey pair-wise analysis grouping of 27 species of passerines based on the number of shrubs < 5 m/100 m<sup>2</sup> at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan, 21 May – 27 June 2012.

Species	Mean SHL5	Groups			
SWSP	35.99	A			
YEWA	33.98	A			
WOTH	28.07	A	B		
BHCO	26.93	A	B		
RWBL	25.44	A	B		
GRCA	25.36	A	B		
SOSP	22.31	A	B		
BCCH	21.44	A	B	C	
CEWA	19.58	A	B	C	D
TUTI	18.66	A	B	C	D
BTBW	17.53	A	B	C	D
EATO	17.42		B	C	D
BWWA	17.30		B	C	D
COYE	16.95		B	C	D
NOCA	14.48		B	C	D
GCFL	13.61		B	C	D
OVEN	12.76		B	C	D
REVI	12.29		B	C	D
AMRO	12.01		B	C	D
WBNU	10.58		B	C	D
ACFL	10.58		B	C	D
INBU	9.75		B	C	D
TRSW	8.85		B	C	D
CHSP	8.23		B	C	D
EAWP	7.14			C	D
RBWO	5.87			C	D
FISP	4.93				D

Table 6. Tukey pair-wise analysis grouping of 27 species of passerines based on the number of shrubs > 5 m/100 m<sup>2</sup> at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan, 21 May – 27 June 2012.

Species	Mean SHG5	Groups		
SWSP	118.44	A		
YEWA	91.25	A	B	
RWBL	84.47	A	B	
BHCO	56.08		B	C
CEWA	55.39		B	C
GRCA	46.53		B	C
EATO	41.82		B	C
SOSP	40.27			C
WOTH	38.85			C
BWWA	33.60			C
COYE	33.49			C
BTBW	26.40			C
BCCH	24.86			C
TUTI	23.80			C
GCFL	21.80			C
AMRO	19.42			C
INBU	16.70			C
CHSP	15.93			C
REVI	15.92			C
NOCA	14.86			C
ACFL	12.00			C
OVEN	11.13			C
TRSW	9.33			C
FISP	8.75			C
WBNU	8.23			C
EAWP	6.81			C
RBWO	5.49			C

Young trees were of significant importance for Swamp Sparrows ( $\bar{x} = 16.6/100 \text{ m}^2$ ), but for many species this vertical vegetative level was not a significant separating factor in habitat selection (Table 7).

Smaller mid-sized trees (Table 8) were significant for Wood Thrush ( $\bar{x} = 4.4/100 \text{ m}^2$ ) but were less favored by Red-winged Blackbirds and Field Sparrows ( $\bar{x} = 0.3/100 \text{ m}^2$  and  $0.3/100 \text{ m}^2$ ).

Ovenbirds ( $\bar{x} = 2.1/100 \text{ m}^2$ ) showed significant preferences for larger mid-sized trees (DBH=15.3-22.9cm/ $100 \text{ m}^2$ ) compared to other species of birds. More field specialized birds (COYE, EATO, SWSP, RWBL, TRSW, FISP;  $\bar{x} = 0.2$  to  $0.6/100 \text{ m}^2$ ) showed significant preferences for areas without this vertical structure (Table 9).

Large diameter trees (Table 10) were significantly important for Red-bellied Woodpeckers, Ovenbirds, Black-throated Green Warblers and Eastern Wood-pewees ( $\bar{x} = 2.8 - 2.4/100 \text{ m}^2$ ). Reduced coverage of large diameter trees was significant for Red-winged Blackbirds, Field Sparrows and Tree Swallows ( $\bar{x} = 0$  to  $0.7/100 \text{ m}^2$ ).

We then used a distribution fitting model to determine what characteristics of the horizontal and vertical vegetative structure were key determinants of specific breeding passerines in a mixed landscape matrix. These vegetative characteristics were combined into a single figure for each species to simultaneously create a habitat character space for the species. This habitat character space provides a snapshot of the nine vegetative structural preferences related to observations of the species over a six-week breeding season. Box plots show 50% of the variability with means and medians included. Figure 1 shows the habitat character space map for the Acadian flycatcher. Habitat character space maps for the other 26 species with sufficient observations are included in Appendix C.

Table 7. Tukey pair-wise analysis grouping of 27 species of passerines based on the number of tree (< 5 m) trunks with DBH = 2.5-7.5 cm/100 m<sup>2</sup> at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan, 21 May – 27 June 2012.

Species	Mean	Groups		
	TR1			
SWSP	16.62	A		
WOTH	14.46	A	B	
RWBL	11.69	A	B	
YEWA	11.67	A	B	
CEWA	9.61	A	B	C
BCCH	9.40	A	B	C
TUTI	8.63	A	B	C
BHCO	8.52	A	B	C
BTBW	7.77	A	B	C
ACFL	7.09		B	C
OVEN	6.23		B	C
NOCA	6.07		B	C
SOSP	5.53		B	C
WBNU	5.50		B	C
GCFL	5.48		B	C
REVI	5.46		B	C
AMRO	5.32		B	C
GRCA	4.54		B	C
COYE	4.04			C
RBWO	3.59			C
EAWP	3.19			C
BWWA	3.15			C
INBU	2.07			C
EATO	1.41			C
TRSW	1.40			C
CHSP	0.76			C
FISP	0.44			C

Table 8. Tukey pair-wise analysis grouping of 27 species of passerines based on the number of tree trunks with DBH = 7.6-15.2 cm/100 m<sup>2</sup> at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan, 21 May – 27 June 2012.

Species	Mean TR2B	Groups			
WOTH	4.44	A			
TUTI	2.91	A	B		
BTBW	2.77	A	B		
NOCA	2.61	A	B		
GCFL	2.58	A	B		
OVEN	2.52	A	B		
ACFL	2.44		B		
RBWO	2.35		B	C	
BCCH	2.32		B	C	
WBNU	2.30		B	C	
REVI	2.18		B	C	
AMRO	2.11		B	C	
CEWA	1.96		B	C	
GRCA	1.84		B	C	
BHCO	1.79		B	C	
BWWA	1.64		B	C	D
SOSP	1.31		B	C	D
EATO	1.30		B	C	D
COYE	1.21			C	D
EAWP	1.16			C	D
INBU	1.11			C	D
YEWA	1.10			C	D
CHSP	0.66			C	D
SWSP	0.36			C	D
TRSW	0.32			C	D
RWBL	0.30				D
FISP	0.28				D

Table 9. Tukey pair-wise analysis grouping of 27 species of passerines based on the number of tree trunks with DBH = 15.3-22.9 cm/100 m<sup>2</sup> at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan, 21 May – 27 June 2012.

Species	Mean TR3	Groups			
OVEN	2.11	A			
RBWO	1.98	A	B		
GCFL	1.88	A	B		
NOCA	1.74	A	B		
CEWA	1.65	A	B	C	
BTBW	1.42	A	B	C	
AMRO	1.31	A	B	C	
TUTI	1.20	A	B	C	D
WBNU	1.15	A	B	C	D
EAWP	1.14		B	C	D
BCCH	1.06		B	C	D
WOTH	1.02		B	C	D
REVI	0.97		B	C	D
INBU	0.91		B	C	D
GRCA	0.90		B	C	D
ACFL	0.90			C	D
CHSP	0.88			C	D
BHCO	0.88			C	D
SOSP	0.81			C	D
YEWA	0.77			C	D
BWWA	0.70			C	D
COYE	0.65				D
EATO	0.63				D
SWSP	0.60				D
RWBL	0.39				D
TRSW	0.26				D
FISP	0.20				D



Table 10. Tukey pair-wise analysis grouping of 27 species of passerines based on the number of tree trunks with DBH > 22.9 cm/100 m<sup>2</sup> at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan, 21 May – 27 June 2012.

