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Bird Diversity and Abundance in Relation to Habitat Complexity at Jack Mountain Wildlife Management Area

Grace Tidwell

SENIOR THESIS APPROVAL

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Bird Diversity and Abundance in Relation to Habitat complexity at Jack Mountain Wildlife Management Area

written by

Grace E. Tidwell

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the requirements for completion of
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and has been approved by the undersigned readers.

Dr. Christin Pruett, thesis director

Dr. Sharon Hamilton, second reader

Dr. Jay Curlin, third reader

Dr. Barbara Pemberton, Honors Program director

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THESIS:

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Grace E. Tidwell

Ouachita Baptist University

TID69780@obu.edu

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Table of Contents

List of Figures and Tables

Abstract

Since 1973, North America has lost 2.9 billion birds due to habitat loss and fragmentation. To assess the effects of habitat complexity on bird diversity and abundance, 96 locations were surveyed at Jack Mountain Wildlife Management Area (WMA) using ten-minute point counts. All birds seen and heard at each point were documented, and habitat complexity was assessed by examining the percentage of ground coverage, shrub coverage, midstory tree layer, and canopy coverage at each point. A habitat complexity index was generated from these plant surveys. Previous research at Jack Mountain has shown that habitats dominated by pine trees had the highest bird species diversity and abundance in comparison to mixed or deciduous woodlands. Habitat complexity has been associated with an increase in bird species diversity, and thus, we hypothesized that pine habitats would have greater habitat complexity and that habitat complexity would be positively correlated with bird diversity and abundance.

Statistical tests were performed in R to assess these hypotheses. In comparisons between species abundance or diversity with the habitat complexity index, no significant correlations were observed. We then compared each of the four aspects of the habitat complexity index with species diversity and abundance, using a multivariate model, and found a significant negative correlation between species abundance and diversity versus canopy coverage. Additionally, significant positive correlations were found between species abundance and species diversity versus ground cover and species abundance and diversity versus shrub coverage. Each point location was assigned to a habitat class based on the percentage of pine and deciduous tree cover. As found in previous summers by students at Ouachita Baptist University, a comparison among habitat classes and species diversity showed higher numbers of species in pine habitats, however, the habitat complexity index did not differ among habitat classes. To further evaluate, the

abundance of birds in pine habitats, aspects of the habitat index were then compared to the habitat classes. We found smaller amounts of canopy coverage and larger amounts of ground cover and shrub cover in pine habitats than in deciduous or mixed habitats.

The most common bird species inhabiting Jack Mountain WMA are insectivores, and thus, they rely primarily on insects as their food source. Therefore, insect abundance was assessed at chosen point locations for both pine and deciduous forests to assess whether habitat complexity or habitat class were drivers of insect abundance and if insect abundance was positively correlated with bird abundance and diversity. Comparisons of the habitat complexity index and insect abundance supported that the two were not correlated. Similarly, associations between the habitat classes and insect abundance were not associated. Additionally, species abundance and diversity were not found to be correlated with the presence of insects either. Canopy coverage was also compared to insect abundance, and a correlation was not observed. Since associations were not found with insect presence, it was concluded that other habitat variables are responsible for bird richness.

These findings suggest that there are more bird species and individuals among pine habitats at Jack Mountain because of less canopy coverage. Areas with higher canopy and mid-story coverage on average had a smaller number of birds present, and areas with higher ground and shrub coverage had a larger number of birds present. A reduction in canopy coverage in pine habitats could lead to an increase in ground and shrub coverage, which are both correlated with an increase in the diversity and abundance of birds. In conclusion, we reject our initial hypothesis about bird diversity and pine habitat's being associated with increasing habitat complexity. Our findings suggest that the population dynamics of birds at Jack Mountain are associated with a diverse set of habitat variables that cannot be simplified into a single habitat complexity index.

Introduction

Population sizes of breeding birds in North America have been in continual decline since the 1970s (Rosenberg et al. 2019). This population decline is primarily due to habitat loss and fragmentation, and this loss has even been identified in species of conservation concern (Fig. 1) in the Arkansas forests (Owens and Bennett 2000). Several of these declining species have been observed at Jack Mountain. In light of this data, surveys regarding biodiversity, habitat use, and abundance of birds were conducted at 96-point locations at Jack Mountain WMA (Fig. 2) . Birds are substantial contributors to the ecosystems of the world with a direct influence on human health, the economy, and food production. Ultimately, habitat complexity governs species richness and abundance (Hurlbert 2004). Thus, suitable complex habitats are essential for maintaining bird populations at Jack Mountain Wildlife Management Area, especially since species of conservation concern have been observed there (Dietz et al. 2020). During the summer of 2021, my research partner Kelsey Bester and I conducted bird, habitat, and insect surveys at Jack Mountain Wildlife Management Area to determine associations between bird species diversity and abundance, habitat complexity, and insect presence (abundance).

As found in previous summers by students at Ouachita Baptist University, pine and deciduous forests at Jack Mountain Wildlife Management Area are an important refuge for a variety of breeding land birds in North America including those of conservation concern. It had also been discovered that habitats dominated by pine trees (> 60% pine trees) had greater species abundance and diversity (Table 1; $F = 3.755$, $P = 0.0274$) than deciduous forests (> 60% deciduous trees) (Pruett, C. L. 2020). The correlation between species diversity and abundance in pine habitats could be attributed to greater opportunities, such as more nesting locations and food resources in these habitats (Robinson and Holmes 1982). The birds at Jack Mountain WMA are primarily insectivores, and thus insect abundance was assessed due to their potential in contributing to bird abundance and species richness (Srivastava and Lawton 1998). Bird populations at Jack Mountain could be negatively affected by the limited number of insects available (Tallamy et al. 2021). It has been thought that the abundance of insectivores strongly influences the abundance of birds present and that habitat complexity can have a direct and indirect effect on the abundance of insects (Robinson and Holmes 1982).

We visited the same 96 randomly placed point locations that students previously had visited during the past two summers. The objective of our study was to perform bird surveys at different points randomly placed throughout Jack Mountain Wildlife Management Area to document the diversity and abundance of bird species, provide an assessment of habitat complexity at each point, examining a percentage of ground cover, shrub layer, mid-story tree layer, and canopy coverage providing insight into the habitat variables associated with bird richness and abundance, generate a habitat index and perform statistical tests in R to analyze data and determine associations between habitat variables, and assess insect abundance in relation to habitat complexity and species richness and abundance.

During this 3-year longitudinal study, seventy-two species of birds were identified, including species of conservation concern (Pruett, C. L. 2020). Of the seventy-two species observed at Jack Mountain Wildlife Management Area, thirty-one are declining in North America (Table 2) (Rosenberg et al. 2019). It is of utmost importance that the discovery of declining species' habitat preferences is identified in order to help maintain their existence at Jack Mountain Wildlife Management Area (Caughley 1994). Therefore, our topic in question was does habitat complexity contribute to the diversity and abundance of these birds at Jack Mountain Wildlife Management Area. Due to previous research, these declining species have been identified at Jack Mountain Wildlife Management Area, and our investigation of this area could aid in the discovery of the driving force behind the habitat selections of species of conservation concern.

Therefore, the following hypotheses were tested: 1) pine-dominated habitats would have greater habitat complexity than deciduous forests, 2) habitat complexity would be positively correlated with bird diversity and abundance, 3) diversity and abundance of birds at Jack Mountain Wildlife Management Area are positively associated with insect abundance. Ultimately, our goal was to provide insight into the management practices that would be beneficial to birds at Jack Mountain Wildlife Management Area.

Methodology

Bird Surveys

Bird and habitat surveys were conducted to assess bird diversity and abundance in relation to habitat complexity at Jack Mountain Wildlife Management Area. Point counts were used to perform these assessments at 96 locations to determine the effects of habitat complexity on bird diversity and abundance. Initially, during the first year of this research in 2019, 100 points were visited, but only 96 of those points were accessible during the early summer of 2021, due to flooding. At each point, a ten-minute count window was observed, and all species heard and seen were documented (Bibby et al. 2000). Each point location was placed at least 150 meters apart to decrease the chances of double counting birds. Surveys were conducted within four hours of sunrise to increase the detection probability (Huff et al. 2000).

To begin, the latitude and longitude were entered into a smartphone GPS so that the location could be reached as closely as possible by a vehicle. Once at the nearest point of the location by vehicle, one would then hike to the point location listening for birds and observing the habitat while walking. The time was recorded before the 10-minute survey began. A range finder was then used to estimate the distance of birds, and all birds seen and heard within 50 meters were recorded on the data sheet (Fig. 3) for the first 3 minutes, minutes 0-3 of the 10-minute point count, during the next 2 minutes, minutes 3-5 of the 10-minute point count, and during the last 5 minutes, minutes 5-10 of the 10-minute point count. Data was recorded similarly for birds heard outside the 50-meter radius and birds that flew over during the survey. Thus, during the first 3 minutes of the survey birds were documented as being within 50 meters, farther than 50 meters, or as a flyover. During the next two minutes, only new birds heard were documented as being within 50 meters, farther than 50 meters, or as a flyover. And lastly, only new birds seen or heard within the last five minutes of the survey were documented as being within 50 meters, farther than 50 meters, or as a flyover. Each ten-minute point count was recorded by smartphone so that recordings could be reassessed to ensure all birds were properly cited and recorded. If a bird call was unidentifiable during the survey, the time of its occurrence was recorded and assessed after the survey had ended.

Habitat Surveys

Habitat assessments were conducted at each point location (Fig. 4). Additionally, location variables were recorded, including the date of the survey, time of the survey, wind speed, temperature, and percentage of cloud coverage. These included an assessment of canopy height, canopy coverage, mid-story tree layer density, shrub-layer density, and ground layer coverage (Fig. 5). Five locations were visited within each 50-meter count circle for each point location

(Sam et al. 2019). For each of the five locations, the following surveys were conducted. First, canopy height was recorded using a laser rangefinder to measure the height of the tallest tree within 50 meters of the point location. Next, canopy coverage was recorded assessing the density of coverage directly above the point. A photograph was taken and examined to determine the amount of light coming through the canopy, and a percentage of coverage was calculated at each location for each point. The mid-story tree layer density was assessed within a 5-meter circle (approximately 15 feet) of the point location, and the percentage of trees 3-10 meters in height (approximately 9-30 feet tall) was estimated. Likewise, the shrub layer density was assessed within the same 5-meter circle (approximately 15 feet) of the point location, and the percentage of shrubs (woody plants) 1-3 meters in height (approximately 3-9 feet tall) was estimated. Lastly, the ground layer coverage was assessed by randomly encompassing a 1-meter squared plot and estimating the percentage of plants less the 0.5 meters in height (less than 19 inches tall) within the plot.

Location 1 was located at the exact latitude and longitude of the point assessed. Location 2 was 8 steps (approximately 5 meters) north of location 1. Location 3 was 16 steps (approximately 10 meters) east of location 1. Location 4 was 32 steps (approximately 20 meters) south of location 1. Location 5 was 65 steps (approximately 40 meters) west of location 1. The direction (north, east, south, or west) was chosen randomly for each point location, but a direction was not recorded twice at a single point location. Thus, habitat complexity was assessed at five different locations at the point, 5 meters from the point, 10 meters from the point, 20 meters from the point, and 40 meters from the point. Additionally, each of the assessments was conducted in a direction north, south, east, and west of the main point location. Therefore, the five categories of assessment - canopy height, canopy coverage, mid-story tree layer density, shrub-layer density, and ground layer coverage were assessed at 5 locations at each of the 96 points visited. Habitat complexity variables were measured 5 times for each point, giving a total of 25 habitat assessments for each point location. A single habitat complexity index value was calculated using the Shannon-Wiener index of diversity (Shannon 1948).

Insect Surveys

To assess the abundance of insects present at randomly chosen point locations, pitfall traps and flight intercept traps were utilized (Steininger et al. 2015). These surveys were conducted at 33 of the 96-point locations surveyed. 15 of these insect surveys were conducted in deciduous-dominated forests, and the other 18 surveys were conducted in pine-dominated forests (Fig. 6). Insect traps were placed on the morning of the conduction of bird surveys, and insect traps along with the captured insects were gathered the following morning. The traps were lined with Vaseline and honey to attract and trap the insects (Fig. 7). Insects were removed from traps and stored in separate containers for each point location. The insects were tentatively identified using dichotomous keys.

Statistical Analyses

The R statistical software was used to perform statistical tests (R core team 2021). Bird diversity (number of species observed) and abundance (number of individuals observed) were compared to habitat class (pine, mixed, deciduous) using one-way Analysis of Variance (ANOVA). Each point location was assigned to a habitat class based on the percentage of pine and deciduous tree cover. Habitats with pine tree coverage greater than 60% were assigned to the pine habitat class. A habitat that had less than 60% pine coverage and less than 60% deciduous coverage was assigned to the mixed habitat class. Lastly, habitats with deciduous tree coverage greater than 60% were assigned to the deciduous habitat class (Fig. 8) (Pruett. L. C. 2020). To determine if habitat classes differed from one another, a Tukey's honest significant difference tests was run (Rohlf and Sokal 1981). A correlation analysis was used to compare species abundance and diversity with the habitat complexity index. The Information Theoretic Model selection methods was used to examine the association between the habitat variables within the habitat complexity index in relation to species abundance and diversity (Anderson 2008). Habitat classes were compared with the habitat complexity index and each of the variables within the habitat complexity index using the Kruskal-Wallis test (Kruskal, W.H. and Wallis, W.A., 1952.). Correlations between habitat variables and bird abundance and diversity were assessed using Pearson's correlations coefficients. When a significant difference was found among habitats, the posthoc Dunn's test was performed (Dunn, O. J. 1964). The Wilcoxon Rank Sum Test was performed to see if there was a difference in the mean number of insects between pine and deciduous forests. Correlation analyses were once again utilized to compare insect presence with habitat complexity index, habitat class, species abundance and diversity, and canopy coverage.

