Multilevel Trophic Interaction of Biodiversity for Forbs, Insects, and Birds in the Intermountain Bunchgrass Prairie Ecosystem

BIOS 35502: Practicum in Environmental Field Biology

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Abstract

The biodiversity of a lower trophic level can affect higher trophic levels by providing a variety of ecological niches. The Intermountain Bunchgrass Prairie is a unique ecosystem that has very few expanses left. From the years 1970 to around 2000 this ecosystem has seen overall decreases in vegetation richness and percent forb cover. My research is focused on how vegetation biodiversity, specifically forbs, is related to higher trophic level biodiversity, in this case, insects. Bird abundance was also studied in relation to both forb and insect diversity. I hypothesized that as forb diversity increased so would insect family diversity but bird abundance would not be significantly impacted by either. This study took place on and near the National Bison Range in Charlo, MT. Ten sites were sampled for forb diversity, ground and aerial insect family diversity, as well as bird abundance. Across the sites the forb biodiversity was significantly different as well as the diversity of insect families caught in pitfall traps, but the diversity of insect families caught in sweep nets was not significantly different. A parabolic relationship was seen between bird abundance and forb diversity as well as sweep net insect diversity. No significant correlation was found between forb diversity and either insects caught in pitfall traps or sweep nets. This result does not mean that the biodiversity of forbs does not affect the biodiversity of insects, but it is not the only factor. Future work should attempt to do more manipulative studies to learn how the biodiversity of different trophic levels affect each other in the Intermountain Bunchgrass Prairie.

Introduction

Interactions between different trophic levels are an important factor in any ecosystem. The abundance and diversity of one trophic level can often be correlated with the abundance and diversity of other trophic levels (van Klink et al., 2016 & Evans et al., 2015). The greater biodiversity of lower trophic levels can help increase the biodiversity of higher trophic levels by providing functional redundancy as well as higher biomass of prey items. Communities with greater niche diversity and a range of niches are shown to have greater diversity (Levine & HilleRisLambers, 2009). Furthermore, biodiversity of an ecosystem can indicate the overall health of an ecosystem because it provides more stability, so management for biodiversity is important in conservation.

Grasslands are one type of biome where changes in the lower trophic level can affect higher trophic levels. Forbs and grasses are the typical primary produces in grasslands. Herbivores, especially grazers, can have profound impacts on the composition and structure of the vegetation in grasslands (Elson & Hartnett, 2017, Koerner & Collins, 2014, & Milchunas & Laurenroth, 1993). Grazing has been seen to increase the forb diversity in grasslands because grazers reduce the competition between forbs and grasses due to their preference for grasses (Ruthven, 2007, & Elson & Hartnett, 2017). Native herbivores may increase the plant diversity more than non-native grazers (Olff & Ritchie, 1998). In the tallgrass prairie system Bison increase both the diversity and performance of forbs (Elson & Hartnett, 2017). Native grazers increase the diversity of insects in grasslands (Pryke et al., 2016). Could this observed increase in insect diversity be caused by the grazers increasing the forb diversity of the area?

The Intermountain Bunchgrass Prairie in Western Montana is a unique grassland that is one of the most endangered ecosystems in North America. Between the years 1970 and 2002, the northwest bunchgrass area of Montana, which includes the National Bison range, saw a mean decrease in vegetation species richness as well as a 20% decrease in forbs and a 20% increase in grasses (Sikkink, 2005). If forb diversity has a positive effect on insect diversity then a decrease in percentage of fords could also negatively affect the insect community. Determining the relationship among the biodiversity of the different trophic levels in the Intermountain Bunchgrass Prairie could further our understanding of the role of biodiversity in this endangered biome.

The main objective of this work was to determine if forb biodiversity in the Intermountain Bunchgrass Prairie ecosystem is positively correlated to the diversity of ground and aerial insect families. A second minor objective was to determine the relationship between bird abundance and insect diversity as well as forb diversity. These objectives can help in understanding how the biodiversity of one trophic level can impact the biodiversity of other trophic levels. I hypothesize that as the biodiversity of the forbs increases across sites, the biodiversity of the families of insects will increase as well. I expect the forb diversity will be correlated to insect diversity because the higher diversity of forbs allows for an increase in niches to be filled by different types of insects as well as a greater variety of food resources. I hypothesize that bird abundance will not be correlated with insect or forb diversity. I expect this because birds are able to move more between different environments for varying needs.

Methods

Study site

Sampling took place on the National Bison Range in Charlo, MT as well as on some surrounding WPA (Waterfowl Production Area) sites. A total of six sites on the National Bison Range were sampled: Pauline, Triangle, Trisky, Ravalli, Turkey Women, and North Boundary. Four sites located on WPAs included: Duck Haven, Crow, Anderson, and Sandsmark (Fig. 1). These areas were chosen because the Bison Range is one of the largest remaining areas of Intermountain Bunchgrass Prairie and the surrounding sites were also chosen to get varying degrees of forb diversity and to increase the distance between the sites.