Species	Mean TR4	Groups		
RBWO	2.81	A		
OVEN	2.77	A		
BTBW	2.74	A		
EAWP	2.41	A		
NOCA	2.15	A	B	
AMRO	2.03	A	B	
BCCH	2.03	A	B	
BHCO	1.99	A	B	
CEWA	1.98	A	B	C
REVI	1.68	A	B	C
GCFL	1.65	A	B	C
SWSP	1.48	A	B	C
TUTI	1.46	A	B	C
WBNU	1.44	A	B	C
ACFL	1.38	A	B	C
YEWA	1.23	A	B	C
INBU	1.21	A	B	C
SOSP	1.20	A	B	C
WOTH	1.15	A	B	C
COYE	1.12		B	C
BWWA	0.97		B	C
EATO	0.74		B	C
GRCA	0.73		B	C
CHSP	0.72		B	C
RWBL	0.71			C
FISP	0.36			C
TRSW	0.00			C

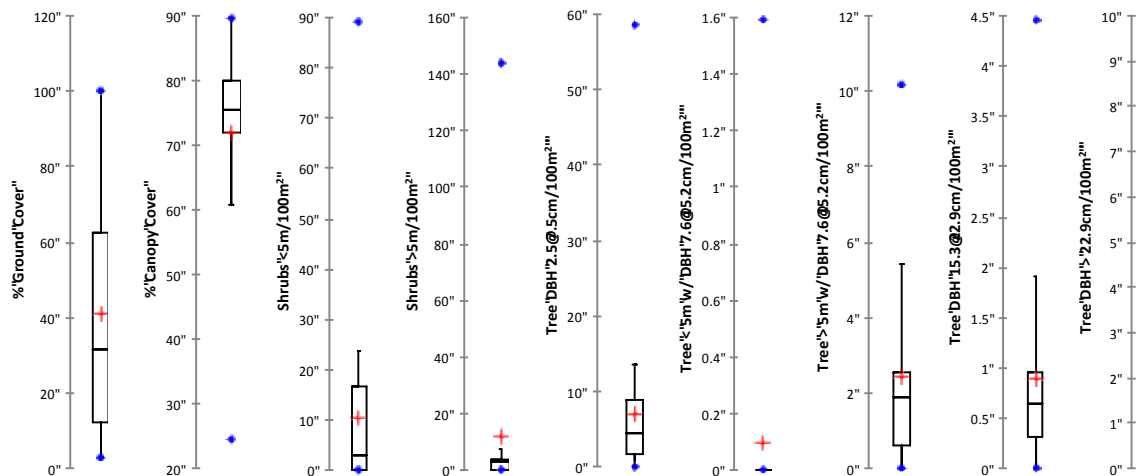


Figure 1. Habitat character space map showing vegetative structure preferences for Acadian flycatcher ( $N = 103$ ) observations at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan, 21 May – 27 June 2012. The + symbol designates the median point; – within the box designates the mean; and the square dots at the top and bottom show the high and low points recorded.

We performed a multivariate analysis on the observed species to determine which variables were the most influential in determining habitat selection. Analysis showed that canopy cover was the greatest discriminating factor in habitat selection by the various bird species observed (68.4%), with ground cover being the second most discriminating factor (9.9%). Plotting species against these two factors showed the variability among the observed species (Figure 2).

## Hypothesis 2: Bird Diversity

Our vegetative structure data contained a wide range of complexity. A linear regression analysis between bird diversity and overall vegetative complexity showed a significant correlation ( $R^2 = 0.32$ ,  $P < 0.0001$ ) (Figure 3). Additional linear regression analysis comparing bird diversity and horizontal vegetative complexity showed a significant correlation ( $R^2 = 0.35$ ,  $P < 0.0001$ ) (Figure 4). There was also a significant correlation between bird diversity and vertical vegetative complexity ( $R^2 = 0.22$ ,  $P < 0.001$ ) (Figure 5).

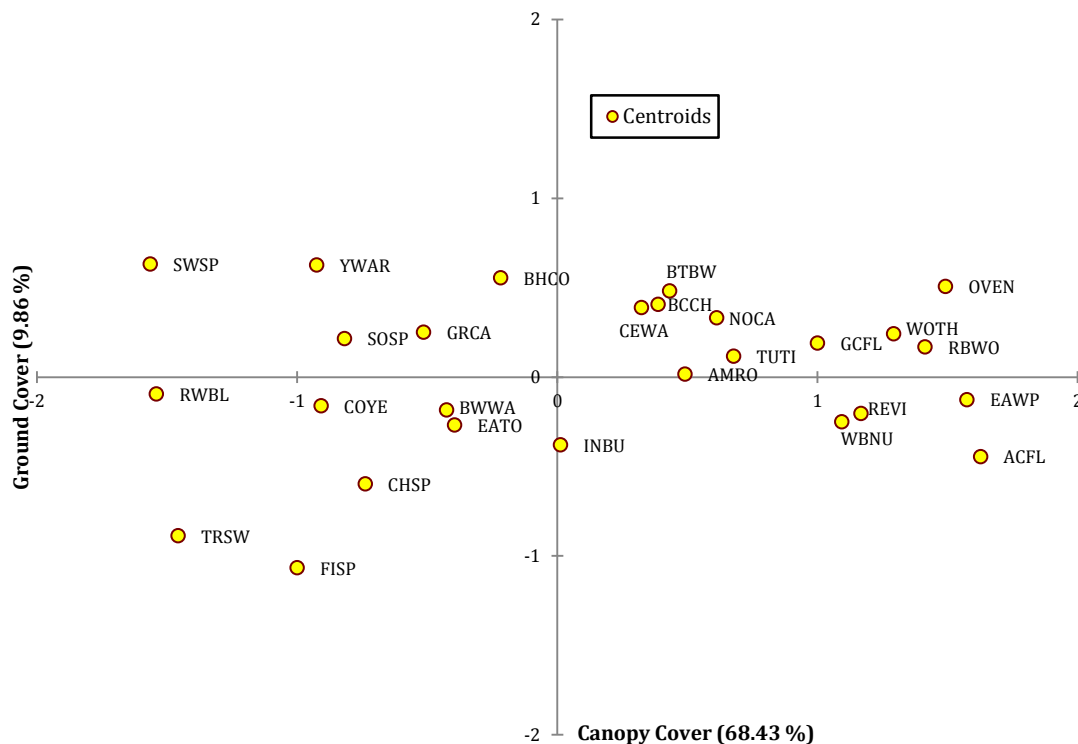


Figure 2. Multivariate analysis of vegetative structural components at 45 point count sites with diversity based on 1,771 bird observations at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan, 21 May – 27 June 2012.

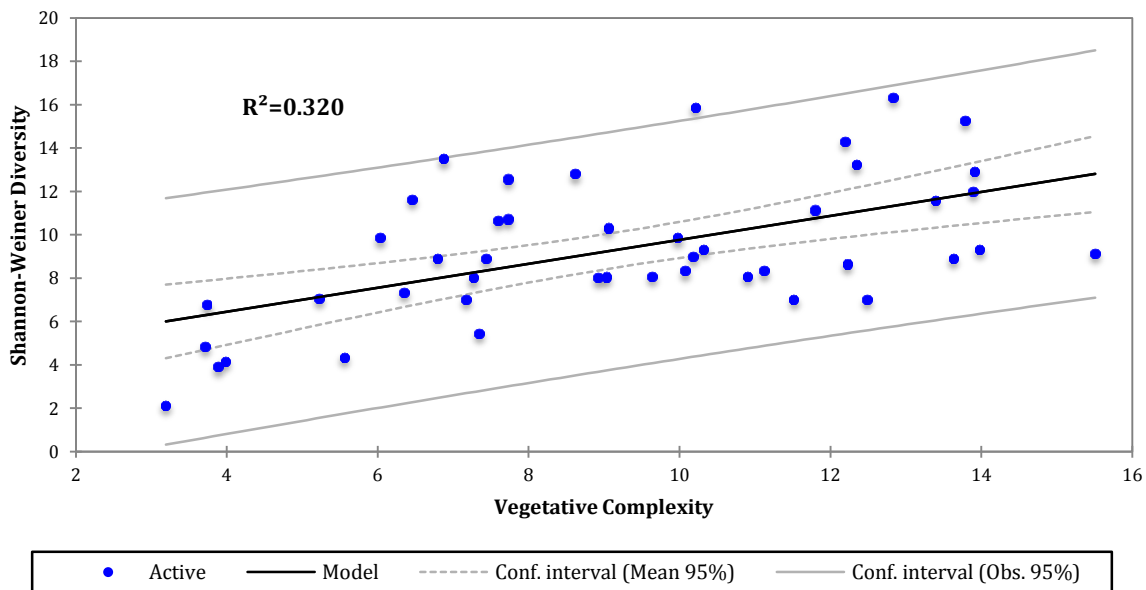


Figure 3: Correlation between overall vegetative structure complexity and breeding bird diversity at 45 point count sites with diversity based on 1,771 bird observations at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan, 21 May – 27 June 2012.

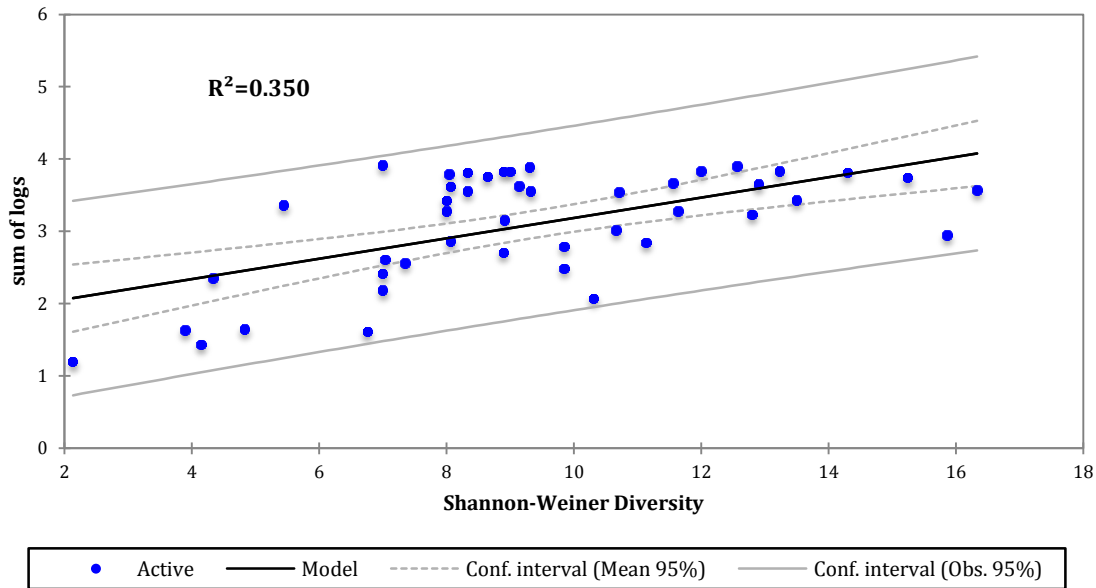


Figure 4: Correlation between horizontal vegetative structure complexity and breeding bird diversity at 45 point count sites with diversity based on 1,771 bird observations at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan, 21 May – 27 June 2012.