Results

During summer 2021, forty-two species were observed at the 96-point locations assessed at Jack Mountain WMA. The species observed the most were the Indigo Bunting (*Passerina cyanea*), American Crow (*Corvus brachyrhynchos*), and the Red-Eyed Vireo (*Vireo olivaceus*). A total of 854 individual birds were documented. In comparisons between species abundance (Fig. 9; Table 3; $r = 0.115$, $P = 0.28$) or diversity (Fig. 10; Table 3; $r = 0.116$, $P = 0.28$) with the habitat complexity index, no significant correlations were observed. We then compared each of the four aspects of the habitat complexity index with species diversity and abundance using a multivariate model. Ground coverage was positively correlated with species abundance (Fig. 11;

Table 3; r = 0.405, P < 0.001) and diversity (Fig. 12; Table 3; r = 0.378, P < 0.001). Shrub coverage was also positively correlated with species abundance (Fig. 13; Table 3; r = 0.231, P = 0.022) and diversity (Fig. 14; Table 3; r = 0.226, P = 0.025). Mid-story tree coverage was not significantly associated with bird abundance (Fig. 15; Table 3; r = -0.089, P = 0.386) or diversity (Fig. 16; Table 3; r = -0.021, P = 0.834). Canopy coverage was negatively correlated with species abundance (Fig. 17; Table 3; r = -3.72, P < 0.001) and diversity (Fig. 18; Table 3; r = -0.383, P < 0.001). The habitat complexity index did not differ among habitat classes (Fig. 19; Table 4; F = 2.327, P = 0.103), but there were associations found within the index. A comparison of the habitat class and the amount of ground cover in each class did not show a significant difference (Fig. 20; Table 4; F = 2.38, P = 0.098), but there was a significant difference among habitat classes for canopy (Fig. 21; Table 4; F = 5.706 P = 0.005) coverage. A posthoc test was performed to access the significant differences between canopy coverage and habitat class. The test revealed that the significance with canopy coverage was between pine and deciduous forests (Table 4; P = 0.0037). When comparing the habitat class with shrub coverage, a significant difference was discovered (Fig. 22; Table 4; F = 8.06 P = < 0.001). Once again, to assess this significance, a posthoc test was performed. The posthoc test revealed significant differences between pine and deciduous (Table 4; P = 0.002) forests, and between pine and mixed (Table 4; P = 0.003) forests. No differences were found among the midstory coverage of habitat classes (Fig. 23; Table 4; F = 0.403, P = 0.669).

A comparison of habitat classes and species diversity showed a higher number of species in pine habitats (Table 1; F = 3.755, P = 0.0274). Pine and mixed habitats had lower canopy coverage than deciduous habitats, with pine having the lowest amount of canopy coverage (Table 1; F = 0.4538, P = 0.0134). Shrub coverage also differed among habitat classes, with pine habitats having significantly more shrub coverage than deciduous or mixed forests (Table 1; F = 6.879, P = 0.0017). Additionally, pine habitats had more ground coverage than the other habitat classes (Table 1; F = 4.538, P = 0.0134). Species diversity (Fig. 24; Table 4; F = 4.09, P = 0.020) has a significant difference with habitat class, and a posthoc test found that the most profound difference was between pine and deciduous forests (Table 4; P = 0.018). Species abundance (Fig. 25; Table 4; F = 2.36, P = 0.100) did not have a significant difference with habitat class.

Comparisons of the habitat complexity index and insect abundance supported that the two were not correlated (Table 5; r = 0.026, P = 0.887). Similarly, associations between habitat types and insect abundance were not associated (Table 5; r = 0.81, P = 0.43). Both pine and deciduous forests had a similar number of insects (Fig. 26; W = 117, P = 0.526) (Pruett, C. L. 2022). Additionally, bird abundance (Table 5; r = 0.096, P = 0.595) and bird diversity (Table 5; r = 0.22, P = 0.211) were not found to be correlated with the presence of insects either. Canopy coverage was also compared to insect abundance, and a correlation was not found (r = 0.136, P = 0.450).

Discussion

Hypothesis 1: Pine-dominated habitats have greater habitat complexity than deciduous forests

Pine-dominated forests were not found to be more complex than deciduous forests. However, we did find that pine habitats had lower canopy coverage and more ground and shrub coverage than mixed and deciduous forests, which were all associated with an increase in the abundance and diversity of birds. The negative correlation between canopy coverage and bird diversity and abundance indicates that, with less canopy coverage, bird diversity and abundance increases. The positive correlation between ground and shrub coverage with bird diversity and abundance indicates that, with more ground and shrub coverage, bird diversity and abundance increases. Thus, with less canopy coverage, there is more sunlight penetrating through the canopy which leads to an increase in ground and shrub coverage. These findings suggest that there are more bird species and individuals among pine habitats at Jack Mountain because of less canopy coverage and that this reduction in canopy coverage could lead to an increase in ground and shrub coverage, which are both correlated with an increase in the diversity and abundance of birds.

Hypothesis 2: Habitat complexity is positively correlated with bird diversity and abundance

Habitat complexity governs species richness and abundance (Hurlbert 2004), and the correlation between species diversity (richness) and abundance in pine habitats could be attributed to greater opportunities, such as more nesting locations and food resources in these habitats (Robinson and Holmes 1982). The habitat complexity index and its variables were weakly associated with species abundance and diversity. Although the habitat complexity index did not have a significant correlation with bird diversity and abundance, the same cannot be concluded for the variables within the index. There were strong associations between many of the variables that contribute to the babitat complexity index, but the habitat complexity index itself did not have an association with bird diversity and abundance. The habitat complexity index included percentage of canopy coverage, mid-story tree layer, shrub layer, and ground coverage. As a whole, no significant correlations were found, but, when broken down into variables, many significant associations were observed. We saw strong correlations between increased species richness and bird diversity with more ground and shrub coverage and less canopy coverage. Since less canopy coverage would indicate less shade and more sunlight for understory growth, we could infer that canopy coverage could be the driving factor in determining if an area is suitable for a greater diversity and abundance of birds. Therefore, our initial hypothesis was rejected since the habitat complexity index as a whole was not correlated with bird diversity and abundance. These findings suggest that the diversity and abundance of birds at Jack Mountain WMA are associated with a diverse set of habitat variables that cannot be simplified into a single habitat complexity index.

Hypothesis 3: Diversity and abundance of birds at Jack Mountain Wildlife Management Area are positively associated with insect abundance.

An association between the diversity and abundance of birds and insect abundance was not observed. Additionally, a difference between insect abundance and habitat class was not found. Our research regarding insect abundance was limited and is still under review and could be improved and expanded if the insect surveys were to be conducted again. Future research could assess insect abundance in relation to different habitat classes and variables within the habitat complexity and also work to improve the accuracy of the traps to catch insects. Although our research shows that insect abundance does not play a role in bird diversity and abundance, it could potentially be positively correlated with the spread of human disease. Many insects are the primary hosts or carriers of human diseases, including Malaria, Plague Lyme disease, etc. The deadliest arthropod-borne disease in the world is Malaria, which infects over 250 million people and is responsible for the death of 2 million people annually (Smithsonian Institution).

Conclusion

Pine and deciduous forests at Jack Mountain WMA are an important refuge for land birds in Arkansas. Thus, preservation of habitats at Jack Mountain WMA is essential. Jack Mountain provides habitats not only for species of conservation concern (Fig. 1), but for rare species in decline as well. The bird, habitat, and insect surveys conducted during summer 2021 could offer valuable insight into the management practices of this area. This research has allowed us to confirm that habitat complexity variables govern species abundance and diversity. Less canopy coverage proved to be significantly correlated with an increase in diversity and abundance of birds, and thus forests at Jack Mountain should be managed accordingly.

Reflection

Although each of the hypotheses tested was rejected, the results from our research are essential in understanding how to maintain suitable complex habitats at Jack Mountain WMA. The variables within the habitat complexity index proved to be strongly correlated with bird diversity and abundance, ultimately offering valuable insight to management practices. The bird surveys conducted add to the previous 2 years of data recorded on bird species and diversity, allowing for greater in-depth knowledge on breeding species at Jack Mountain, including species of conservation concern. The summer of 2021 was the first year for examining bird species richness and abundance in relation to insect abundance. Although no significant correlations were found, this research is the first building block for discovering information regarding insect abundance in different forest types and in relation to habitat complexity and bird abundance.

Figure 1. Species of conservation concern – Indigo Bunting

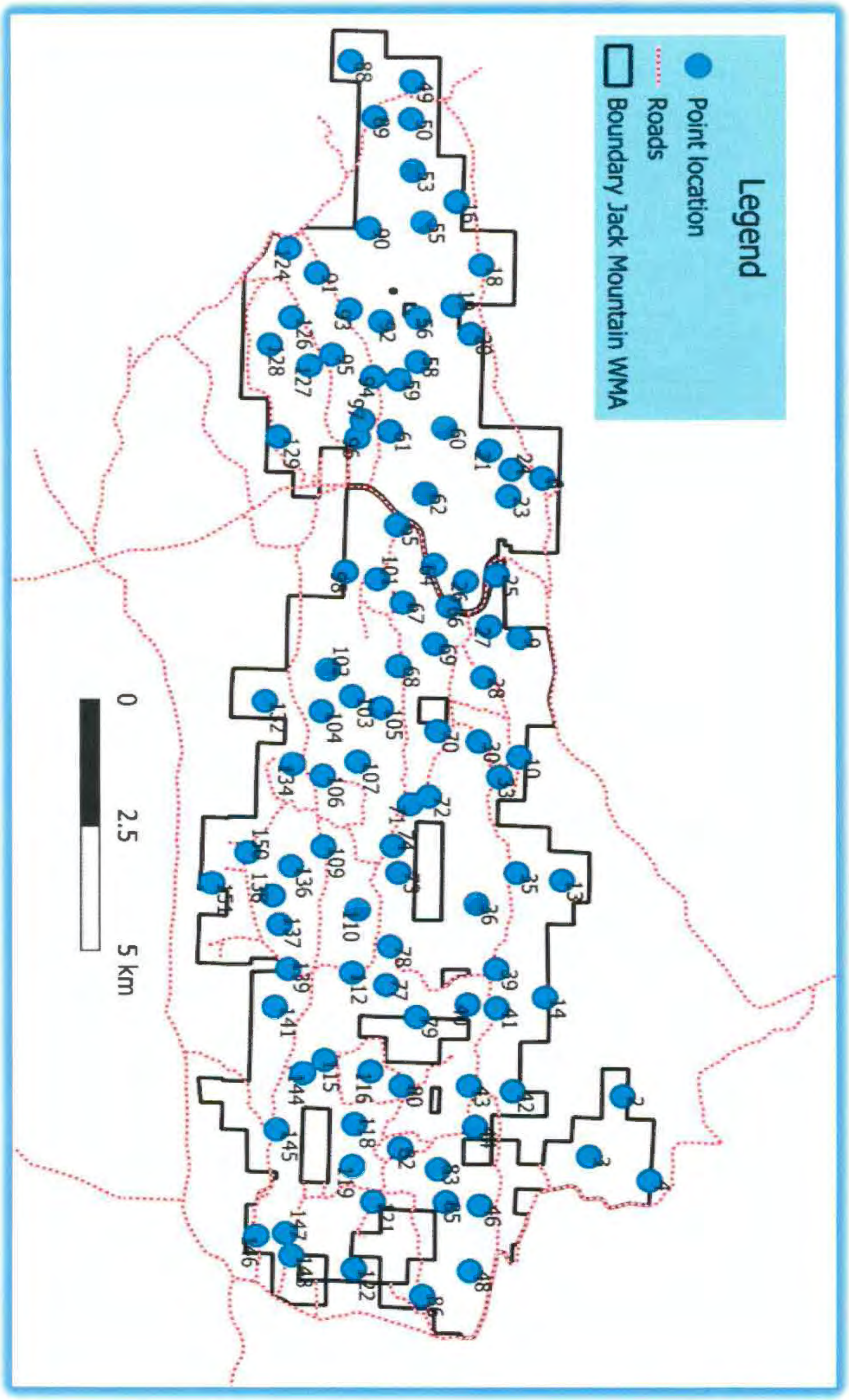

Figure 2. Map of Jack Mountain Wildlife Management Area with 100-point locations. Only 96 points were visited during the summer of 2021

Table 1. Habitat complexity index and its variables associations with the pine habitat.