Data Collection

A total of 10 sites were measured for forb diversity, ground insect diversity, and aerial insect diversity. For each site, one 200-meter transect that was situated 100 meters away from and parallel to artificial boundaries and at least one kilometer away from each other. These transects were used to do bird surveys. These bird surveys were done between sunrise and 10:30 AM and consisted of walking the transect and stopping at seven points along the transect and staying there for a five minute period before moving on. Before starting the initial survey a five minute waiting period was given. All birds seen or heard were identified and an estimation of distance was given. Birds greater than 200 meters away were not counted. Each site was surveyed twice.

For each transect, .5 x .5 meter quadrants were placed at 20 meter intervals along the transect and placed at a random distance between 1-25 meters perpendicular to the transect. In these quadrants the total number of each species of forb were recorded as well as the percent area covered by grasses. Soil moisture was also measured from plots along each transect. The diversity of the forbs was then calculated using the Shannon-Weiner Diversity Index. Once the plants were recorded in each quadrant, a pitfall trap was placed in every other quadrant perpendicular to the transect in the center with the lip flush to the ground. This was used to determine the ground insect diversity. Each pitfall trap consisted of a 16 oz. plastic cup with 5-7 cm. of soapy water and had a 5 by 5 inch screen with ½ inch holes stapled to the ground to prevent unwanted animals from getting caught (Sutton, 2017). The pitfall traps were collected between 5-8 days after they were placed.

Sweep netting was also performed at each transect to sample a potentially distinct insect community from that sampled in the pitfall traps. Sweep netting was done at each 40 meter interval of the 200 meter transect. The sweeping was conducted by walking 25 meters out from each 40 meter interval and along the way doing 25 sweeps, with each sweep representing one back and forth motion (Pryke, 2016). These insects were then placed in kill jars charged with acetone. Then three of those jars from each site were randomly selected to I.D. Each insect was identified to family, except Thysanoptera (thrips), which were identified to order. Spiders and pill bugs were noted, but not identified to Family level. The diversity of the families of the insects was also calculated using the Shannon-Weiner Diversity Index.

Data Analysis

The results of the different diversities were analyzed across the 10 different sites using linear regressions looking at each combination of diversity: forb and pitfall trap insects, forb and sweep net insects. ANOVA's were used to determine if the biodiversity of forbs, pitfall trap insects, and sweep net insects differed between the ten sites. Tukey post-hoc tests were then run if significant differences across sites were found in the ANOVA's. Bird abundance was plotted against the three different diversities and were observed for any relationship.

Because forb diversity and composition was the primary baseline measurement for each site, I used Principal Coordinates Analysis (PCA) to visualize similarities (Bray-Curtis) of the forb communities at all ten study sites.

Results

Across the ten sites over 9,000 individual forbs were identified making up 90 different taxa, over 6,000 individual insects were identified making up over 80 families of insects, and over 700 birds were surveyed. The main objective of the study was to determine if there is a correlation between forb diversity and insect family diversity with the minor objective of looking at the relationship between bird abundance and forb diversity as well as insect diversity.

When average forb diversity was plotted against the average soil moisture no significant relationship was observed (df = 1, F = 0.0836, p = 0.780). The Trisky site had the greatest average forb diversity and Sandsmark had the lowest (Table 1). Sandsmark had the greatest average sweep net insect diversity (Table 1). A PCA (principal coordination analysis) was used to visualize the different plant communities and how similar these were to one another (Fig. 2). This displayed that Sandsmark had a very different forb community than the other sites. The average biodiversity for forbs among the ten sites was found to be significantly different (df = 9, F = 7.66, $p < .001$, Fig. 3).

The average biodiversity for pitfall trap insects was also found to be significantly different between sites (df = 9, F = 2.485, p = 0.0243, Fig. 4). Post-hoc tests only showed differences for Duck Haven-Anderson and Trisky-Duck Haven (p = 0.035 and 0.018).

The average biodiversity for sweep net insects was not found to differ significantly between sites (df = 9, F = 1.844, p = 0.122, Fig. 5).

Neither average pitfall trap insect family diversity nor average sweep net insect family diversity were found to be correlated (df = 1, F ratio = .908, p = 0. .368, Fig. 6, and df = 1, F = 2.224, p = .174, Fig. 7). The sweep net insects did tend toward being inversely related with forb diversity (Fig. 7).

When average bird abundance was plotted versus average forb diversity a unimodal shape was apparent. A 2nd order polynomial trend line was added to the plot and showed a strong relationship ($R^2 = 0.624$, Fig. 8). The same process was done for bird abundance and sweep net insect diversity, which also appeared to have a unimodal relationship ($R^2 = 0.7747$, Fig. 9). No apparent relationship was found for bird abundance and pitfall trap insect diversity.

Overall forb diversity differed more than the insect diversity of both those caught in pitfall traps and those caught in sweep nets. Some of the sites differed in insect diversity for pitfall traps but not for sweep nets. There was no significant relationship between the biodiversity of forbs and insects which was the major objective of this study. There is an apparent relationship between bird abundance and forb diversity as well as sweep net insect diversity.