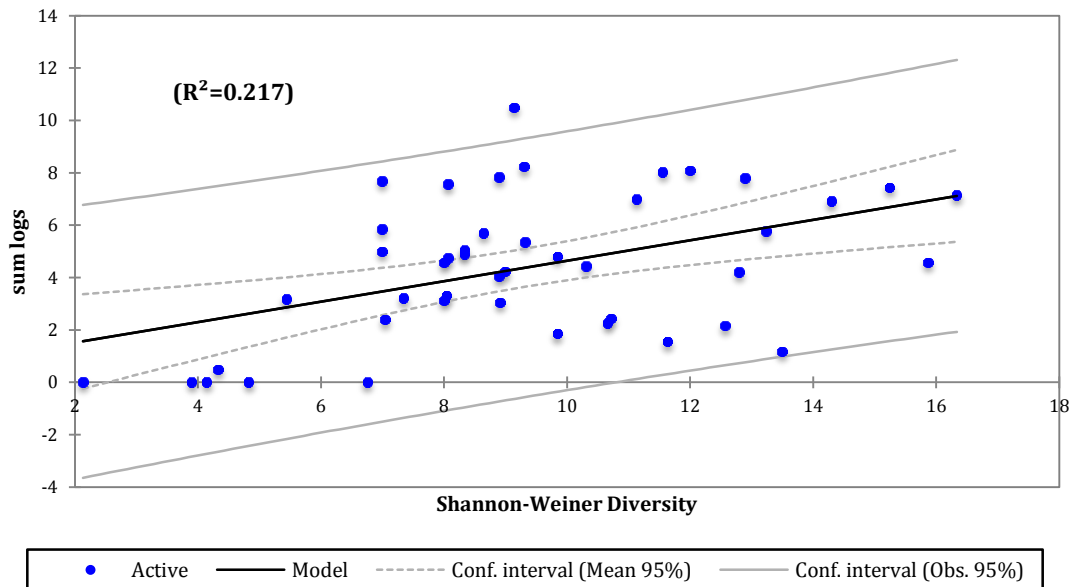


Figure 5: Correlation between vertical vegetative structure complexity and breeding bird diversity at 45 point count sites with diversity based on 1,771 bird observations at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan, 21 May – 27 June 2012.

## **DISCUSSION**

### **Hypothesis 1**

We found that there were significant differences in the use of vegetative structure by breeding season birds. This is not surprising considering the habitat we surveyed contained large differentiation in structure. The habitat character space maps support this by visually demonstrating the differing preferences for vegetative structure.

The habitat character space maps are a novel approach to examining habitat selection by individual species. These maps have a number of possible benefits. First, they allowed us to combine many different structural measures into a condensed and easily understood figure. Habitat character space maps not only demonstrate a species specific set of vegetative structural selection but also what each species tends to avoid. Second, the habitat character space maps could be a way to provide a standard measure of habitat selection in bird species. This would allow one to better predict which species would likely be present in a particular habitat before observing them. We would suggest adding habitat character space maps to bird databases.

Our analysis indicates that a group of species (Appendix C) demonstrates more generalist vegetative requirements based on the broad range in each of the vegetative variables. Another group of species (Figure 1) expresses a more specific set of requirements and would be classified as specialist species based on the narrow range of vegetative requirements for some of the variables. Habitat can be designed to cater to the needs of specialist species with the anticipation that generalist species would fill in the spaces not occupied by the specialists. While multivariate analysis showed discrimination based on canopy and ground cover, extending a view of vegetative structure to a greater set of variables could be more effective in providing quality habitat restoration for more specialist species.

We found that the larger shrubs were not a significant structural feature for most bird species. This is interesting due to the fact that in many of our non-wetland sites, Autumn Olive (*Elaeagnus umbellata*) was a dominant species. It is possible that bird species normally selecting habitat based on large shrubs do not use those areas because of the invasive nature of Autumn Olive in Michigan. Swamp sparrows did show a significant preference for large shrubs, but they were found primarily in wetlands which did not normally contain Autumn Olive.

## **Hypothesis 2**

The correlation between bird diversity and vegetative complexity was significant. It appears that an increase in vegetative complexity will give rise to a moderate increase in diversity. In order to maintain greater diversity, we advise managing for a complex vegetative structure. However, in doing this, some species that prefer minimal structure (see hypothesis 1) in specific layers will likely have reduced numbers.

While it has been shown through this study and other research that birds use various vegetative structures for breeding sites, it is important to realize that the choice of structure by bird species for nesting/breeding sites is more complex than is often reported. Understanding the nature of the complexity of the range of preferences in selection can be important in developing conservation strategies that address greater numbers of species rather than just a specialized target species. However, by looking at these specialized species, we can use habitat character space maps to determine how species with similar vegetative structural components will also benefit from conservation efforts.

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We would like to thank Pierce Cedar Creek Institute for providing financial support of the project through the Undergraduate Research Grants for the Environment program and for use of facilities at the Institute.

## Appendix A: Point count sites with GPS coordinates

Pierce Cedar Creek Institute			Barry State Game Area/Yankee Springs Rec Area		
Point	Latitude	Longitude	Point	Latitude	Longitude
1	42°32'9.00"N	85°18'32.75"W	37	42°36'5.00"N	85°23'18.41"W
2	42°32'6.52"N	85°18'24.01"W	38	42°36'4.86"N	85°23'4.30"W
3	42°31'58.05"N	85°18'18.84"W	39	42°36'19.54"N	85°25'42.01"W
4	42°31'52.82"N	85°18'13.72"W	40	42°36'17.90"N	85°25'19.60"W
5	42°31'48.71"N	85°18'27.81"W	41	42°36'23.95"N	85°28'30.53"W
6	42°31'49.10"N	85°18'5.62"W	42	42°36'17.74"N	85°28'35.84"W
7	42°31'43.87"N	85°17'58.84"W	43	42°36'47.62"N	85°26'18.25"W
8	42°31'48.21"N	85°17'57.88"W	44	42°36'37.46"N	85°26'18.13"W
9	42°31'53.57"N	85°17'57.89"W	45	42°36'38.47"N	85°26'9.76"W
10	42°31'57.91"N	85°17'50.18"W			
11	42°31'56.05"N	85°17'45.15"W			
12	42°31'34.47"N	85°17'54.63"W			
13	42°31'57.68"N	85°17'40.50"W			
14	42°32'11.79"N	85°17'46.64"W			
15	42°32'10.94"N	85°17'53.68"W			
16	42°32'2.97"N	85°17'55.97"W			
17	42°32'16.20"N	85°17'47.70"W			
18	42°31'36.99"N	85°18'3.16"W			
19	42°32'17.23"N	85°17'55.58"W			
20	42°32'24.93"N	85°18'5.74"W			
21	42°32'30.85"N	85°18'8.84"W			
22	42°32'21.17"N	85°18'6.05"W			
23	42°32'37.74"N	85°17'56.76"W			
24	42°32'33.92"N	85°17'45.71"W			
25	42°32'37.42"N	85°17'37.24"W			
26	42°32'31.90"N	85°17'27.94"W			
27	42°32'29.84"N	85°17'22.36"W			
28	42°32'24.71"N	85°17'31.94"W			
29	42°32'19.55"N	85°17'24.42"W			
30	42°32'10.71"N	85°17'34.45"W			
31	42°32'7.60"N	85°17'26.42"W			
32	42°32'40.93"N	85°16'30.60"W			
33	42°32'15.49"N	85°18'3.01"W			
34	42°32'42.99"N	85°16'18.79"W			
35	42°32'42.40"N	85°16'26.24"W			
36	42°32'39.54"N	85°16'21.13"W			