Variables	Habitat Class - Pine
Species Diversity	F = 3.755, P = 0.0274
Ground Coverage	F = 4.538, P = 0.0134
Shrub Coverage	F = 6.879, P = 0.0017
Canopy Coverage	F = 0.4538, P = 0.0134

Table 2. Bird species observed at Jack Mountain WMA

Species Name	Scientific Name	Abundance
American Crow	Passeriformes Corvidae	121
Red-eyed Vireo	Passeriformes Vireonidae	113
Indigo Bunting*	Passeriformes Cardinalidae	79
Pine Warbler	Passeriformes Parulidae	54
Tufted Titmouse	Passeriformes Paridae	53
Carolina Chickadee	Passeriformes Paridae	50
Yellow-throated Vireo	Passeriformes Vireonidae	39
Black-and-White Warbler	Passeriformes Parulidae	38
Mourning Dove	Columbiformes Columbidae	36
Yellow-billed Cuckoo*	Cuculiformes Cuculidae	36
Eastern Towhee	Passeriformes Passerellidae	25
Summer Tanager	Passeriformes Cardinalidae	23
White-eyed Vireo	Passeriformes Vireonidae	23
Prairie Warbler	Passeriformes Parulidae	19

Northern Cardinal	Passeriformes Cardinalidae	18
Blue Jay	Passeriformes Corvidae	17
Carolina Wren	Passeriformes Troglodytidae	15
Ruby-throated Hummingbird	Apodiformes Trochilidae	13
Blue-gray Gnatcatcher	Passeriformes Polioptilidae	11
Yellow-breasted Chat	Passeriformes Icteridae	11
Hooded Warbler	Passeriformes Parulidae	8
Kentucky Warbler	Passeriformes Parulidae	8
Acadian Flycatcher	Passeriformes Tyrannidae	7
Downy Woodpecker	Piciformes Picidae	4
Pileated Woodpecker	Piciformes Picidae	4
Eastern Wood-Pewee	Passeriformes Tyrannidae	3
Great-crested Flycatcher	Passeriformes Tyrannidae	3
Wood Thrush*	Passeriformes Turdidae	3
Yellow-throated Warbler	Passeriformes Parulidae	3
American Goldfinch	Passeriformes Fringillidae	2
Chimney Swift	Apodiformes Apodidae	2
Red-bellied Woodpecker	Piciformes Picidae	2
Scarlet Tanager	Passeriformes Cardinalidae	2

Brown-headed Cowbird	Passeriformes Icteridae	1
Common Grackle	Passeriformes Icteridae	1
Common Yellowthroat	Passeriformes Parulidae	1
Fish Crow	Passeriformes Corvidae	1
Green Heron	Pelecaniformes Ardeidae	1
Hairy Woodpecker	Piciformes Picidae	1
Louisiana Waterthrush	Passeriformes Parulidae	1
Northern Mockingbird	Passeriformes Mimidae	1
Northern Parula	Passeriformes Parulidae	1
Asterisks indicate species of conservation concern *		

Date: 6/3/2021
Visit #: 15
Wind: 0-5 mph
Clouds: 50%
Temperature: 65
Precipitation:0

			≤50 meter			>50 meters			Flyovers		
Point # 5	Time	Species	0-3 min	3-5 min	5-10 min	0-3 min	3-5 min	5-10 min	0-3 min	3-5 min	5-10 min
61	6:12	Indigo Bunting	1			11					
61	6:13	Pine Warbler		1		1					
61	6:15	Tufted Titmouse	1								
61	6:17	Red-Eyed Vireo	1				1				
61	6:18	Mourning Dove		1							
61	6:19	Ruby-Throated Hummingbird									111
61	6:21	Yellow Billed Cuckoo						1			
61	6:22	Summer Tanager			1						

Figure 3. Example of a point count data sheet.

Figure 4. Student assessing habitat.

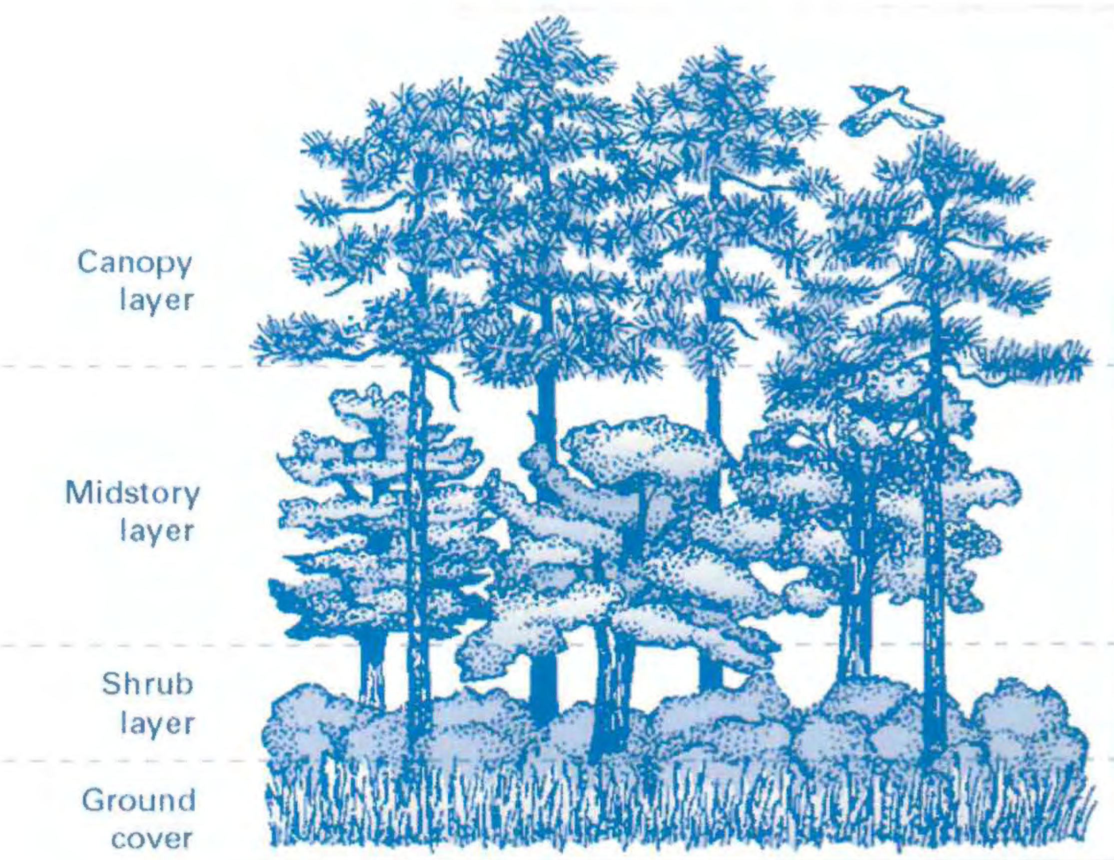

Figure 5. Example of habitat complexity index variables.

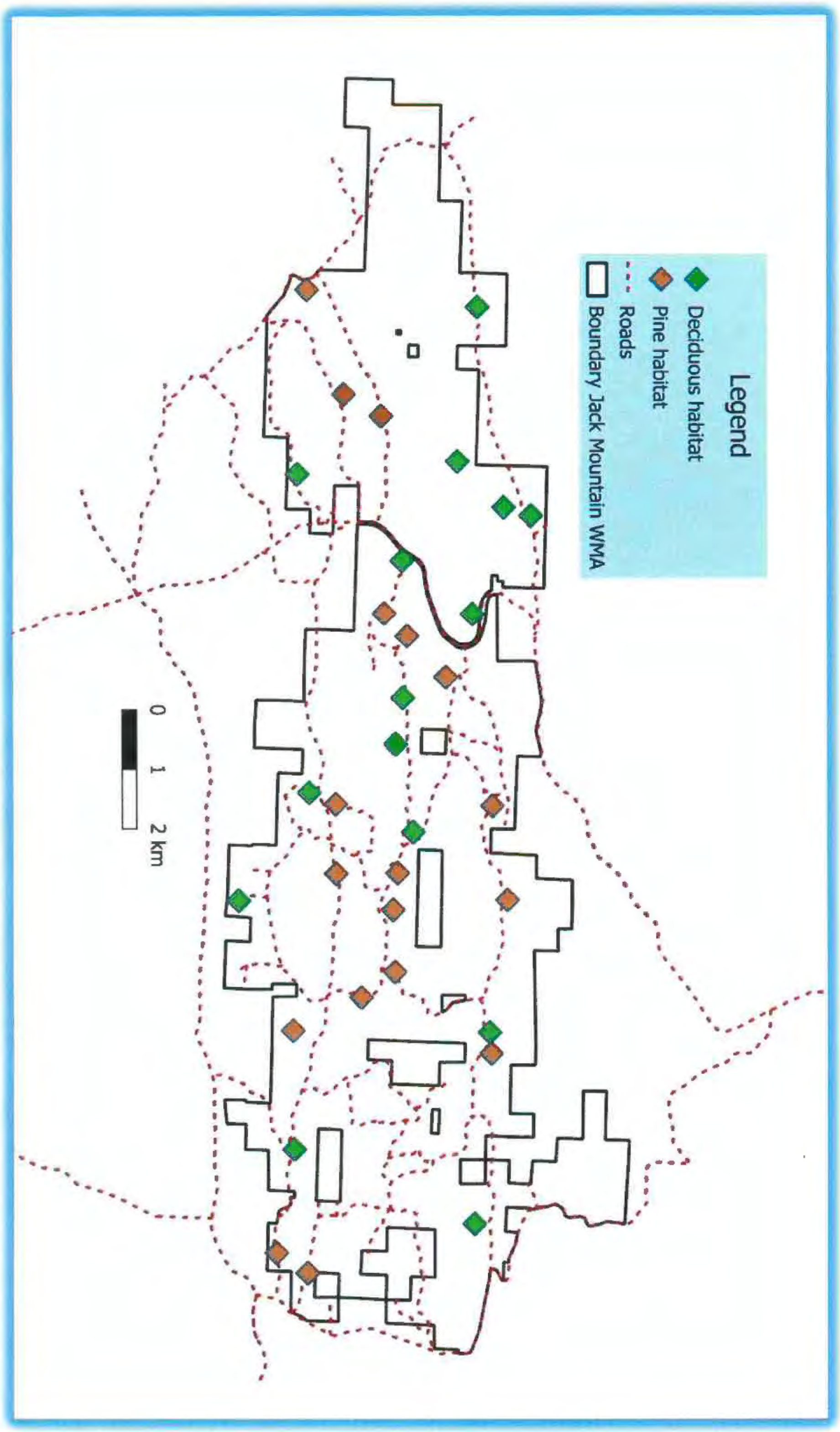

Figure 6. Map of Jack Mountain Wildlife Management Area with the points where insect abundance was assessed (pine or deciduous).

Figure 7. Hanging insect trap

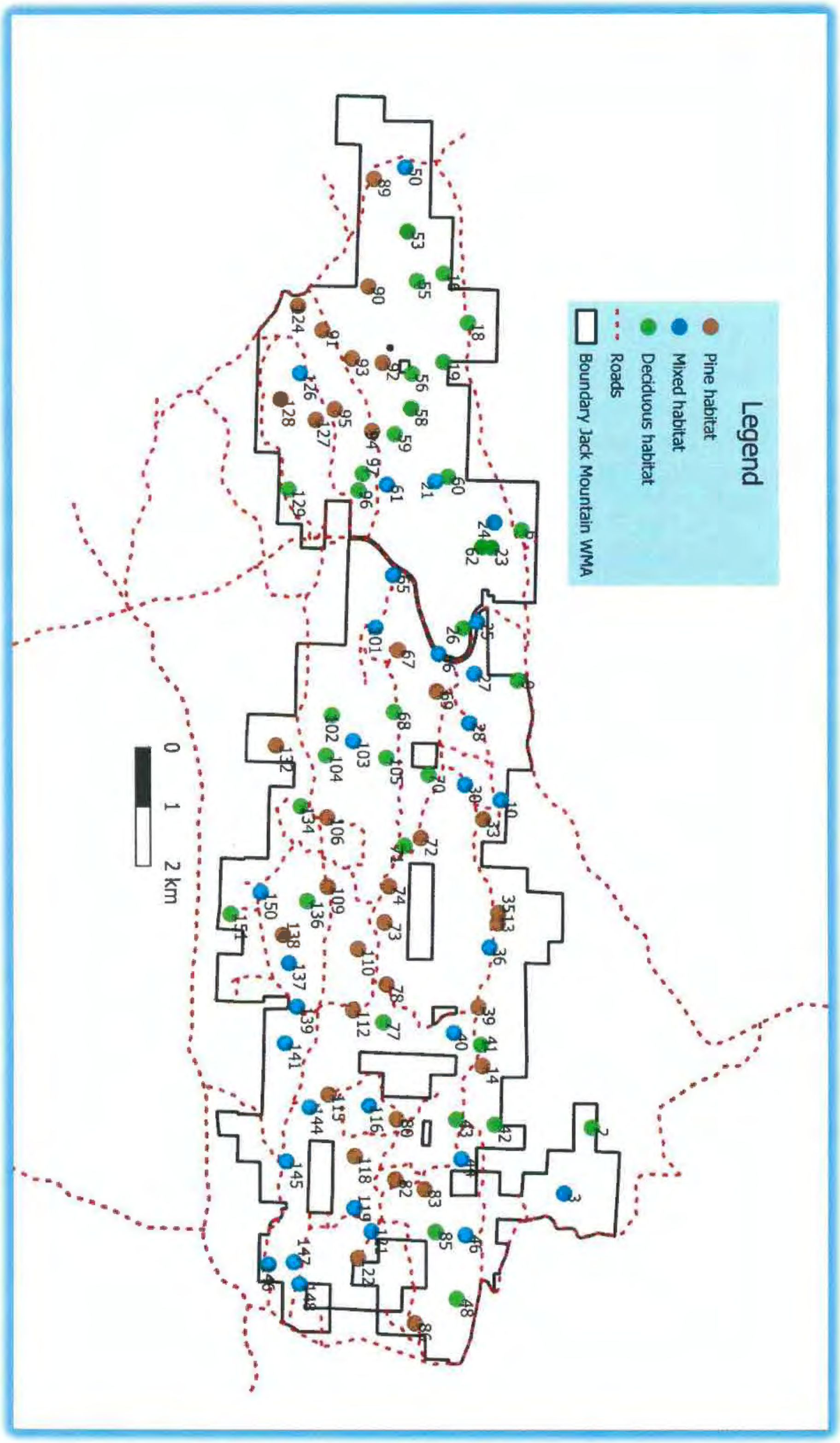

Figure 8. Map of Jack Mountain Wildlife Management Area with each point showing the habitat class (pine, deciduous, and mixed).