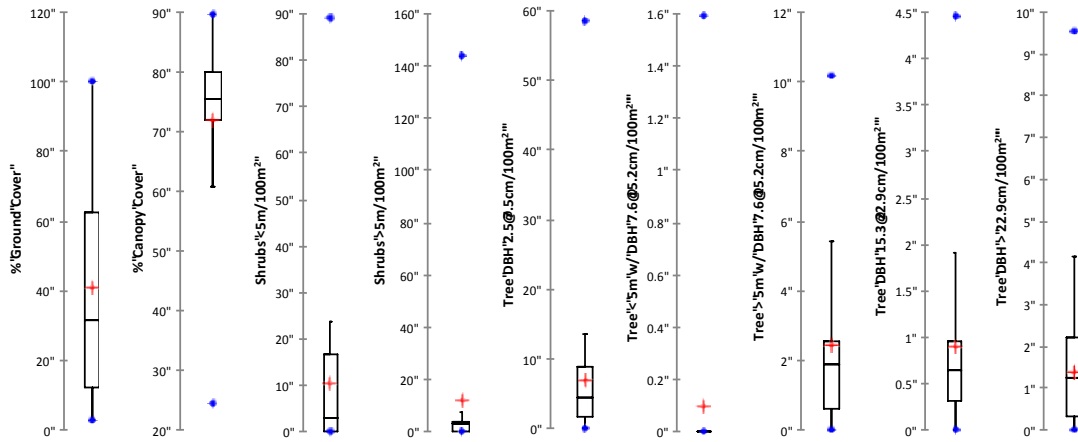
Appendix B – Alphabetical listing of observed bird species with four letter alpha code, 21 May to 27 June 2012 at PCCI, OTIS, BSGA and YSRA, Barry County, Michigan.

Acadian Flycatcher – ACFL*	Red-bellied Woodpecker – RBWO*
Alder Flycatcher - ALFL	Red-eyed Vireo – REVI*
American Crow - AMCR	Red-winged Blackbird – RWBL*
American Goldfinch – AMGO	Rose-breasted Grosbeak - RBGR
American Redstart - AMRE	Ruby-throated Hummingbird - RTHU
American Robin – AMRO*	Scarlet Tanager - SCTA
Baltimore Oriole - BAOR	Sedge Wren - SEWR
Barn Swallow - BASW	Song Sparrow – SOSP*
Belted Kingfisher - BEKI	Swamp Sparrow – SWSP*
Black-and-white Warbler - BAWW	Tree Swallow – TRSW*
Black-capped Chickadee – BCCH*	Tufted Titmouse – TUTI*
Black-throated Blue Warbler – BTBW*	Veery - VEER
Black-throated Green Warbler - BTNW	White-breasted Nuthatch – WBNU*
Blue Jay - BLJA	Willow Flycatcher - WIFL
Blue-gray Gnatcatcher - BGGN	Wood Thrush – WOTH*
Blue-winged Warbler – BWWA*	Worm-eating Warbler - WEWA
Brown-headed Cowbird – BHCO*	Yellow Warbler – YEWA*
Cedar Waxwing – CEWA*	Yellow-billed Cuckoo - YBCU
Cerulean Warbler - CERW	Yellow-throated Vireo - YTVI
Chestnut-sided Warbler - CSWA	
Chipping Sparrow – CHSP*	
Common Yellowthroat – COYE*	
Downy Woodpecker - DOWO	
Eastern Bluebird - EABL	
Eastern Kingbird - EAKI	
Eastern Phoebe - EAPH	
Eastern Towhee – EATO*	
Eastern Wood-Pewee – EAWP*	
Field Sparrow – FISP*	
Gray Catbird – GRCA*	
Great Crested Flycatcher – GCFL*	
Hairy Woodpecker - HAWO	
House Finch - HOFI	
House Wren - HOWR	
Indigo Bunting - INBU	
Least Flycatcher - LEFL	
Marsh Wren - MAWR	
Mourning Dove - MODO	
Mourning Warbler - MOWA	
Northern Cardinal – NOCA*	
Northern Flicker - NOFL	
Northern Rough-winged Swallow - NRWS	
Ovenbird – OVEN*	
Pileated Woodpecker - PIWO	
Pine Warbler - PIWA	

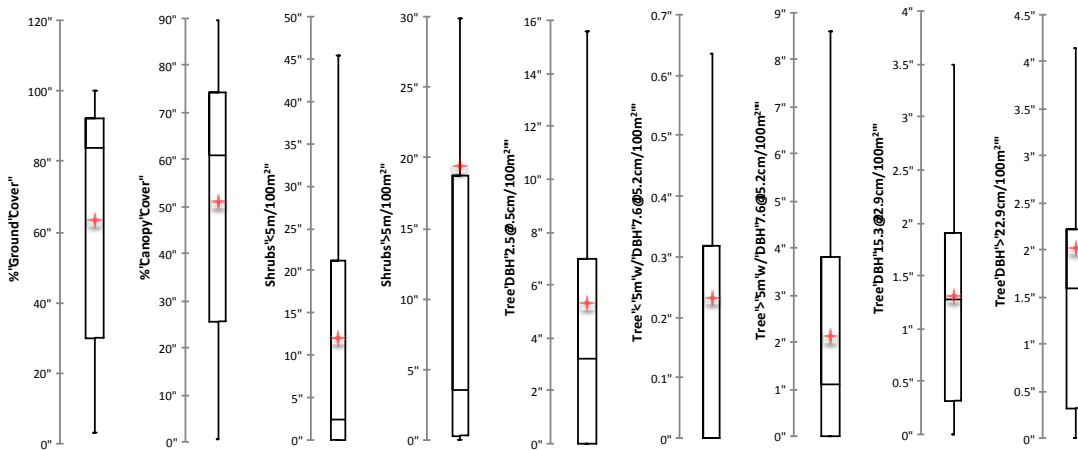
\* Designates species with >20 observations

## Appendix C: Habitat Character Space Maps

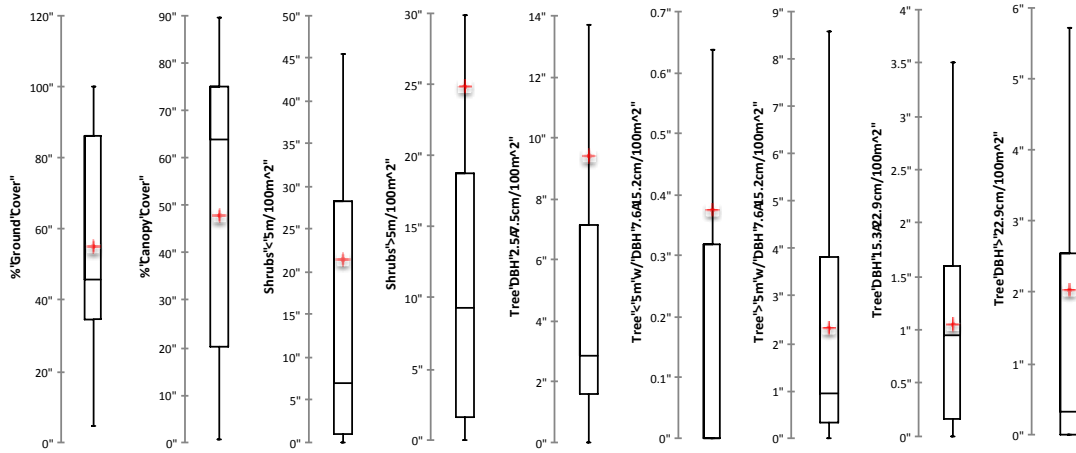
The following habitat character space maps illustrate the variability in the habitat requirements for 27 species of passerines observed ( $N > 20$ ) from 21 May to 27 June 2012 at the Pierce Cedar Creek Institute, Otis Bird Sanctuary, Barry State Game Area and Yankee Springs Recreation Area, Barry County, Michigan. + designates the median point; – within the box designates the mean; dots at the top and bottom the high and low points recorded.



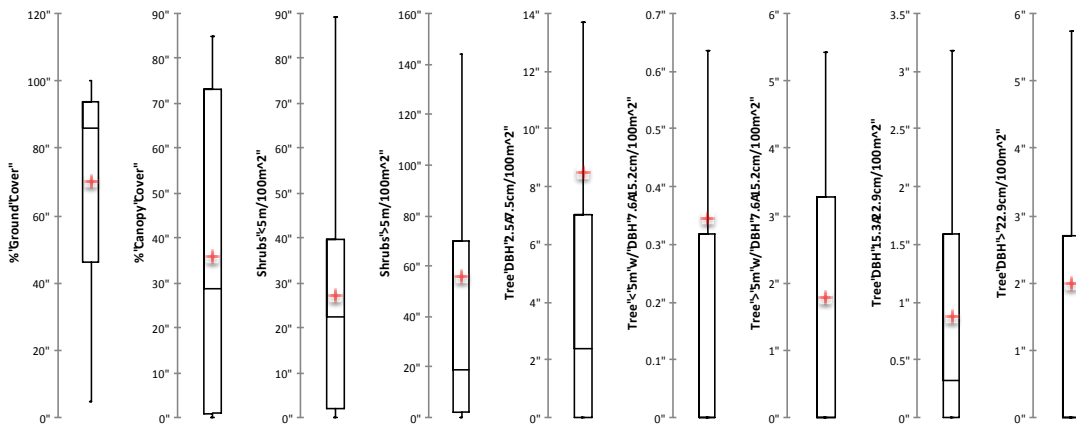
Acadian flycatcher ( $N = 103$ )



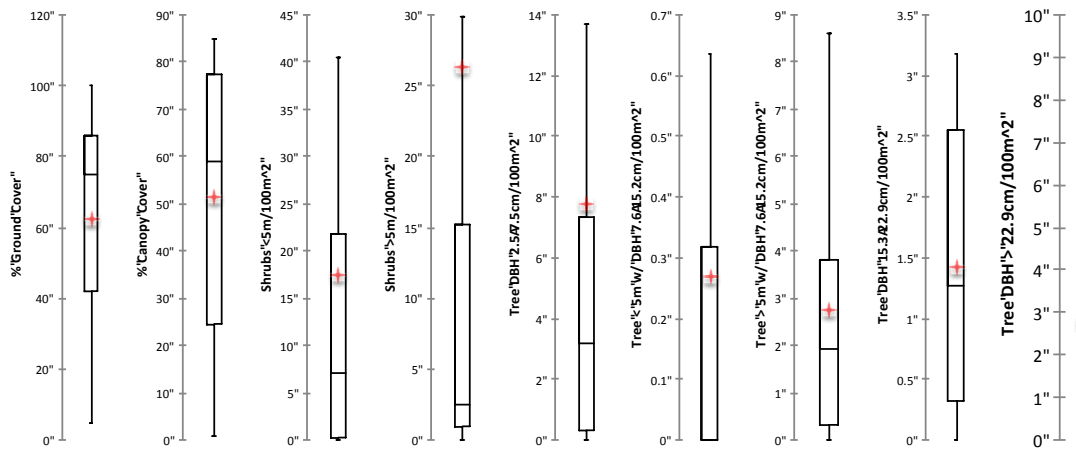
American robin ( $N = 102$ )



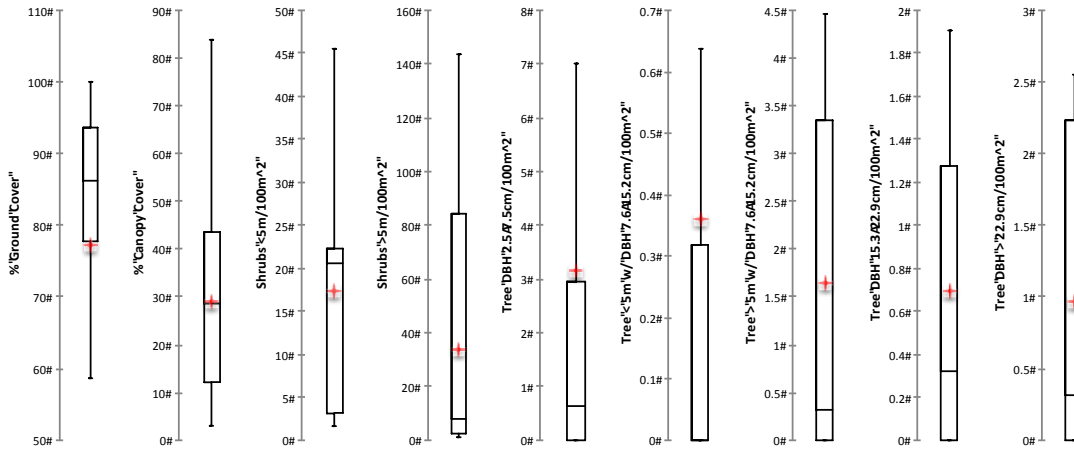
Black-capped chickadee ( $N = 63$ )



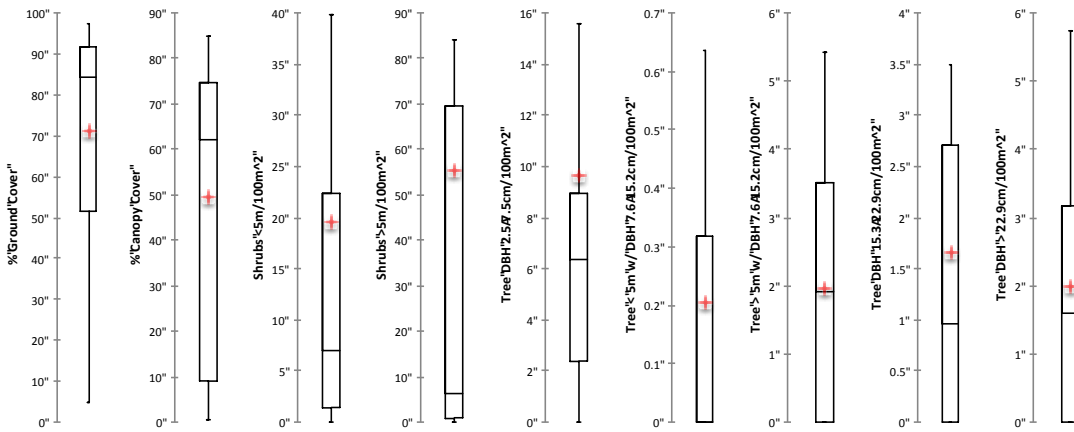
Brown-headed cowbird ( $N = 60$ )



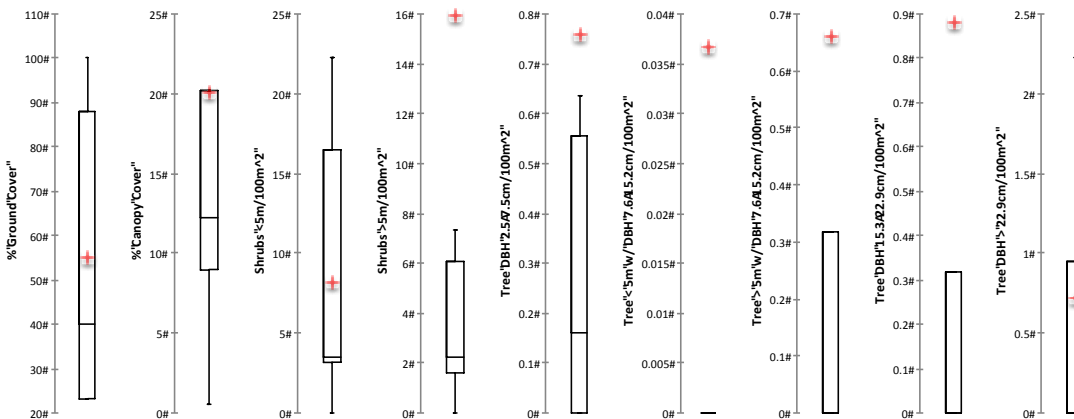
Black-throated blue warbler ( $N = 26$ )



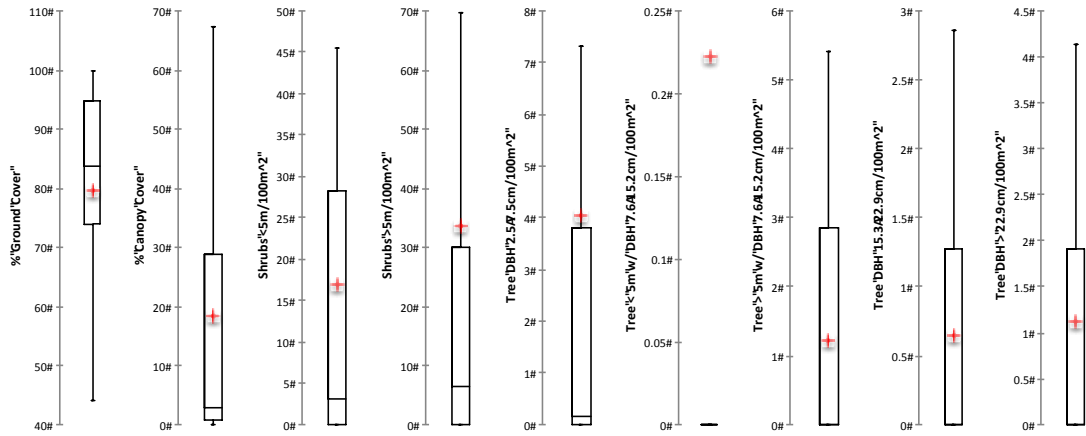
Blue-winged warbler (N = 52)