Table 3. Habitat complexity index and its variables associations with species abundance and diversity.

Variables	Species Abundance	Species Diversity
Habitat Complexity Index	R = 0.115, P = 0.28	R = 0.116, P = 0.28
Ground Coverage	R = 0.405, P < 0.001	R = 0.378, P < 0.001
Shrub Coverage	R = 0.231, P = 0.022	R = 0.226, P = 0.025
Mid-Story Coverage	R = -0.089, P = 0.386	R = -0.021, P = 0.834
Canopy Coverage	R = -3.72, P < 0.001	R = -0.383, P < 0.001

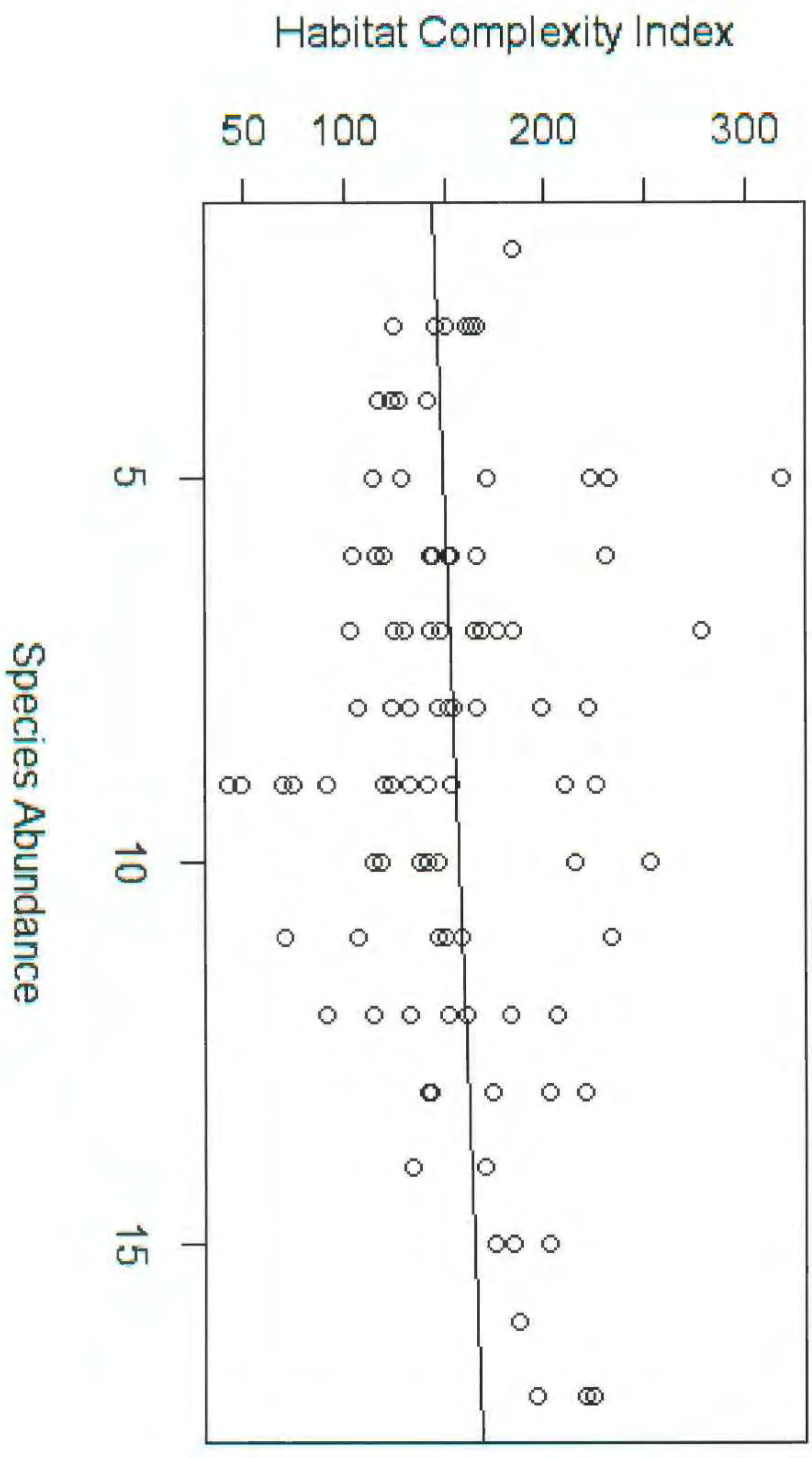

Figure 9. Habitat Complexity Index vs. Species Abundance (R = 0.115, P = 0.28)

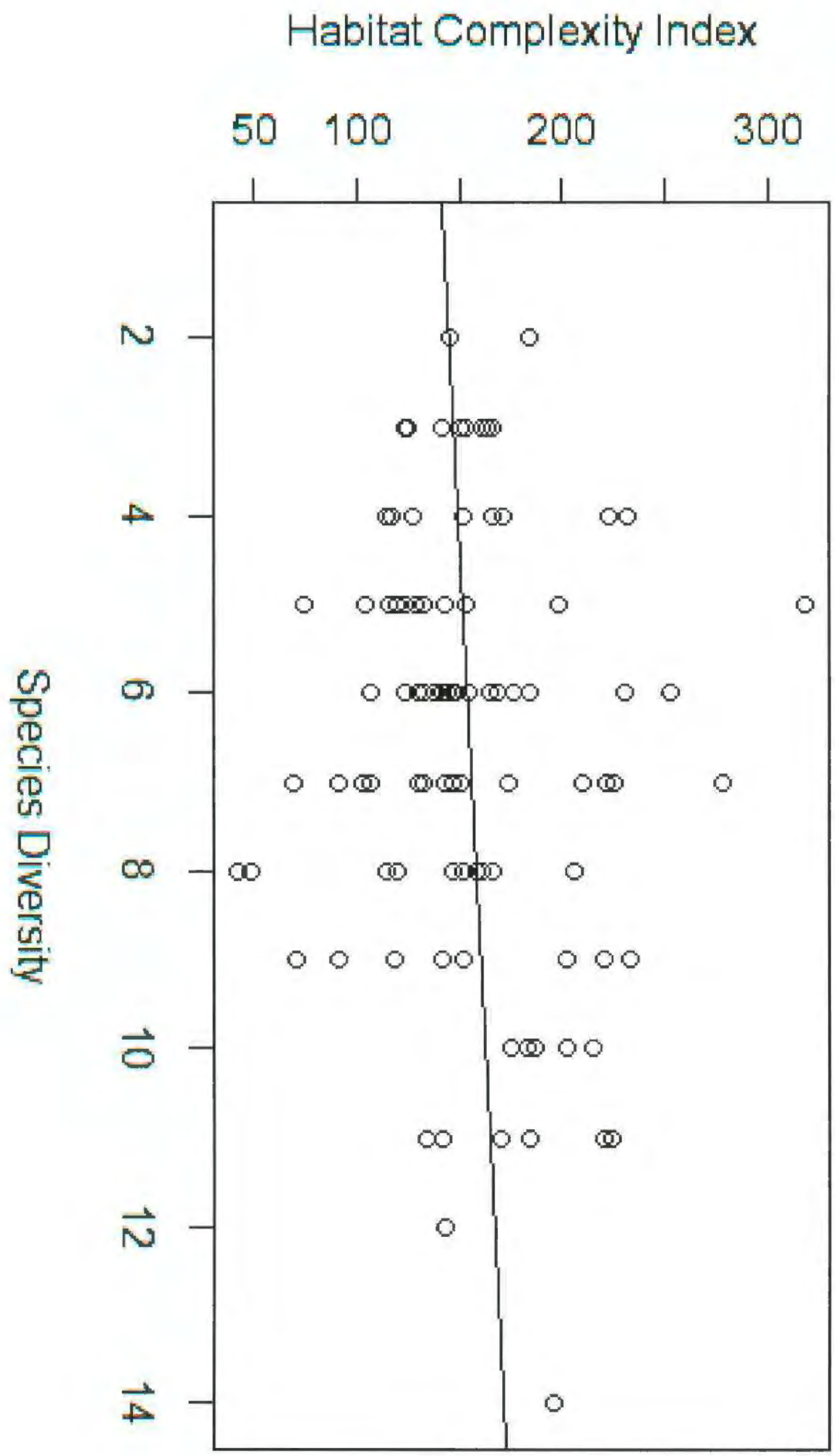

Figure 10. Habitat Complexity Index vs. Species Diversity (R = 0.116, P = 0.28)

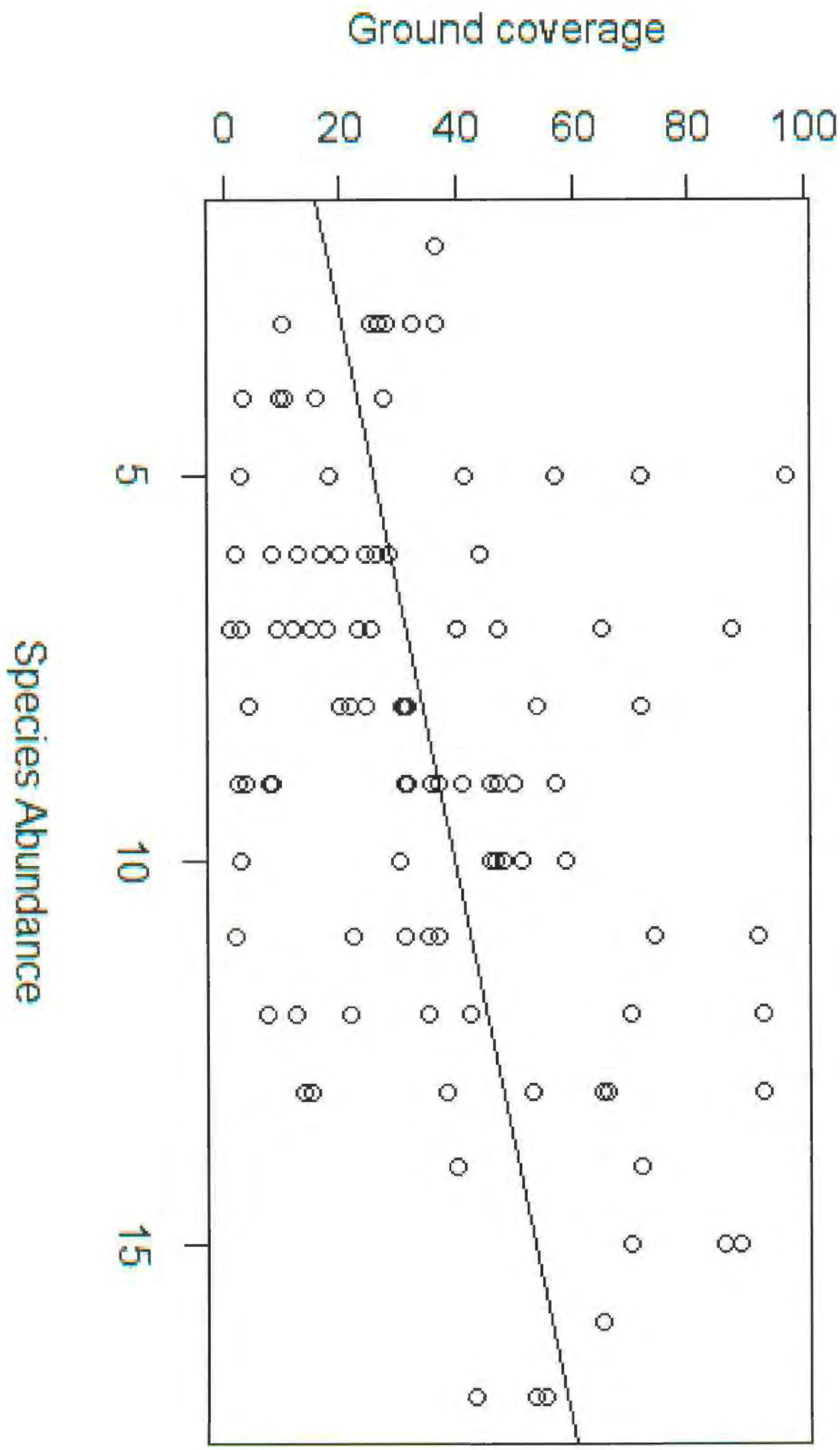

Figure 11. Ground Coverage vs. Species Abundance (R = 0.405, P < 0.001)

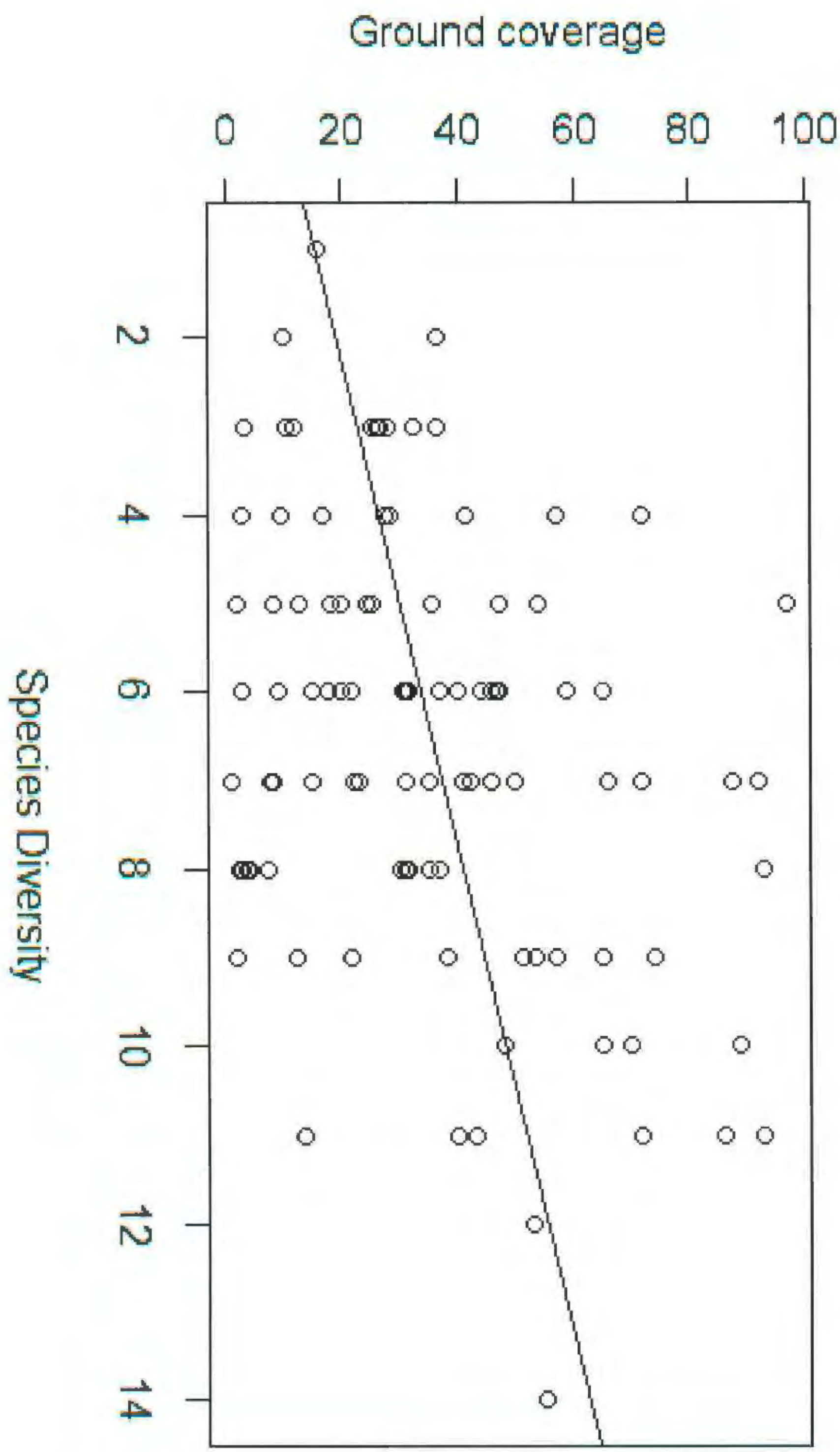

Figure 12. Ground Coverage vs. Species Diversity (R = 0.378, P < 0.001)

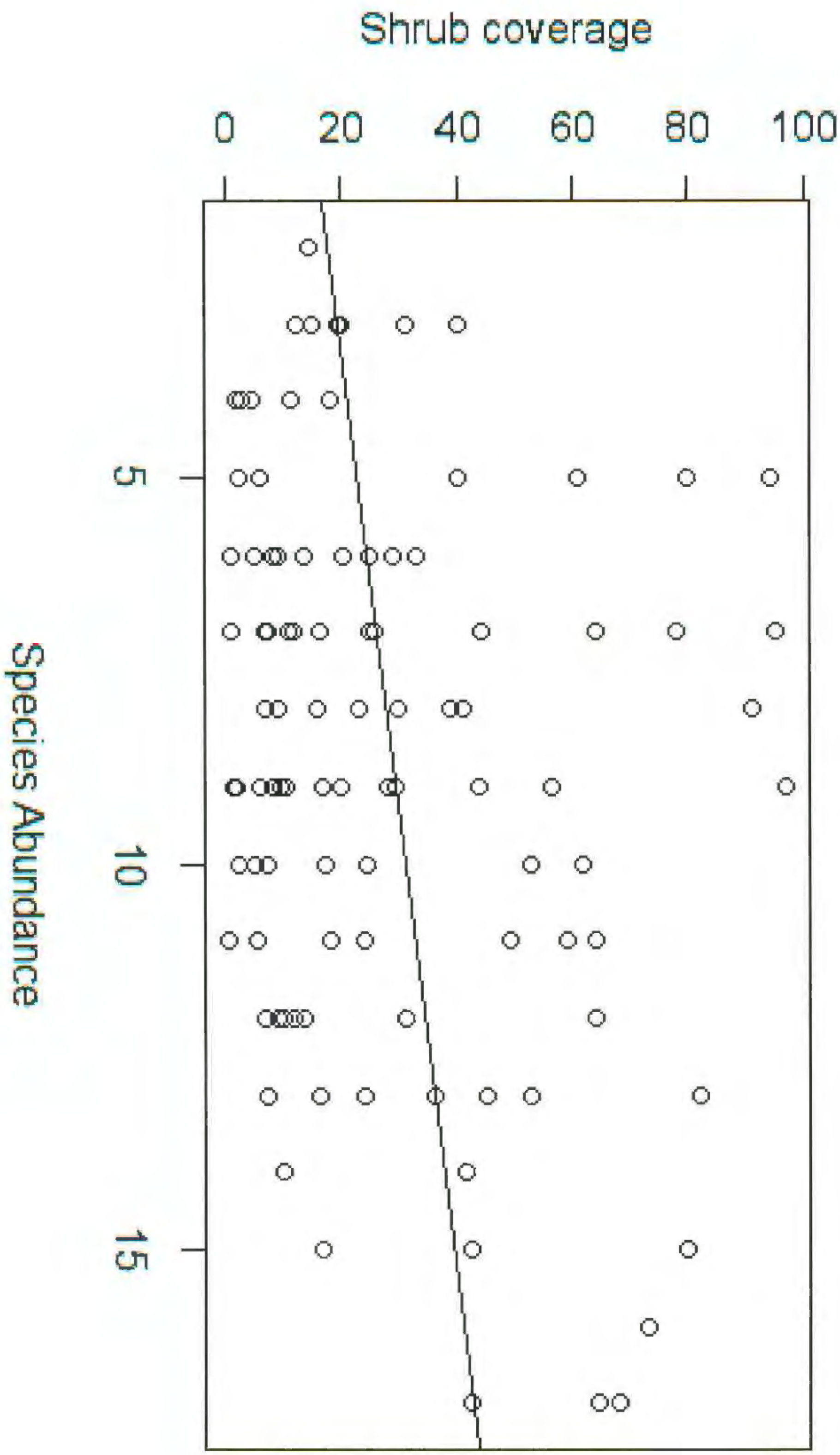

Figure 13. Shrub Coverage vs. Species Abundance (R = 0.231, P = 0.022)

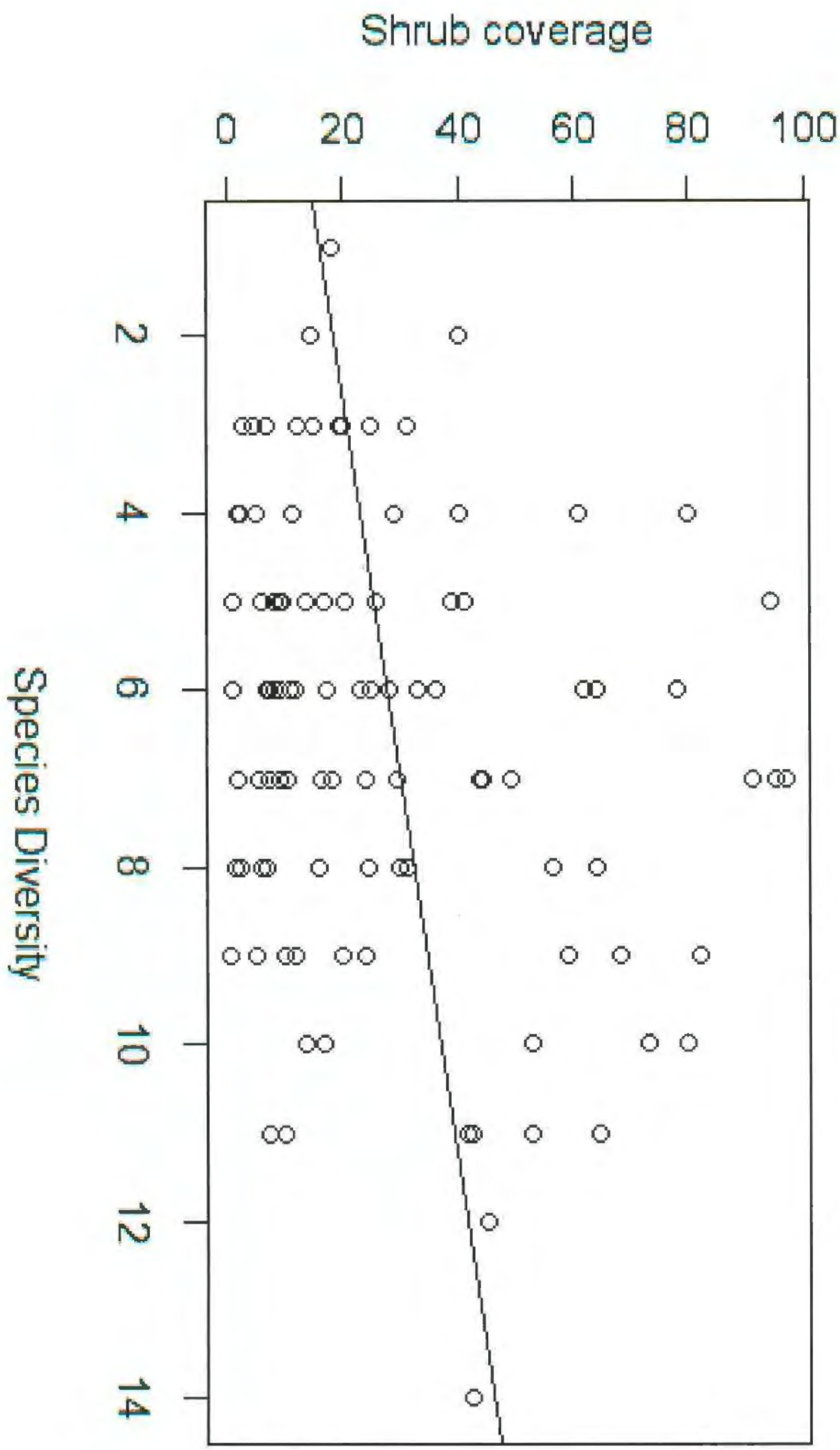

Figure 14. Shrub Coverage vs. Species Diversity (R = 0.226, P = 0.025)

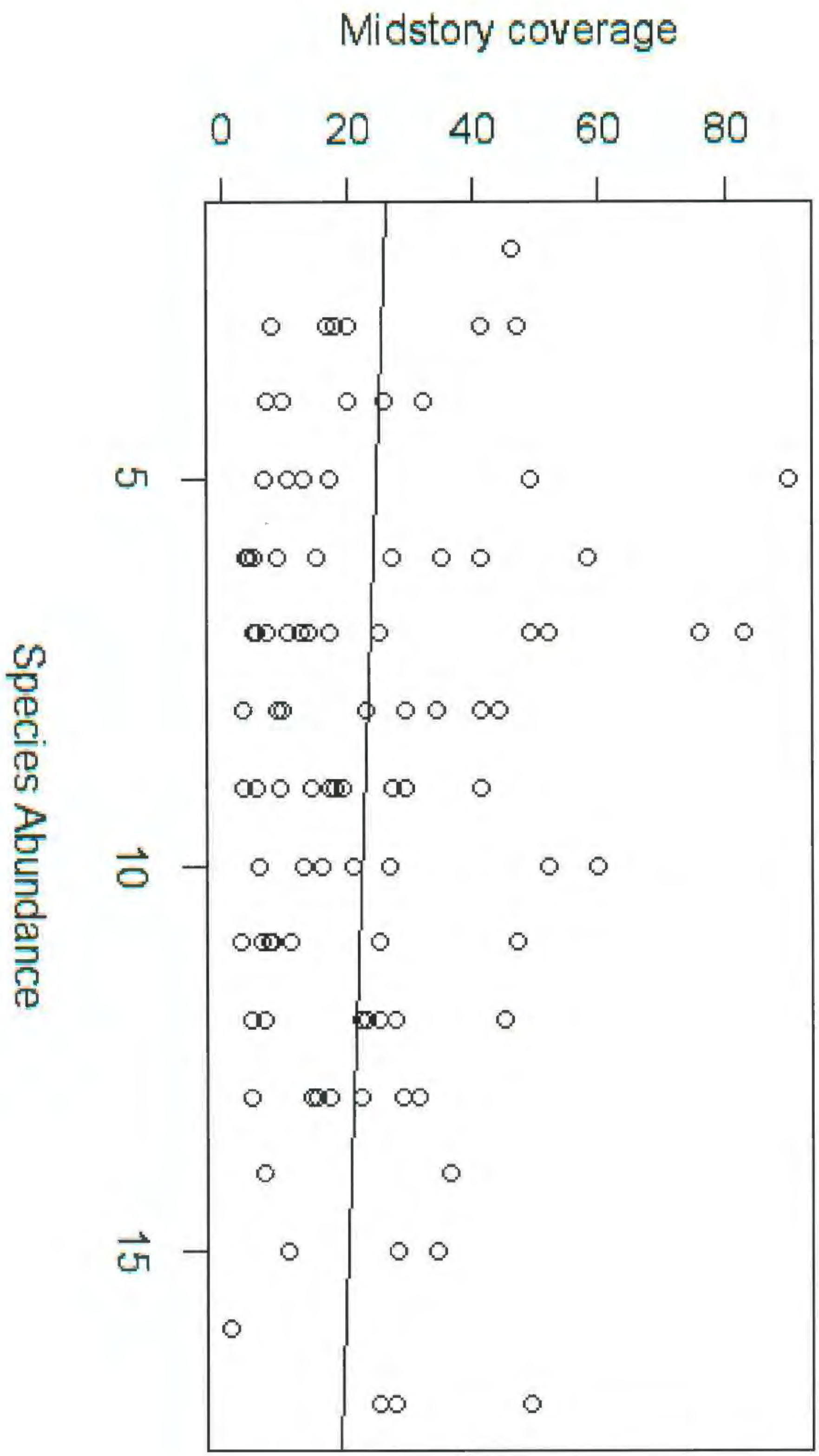

Figure 15. Midstory Coverage vs. Species Abundance (R = -0.089, P = 0.386)