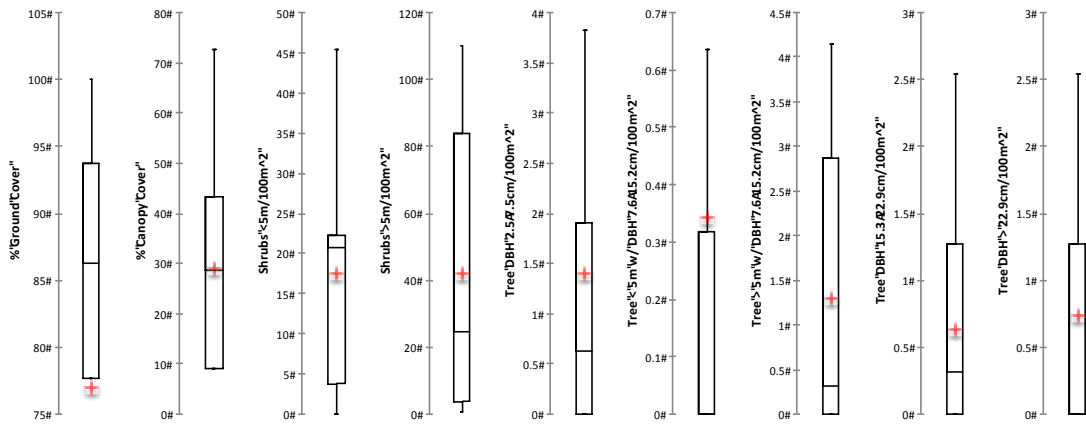
Cedar waxwing (N = 31)



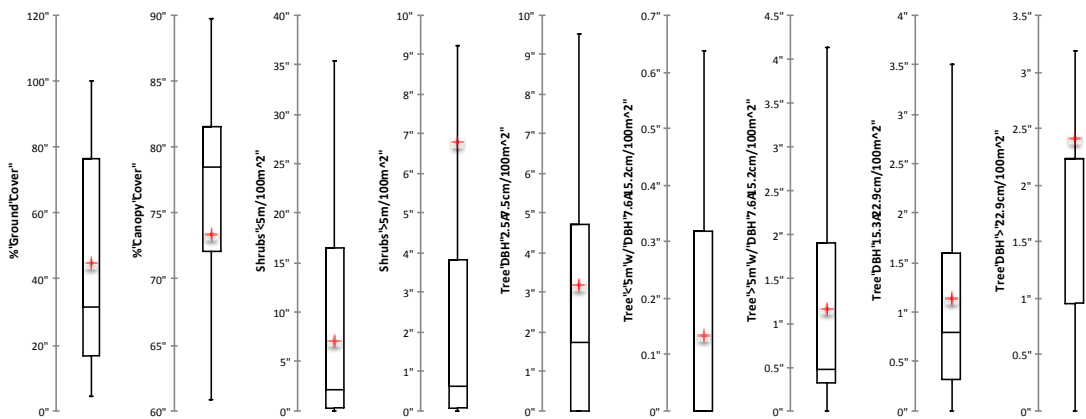
Chipping sparrow (N = 26)



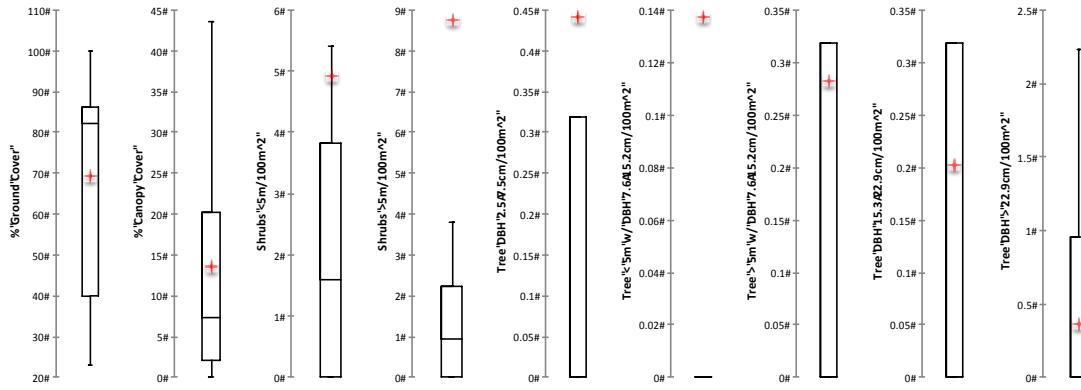
Common yellowthroat (N = 200)



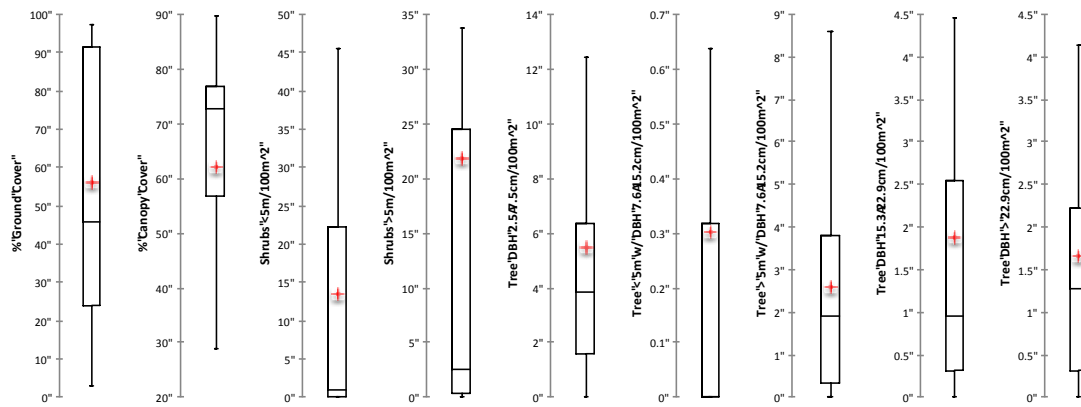
Eastern towhee (N = 41)



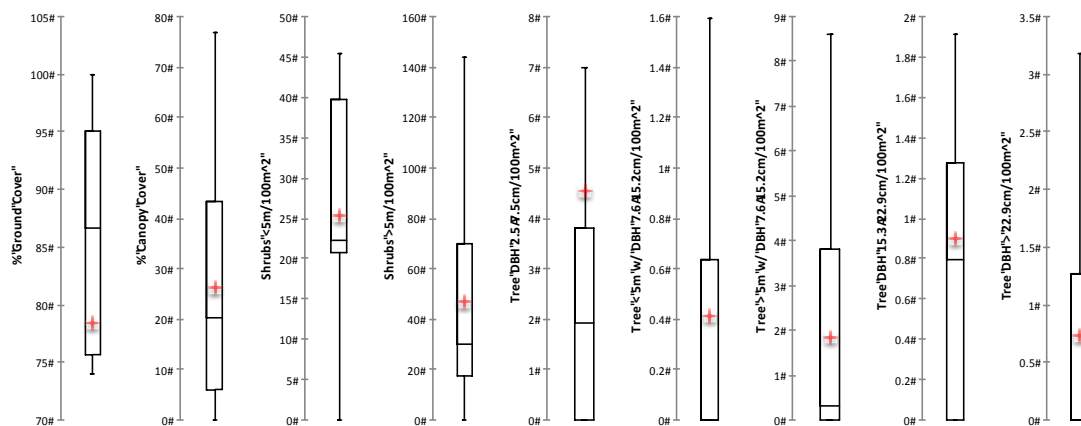
Eastern wood-pewee (N = 62)



Field sparrow ( $N = 44$ )

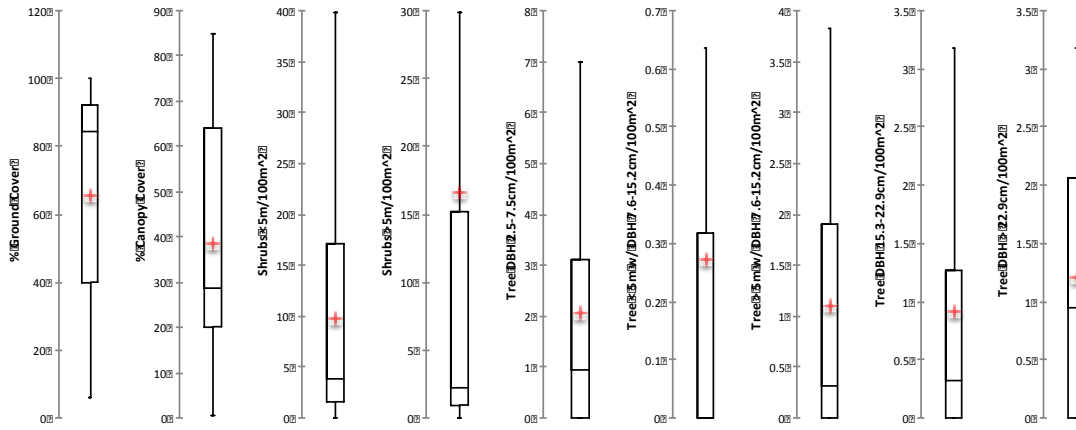


Great-crested flycatcher ( $N = 37$ )