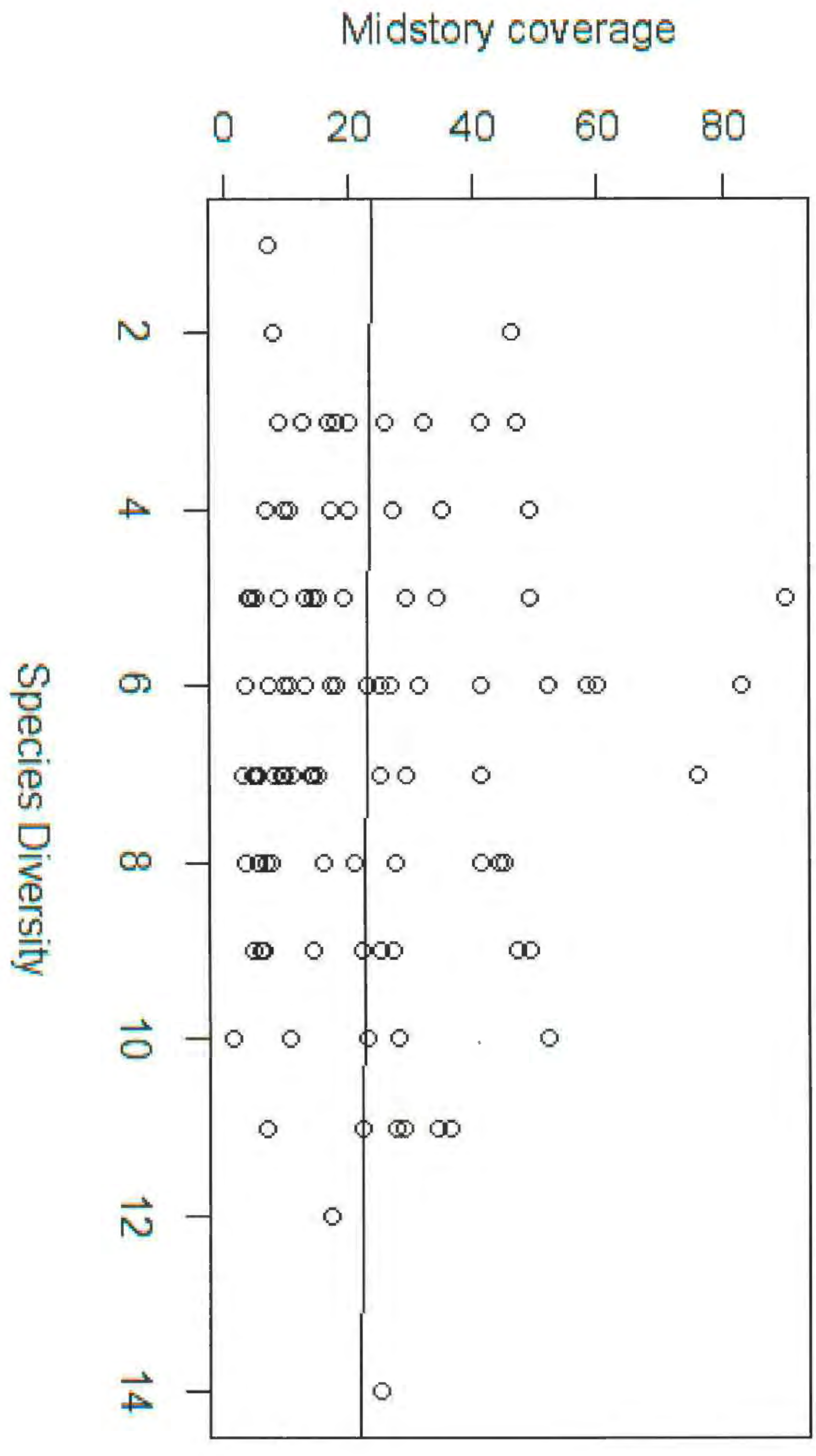

Figure 16. Midstory Coverage vs. Species Diversity (R = -0.021, P = 0.834)

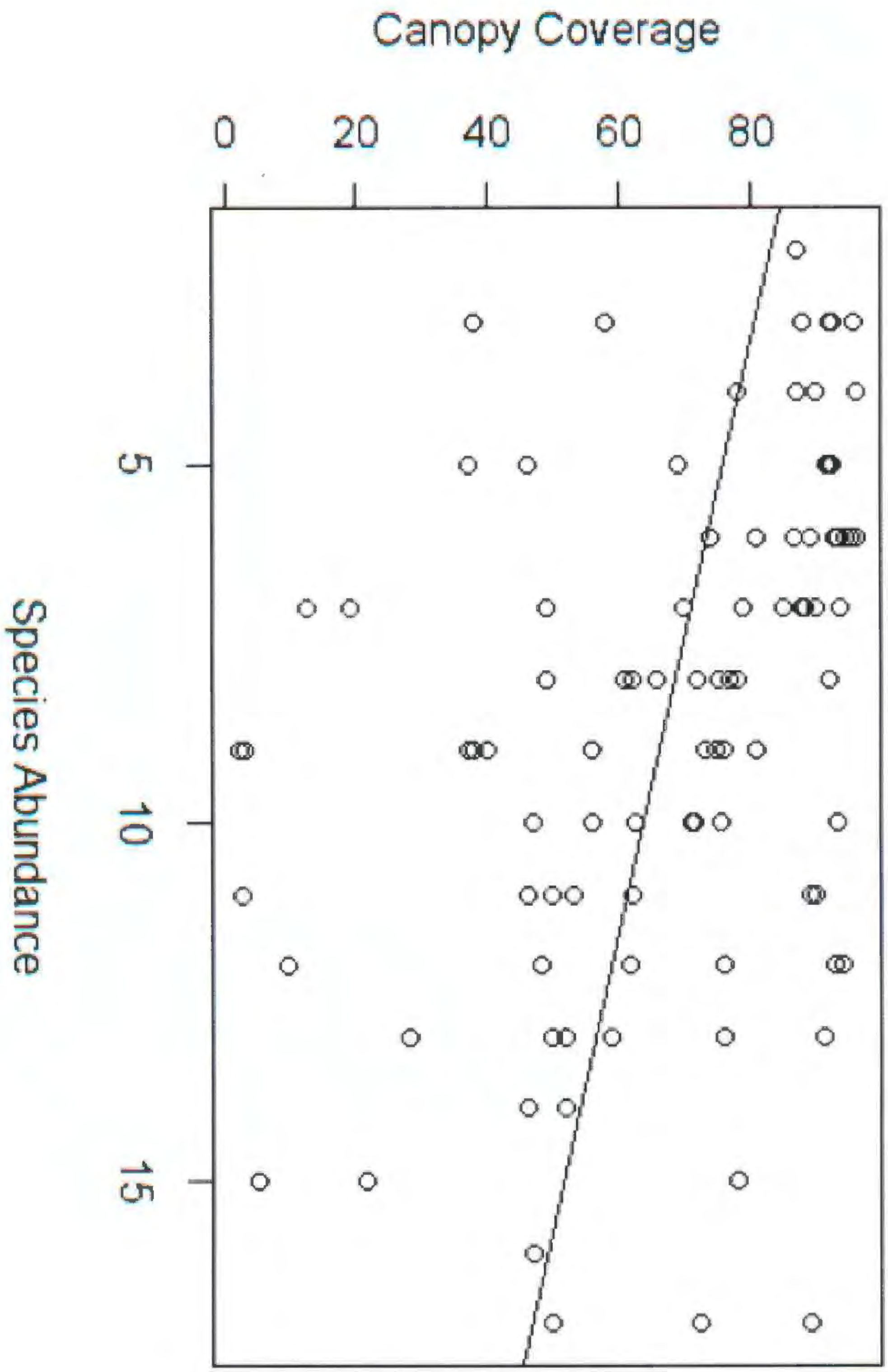

Figure 17. Canopy Coverage vs. Species Abundance (R = -3.72, P < 0.001)

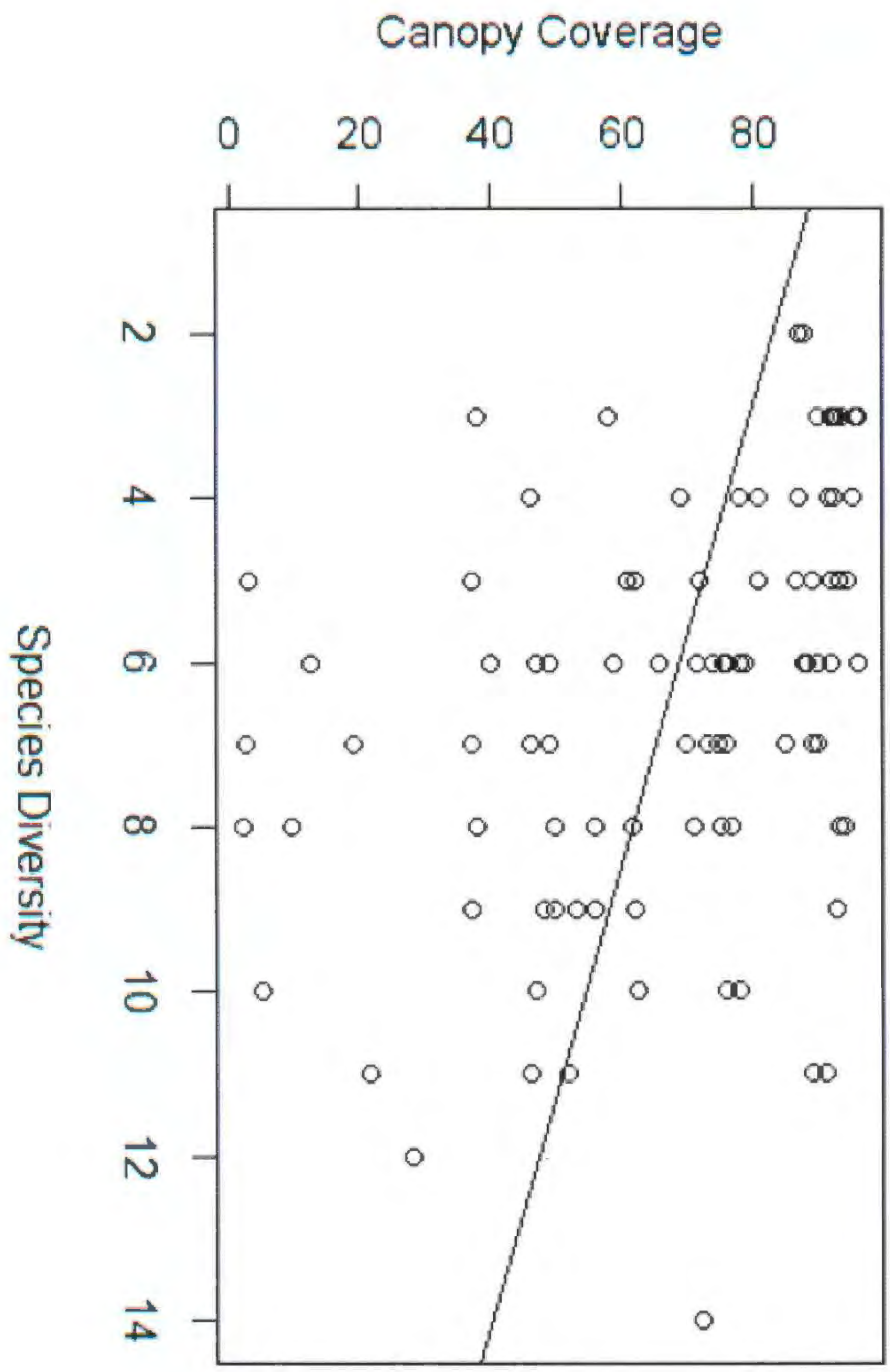

Figure 18. Canopy Coverage vs. Species Diversity (R = -0.383, P < 0.001)

Table 4. Habitat complexity index and its variables and species abundance and diversity associations with habitat class.