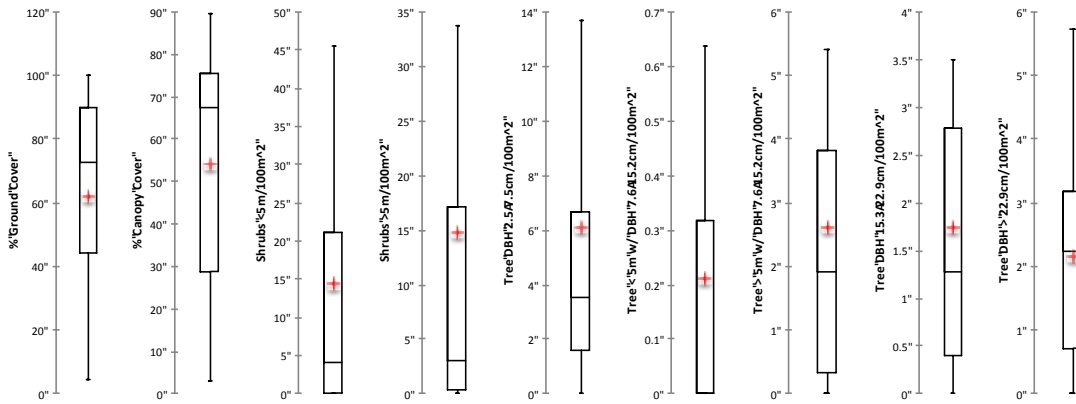


Gray catbird ( $N = 50$ )

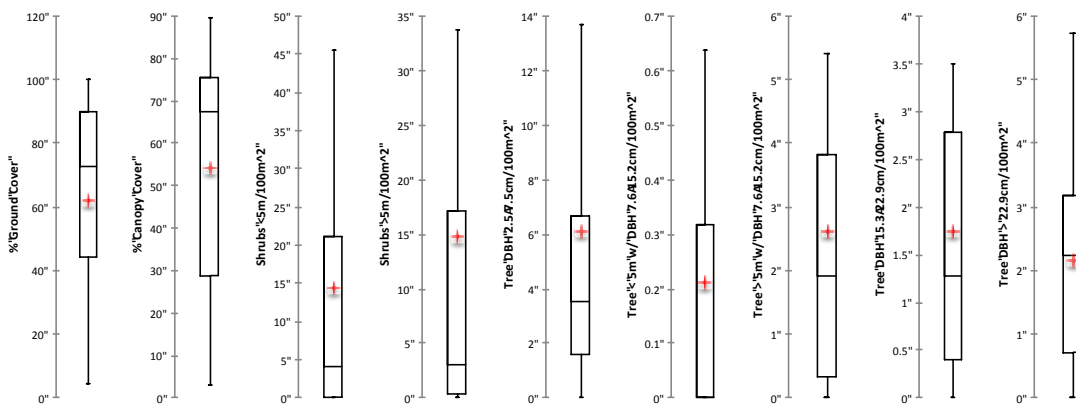




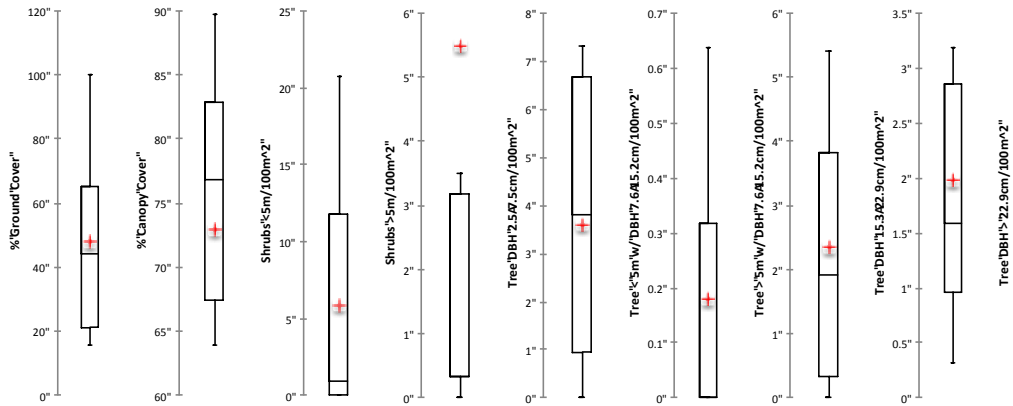
Indigo bunting (N = 42)



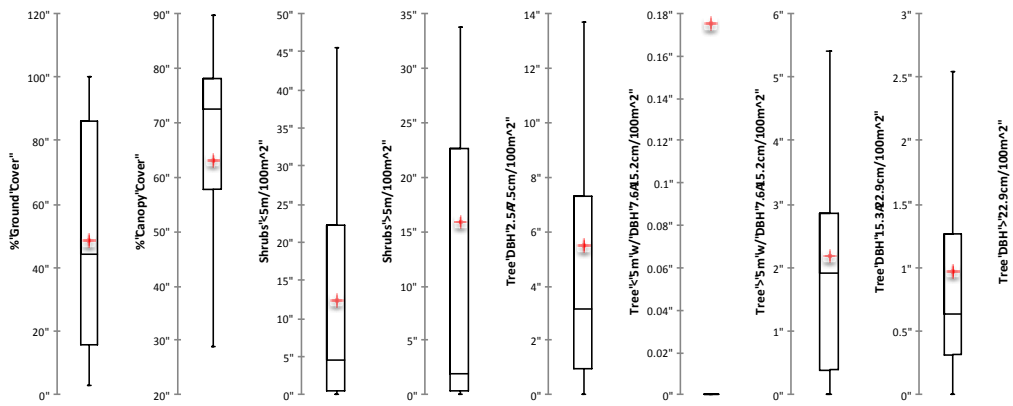
Northern cardinal (N = 54)



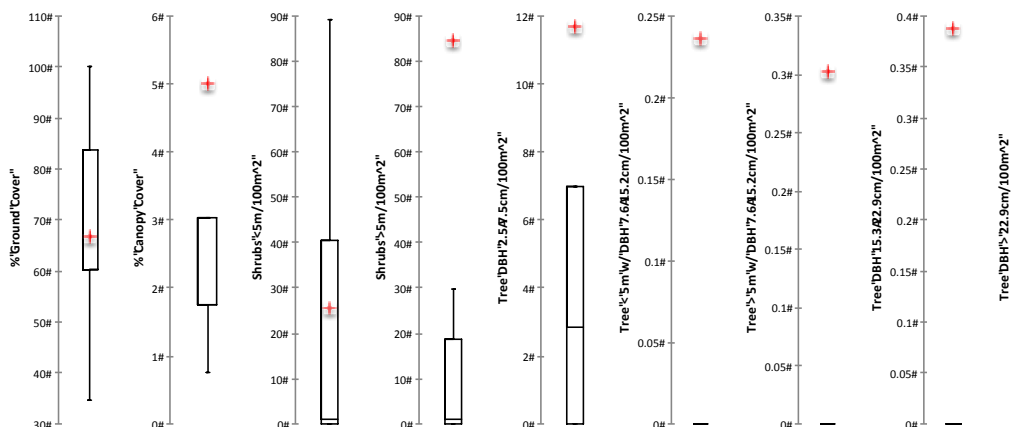
Ovenbird (N = 39)



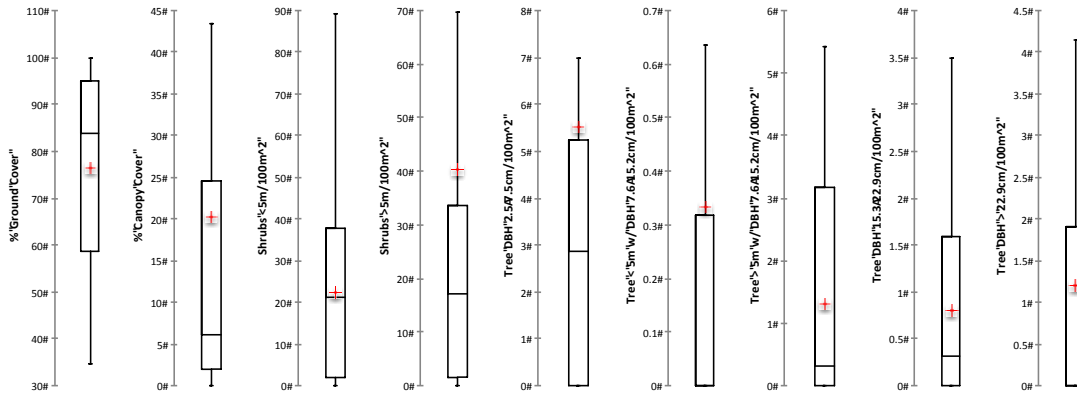
Red-bellied woodpecker (N = 23)