Variables	Habitat Class
Habitat Complexity Index	F = 2.327, P = 0.103
Ground Coverage	F = 2.38, P = 0.098
Shrub Coverage	F = 8.06, P = < 0.001
Posthoc Test: Pine vs. Deciduous	P = 0.002
Posthoc Test: Pine vs. Mixed	P = 0.003
Mid-Story Coverage	F = 0.403, P = 0.669
Canopy Coverage	F = 5.706, P = 0.005
Posthoc Test: Pine vs. Deciduous	P = 0.0037
Species Abundance	F = 2.36, P = 0.100
Species Diversity	F = 4.09, P = 0.020
Posthoc Test: Pine vs. Deciduous	P = 0.018

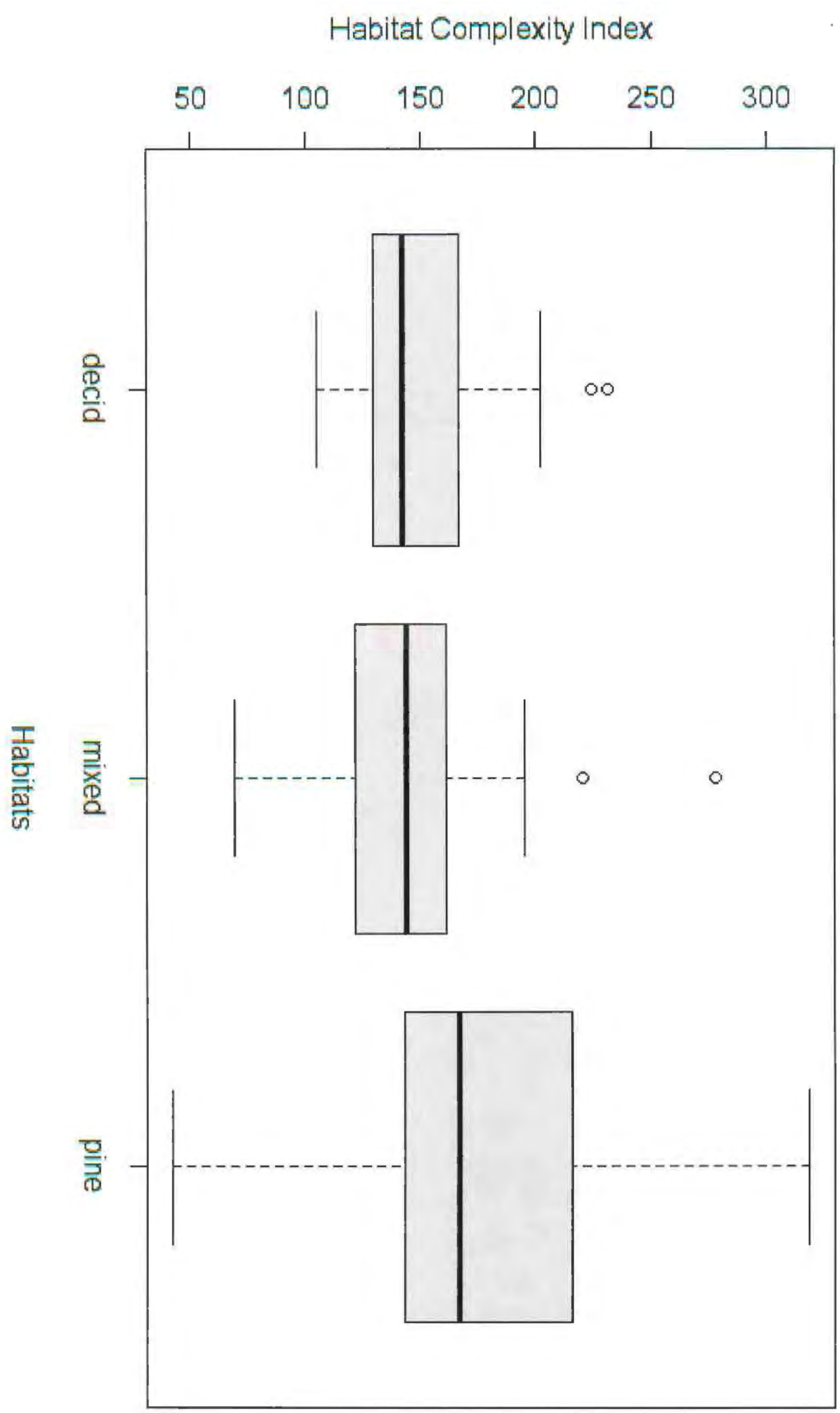

Figure 19: Habitat Complexity Index vs. Habitat Class (F = 2.327, P = 0.103)

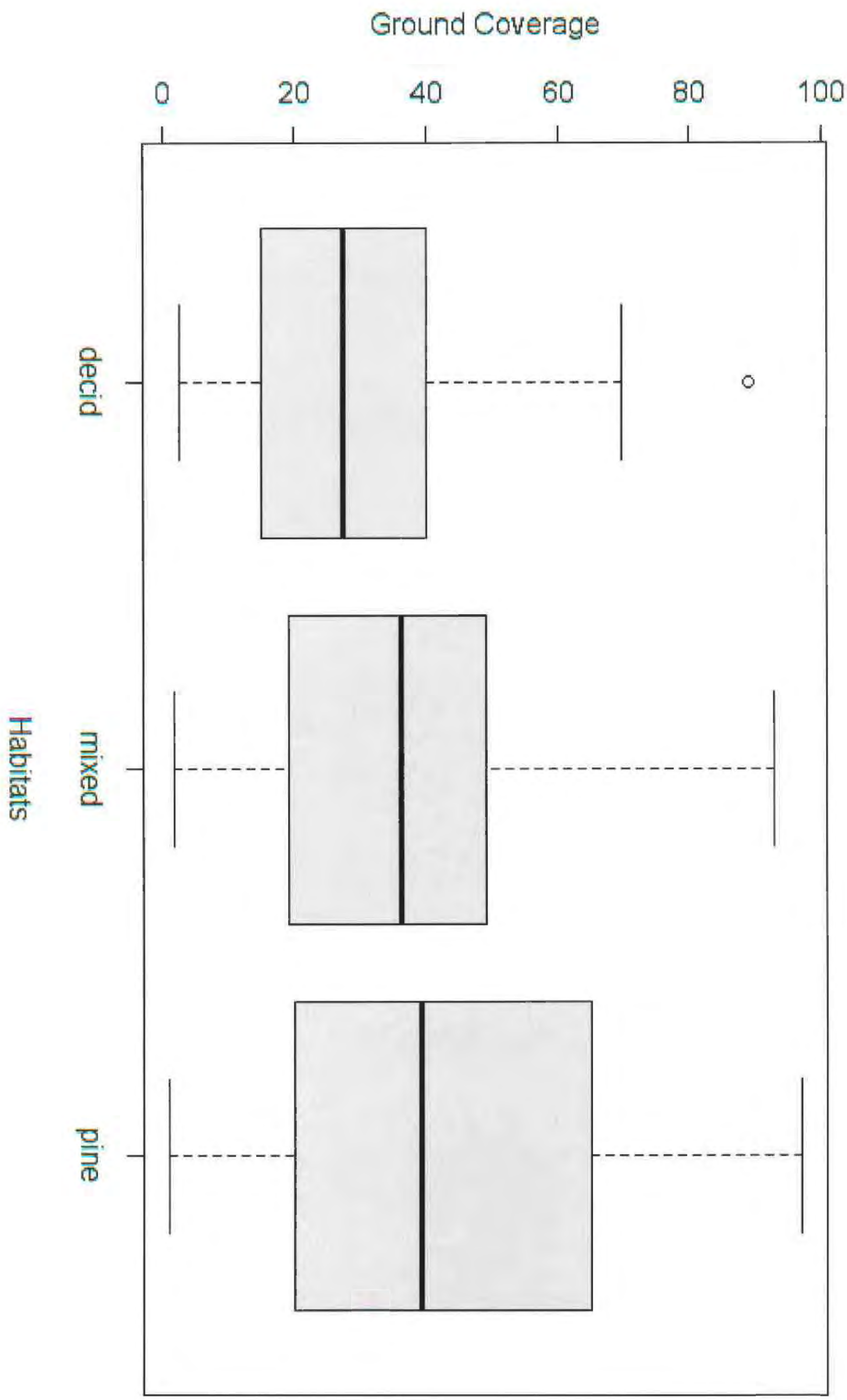

Figure 20: Ground Coverage vs. Habitat Class (F = 2.38, P = 0.098)

Figure 21: Canopy Coverage vs. Habitat Class (F = 5.706, P = 0.005) (Posthoc Test: Pine vs. Deciduous P = 0.037)

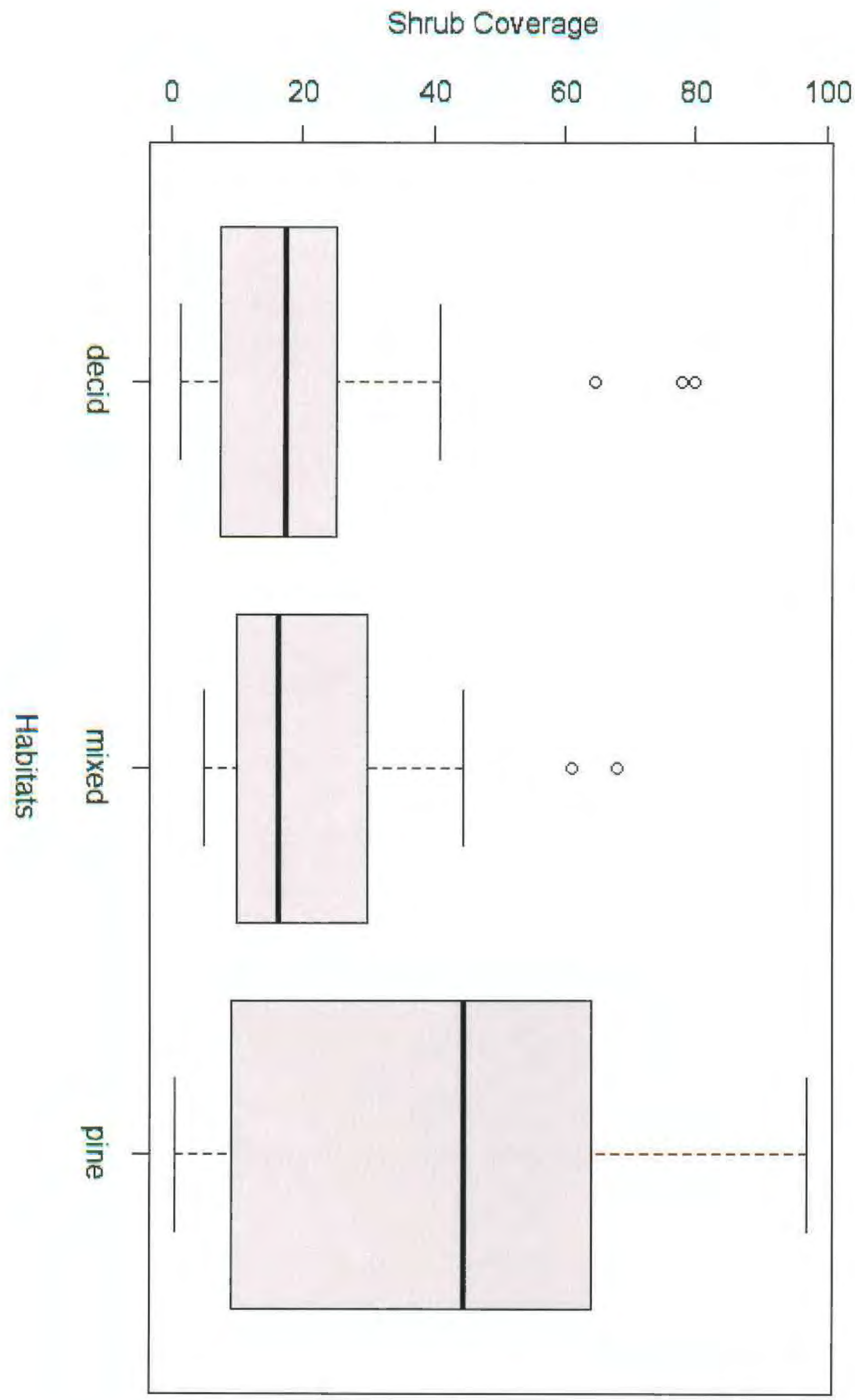

Figure 22. Shrub Coverage vs. Habitat Class (F = 8.06, P = < 0.001) (Posthoc Test: Pine vs. Deciduous P = 0.002) (Posthoc Test: Pine vs. Mixed P = 0.003)