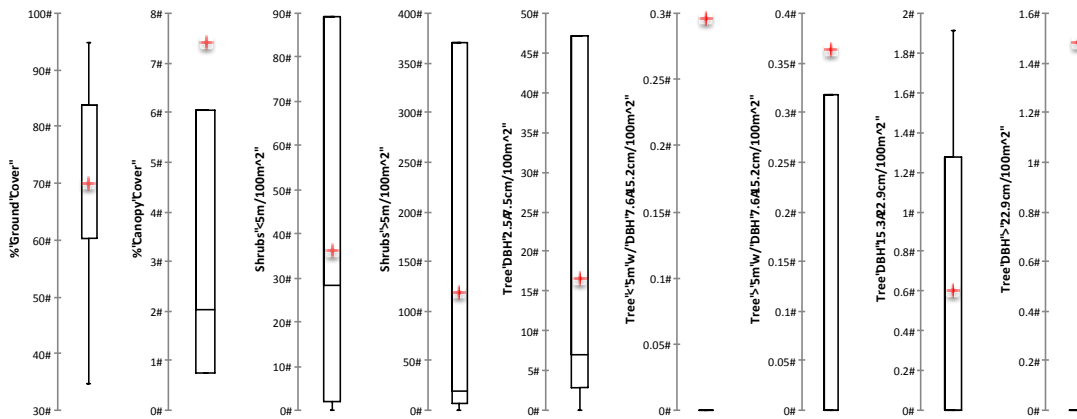
Red-eyed vireo (N = 78)



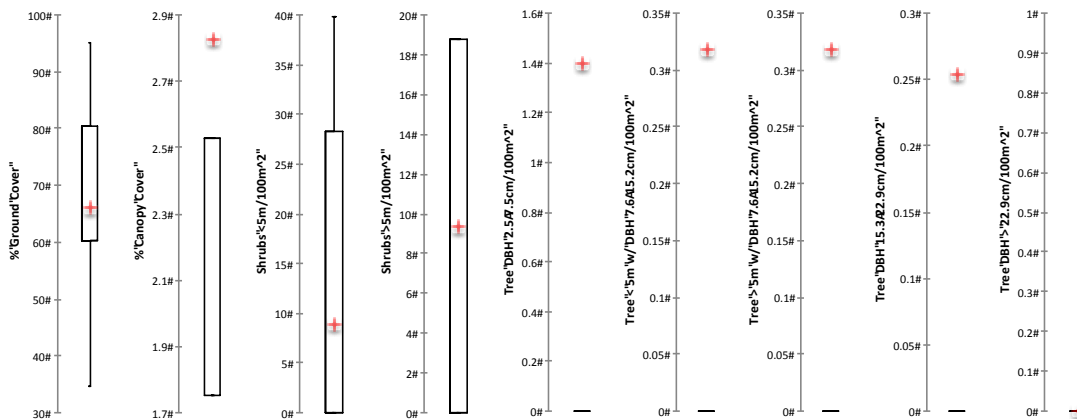
Red-winged blackbird (N = 97)



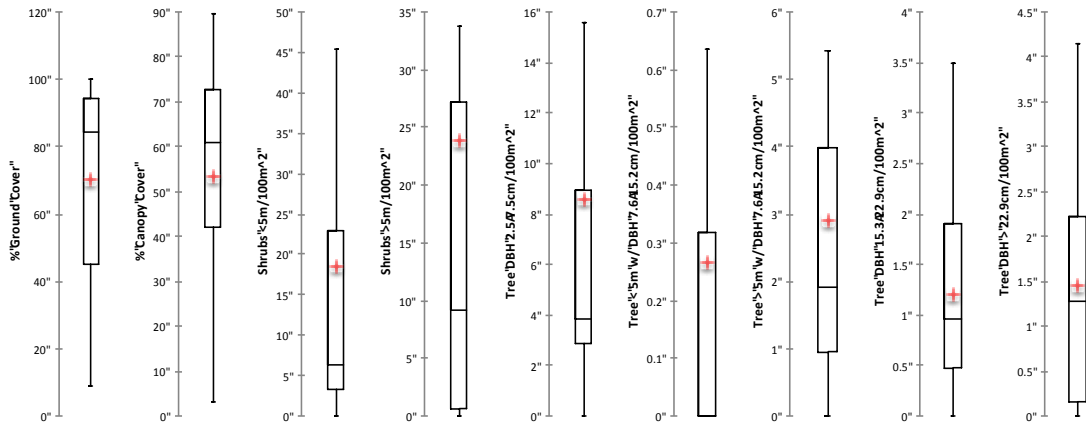
Song sparrow (*N* = 79)



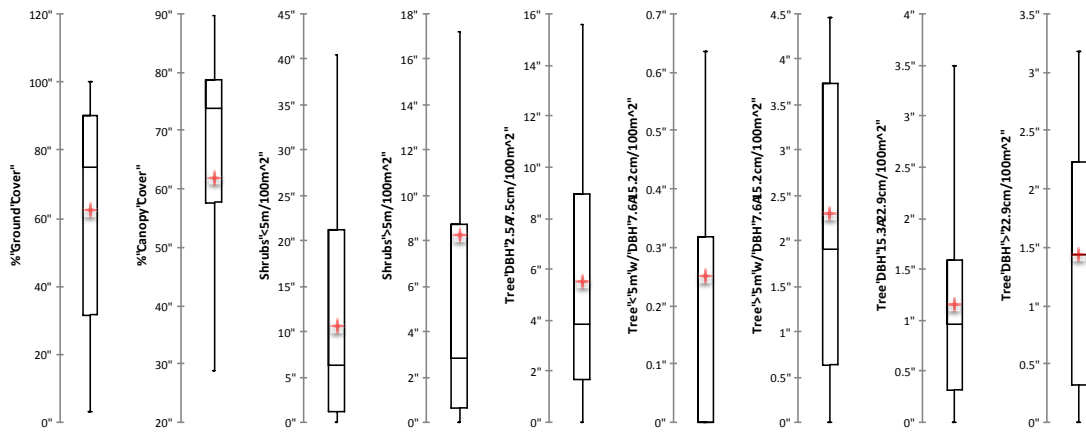
Swamp sparrow (*N* = 43)



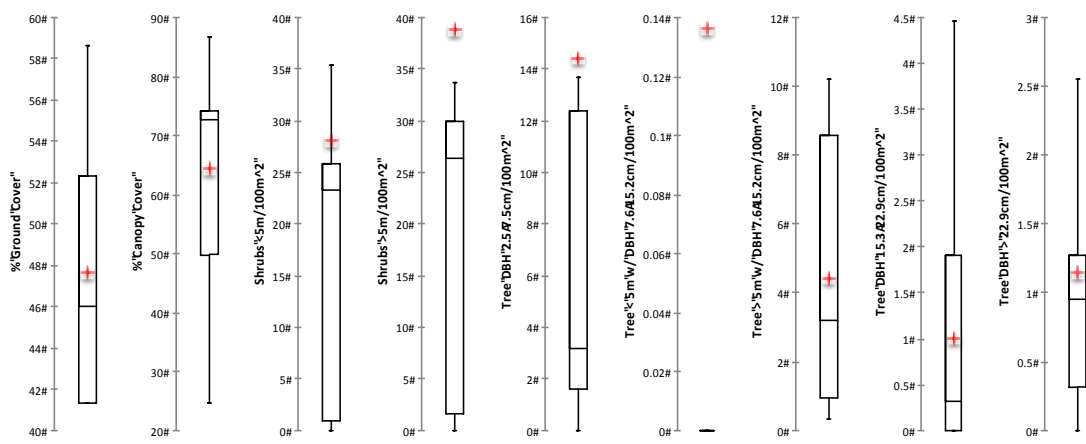
Tree swallow (*N* = 25)



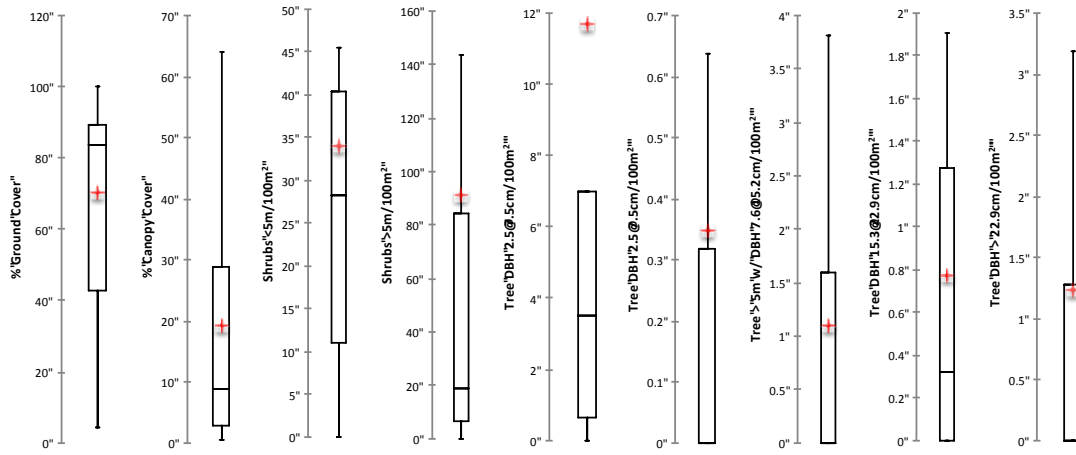
Tufted titmouse (N = 31)



White-breasted nuthatch (N = 38)



Wood thrush (N = 21)



Yellow warbler (N = 67)