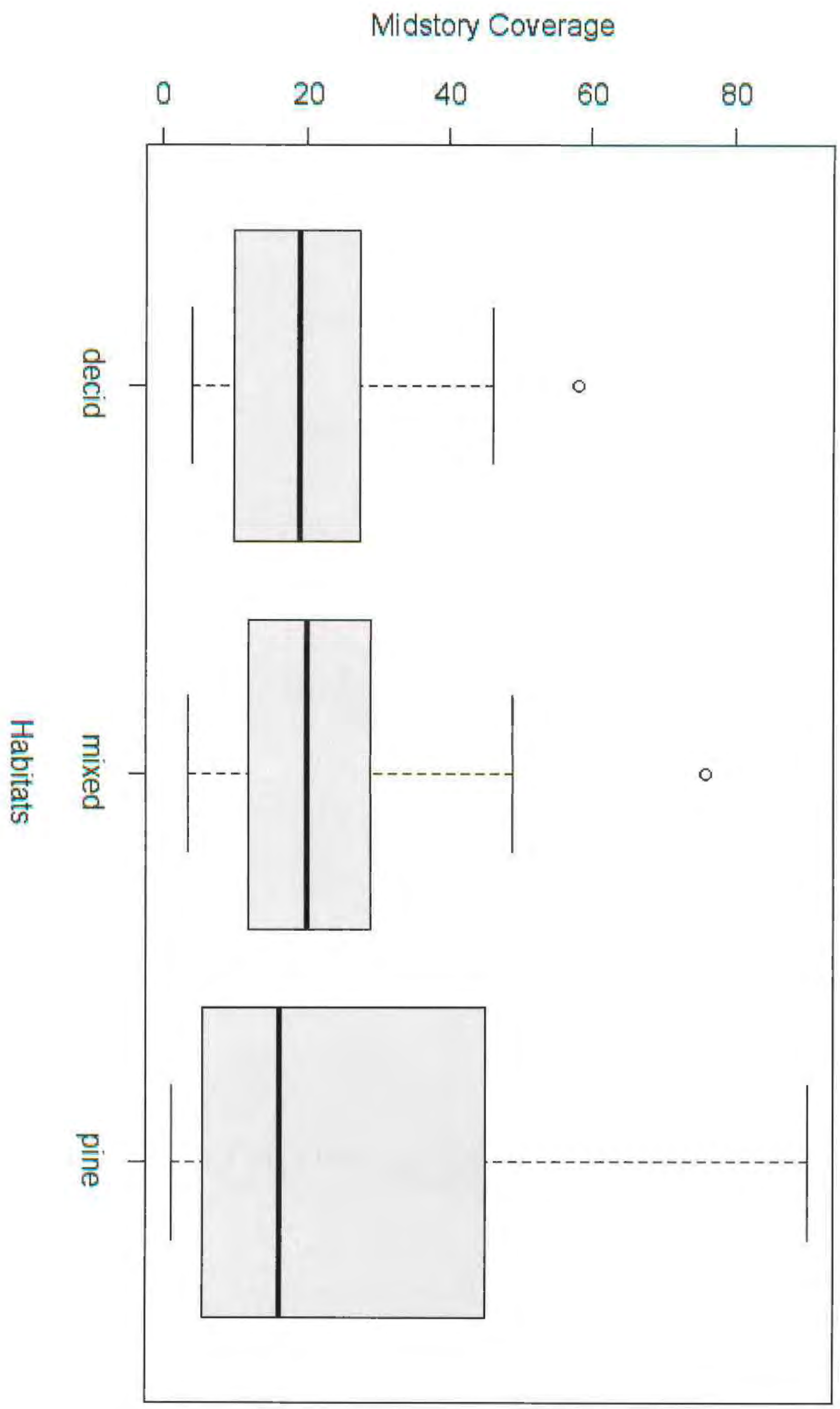

Figure 23: Midstory Coverage vs. Habitat Class ($F = 0.403$, $P = 0.669$)

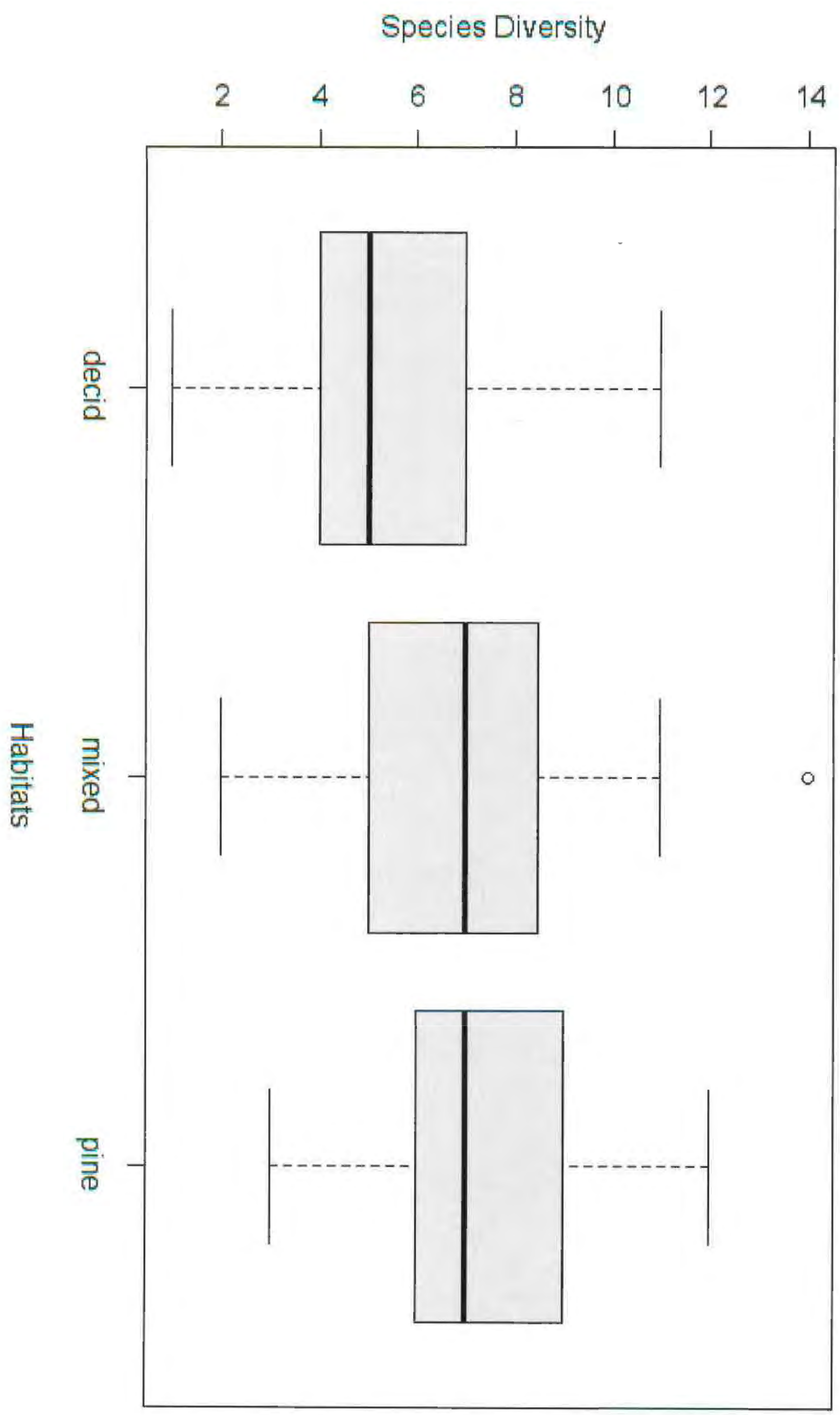

Figure 24: Species Diversity vs. Habitat Class (F = 4.09, P = 0.020) (Posthoc Test: Pine vs. Deciduous P = 0.018)

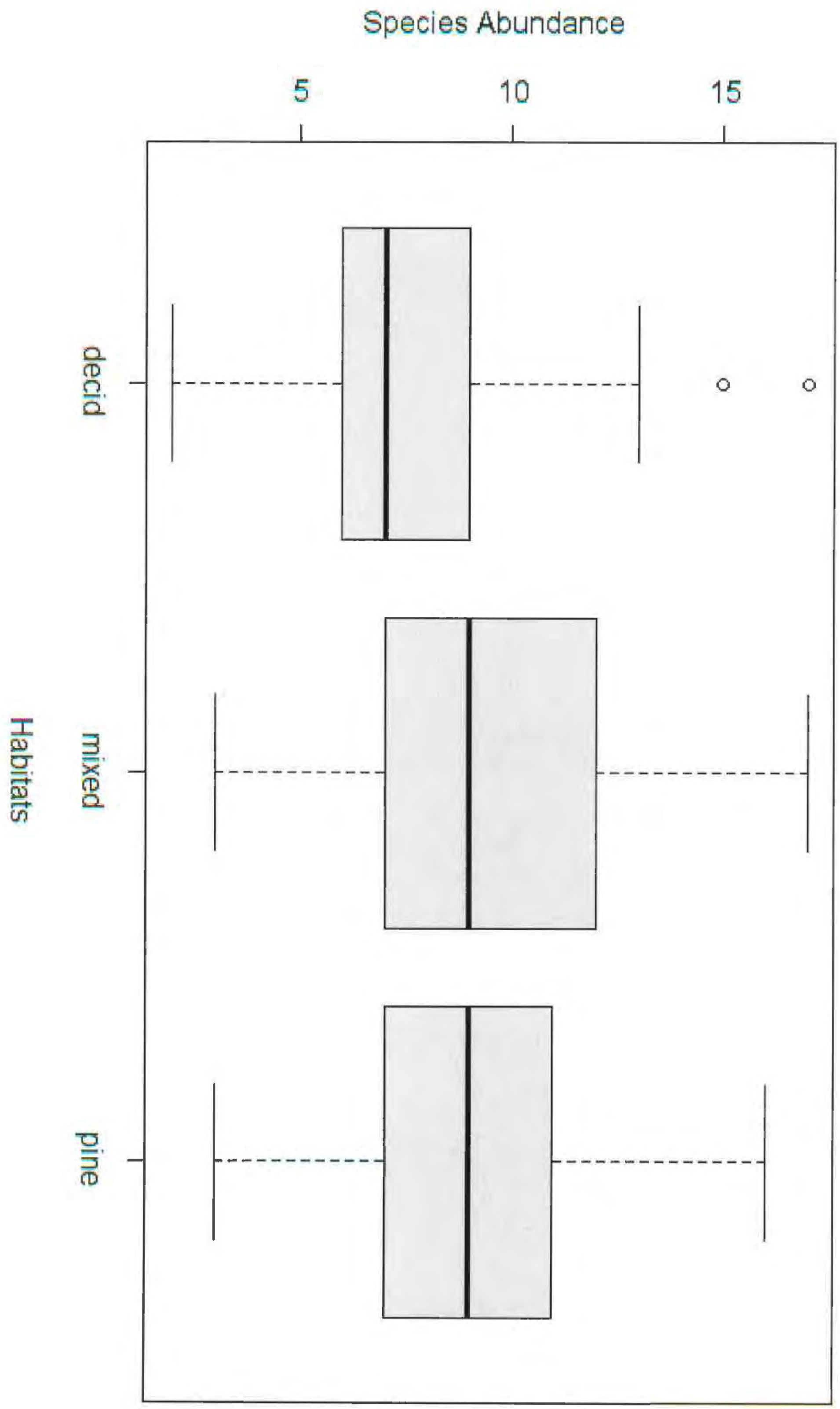

Figure 25: Species Abundance vs. Habitat Class (F = 2.36, P = 0.100)

Table 5. Habitat complexity index, habitat class, species abundance, and species diversity associations with insect abundance.

Variables	Insect Abundance
Habitat Complexity Index	r = 0.026, P = 0.887
Habitat Class	r = 0.81, P = 0.43
Pine & Deciduous Habitats	W = 115, P = 0.526
Species Abundance	r = 0.096, P = 0.595
Species Diversity	r = 0.22, P = 0.211
Canopy Coverage	r = 0.136, P = 0.450

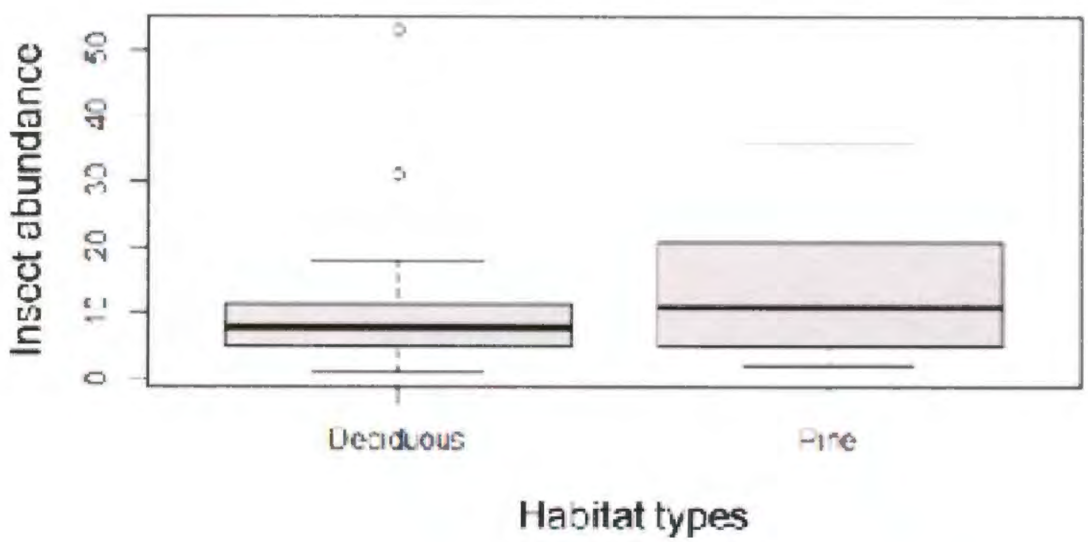

Figure 26. Pine and Deciduous Habitats vs. Insect Abundance (W = 117, P = 0.526).

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