Discussion

The average biodiversity of forbs was significantly different across sites as well as the average biodiversity of insect families caught in the pitfall trap (Fig. 3 and 4), but the average diversity of insect families caught in sweep nets was not found to differ significantly between sites (Fig. 5). Even though the site with the greatest average forb biodiversity also had the greatest pitfall trap insect diversity, no correlation was found between forb biodiversity or the biodiversity of insect families caught in the pitfall traps or sweep nets (Fig. 6 and Fig. 7).

The difference in forb biodiversity between the sites implies that there is a mosaic of different forb communities within the Intermountain Bunchgrass Prairie. These differences in biodiversity may be caused by differing effects of invasive species and grazing intensities (Sikkink, 2005). These sites are also under different management regimes because some sites were located on the National Bison Range while others were WPA sites. One of the WPA sites sampled was Sandsmark, and this area was significantly different from 7 of the 9 other sites (Fig. 3). This area was predominantly dominated by one type of tall grass. Trisky, which had the highest forb diversity (Table 1), was located on the Bison Range and was higher in elevation than some of the other sites. This higher elevation could be one of the causes of the higher biodiversity (Gómez-Díaz et al, 2017). At this site bison or evidence of bison were often observed which could be another factor leading to the higher biodiversity (Elson and Hartnett, 2017). The bunchgrass ecosystem in Western Montana is very dynamic because vegetation communities can change from year to year (Sikkink, 2005). The communities may change from year to year based on how different areas respond to varying biotic or abiotic factors, so these findings for forb diversity may be different in the years to come.

The difference in insect family diversity of those caught in the pitfall traps differed between sites may be related to the different vegetation communities which make up the different sites. In forested areas the diversity of ground insects has been shown to differ between different habitat structures (Gibbs et al, 2007). There were fewer differences between sites for pitfall insect diversity than forb diversity with only Duck Haven being significantly different than Trisky and Anderson (Fig. 4). The same factors which affect the forb diversity of Trisky may also be affecting the biodiversity of the ground insects. Anderson though was at a much lower elevation and was not as dry. Elevation can effect insect species richness but it differs between different types of insects (Corcos et al, 2018). These different habitats may attract differing communities of insects but still have similar biodiversity. One variable which may have led to Duck Haven having a lower diversity was that this area is surround by wetlands and ponds, so many of the insects in the area may be more aquatic than terrestrial. One of the more dominant insects found in the pitfall traps were Carrion Beetles (Silphidae). These insects were prominent in the traps most likely because they were attracted to the dead and decaying insects. By leaving the traps out for a shorter period of time their abundance may decrease and change the perceived biodiversity.

Unlike the pitfall traps, the biodiversity of insect families caught in sweep nets was not found to be significantly different between sites (Fig. 5). One possible explanation for this difference between the two collection methods, is the fact that only three samples were used per site for sweep nets instead of five. Also insects caught in sweep nets are often better fliers than those caught in pitfall traps, so they can move between different areas better and can utilize different habitats for different purposes. Flying insects often utilize a much larger territory than merely where they are born (Dolný et al, 2014).

For my minor objective of looking at the relationship between bird abundance and insect diversity as well as forb diversity. When average bird abundance per site was plotted against the different diversities, both the sweep net insect diversity and forb diversity had similar parabolic looking relationships (Fig. 8 and 9). The reason forb diversity could have a relationship with bird abundance could be that grassland bird diversity and stability increases with spatial heterogeneity (Hovick et al, 2015). This though does not fully explain the relationship seen because at a certain point bird abundance begins to decrease with increasing forb diversity. The same relationship is also seen with the sweep net insect diversity. The bird abundance may increase because there are differing food sources so more birds and a larger variety of birds may be able feed. Then when diversity is too high there is not enough of a certain insect that is more palatable than others. The sites with the highest bird abundance though were associated with areas with wetlands (Ravalli) and/or WPA sites (Duck Haven, Anderson, and Crow) and the wetland areas have intermediate forb and sweep net insect diversity. Migratory bird abundance is often greater near wetlands (Sauer, 2018). Wetlands also provide greater spatial heterogeneity since there is both aquatic and terrestrial areas (Hovick et al, 2015). A larger study with a greater sample size would be needed to come to further conclusions about the relationship between forb diversity as well as insect diversity on bird abundance.

In opposition to my main hypothesis insect family diversity was not significantly correlated with forb diversity in the Intermountain Bunchgrass Prairie (Fig. 6 and 7). One possible reason for why no correlation was observed could be due to looking at insect family diversity instead of species diversity. Within a family there could be many species which fill different ecological niches. The range of family richness found in this study may also be too narrow to accurately determine a correlation. Also insects may have specific habitat requirements for different stages of life and thus change location depending on what resources are required at the moment (Diekötter et al, 2013). Another point to think about is that some forbs can provide more resources and ecological niches than others based on their size. Forb and insect diversity are also affected differently by certain factors such as grazing which if intense can decrease arthropod diversity but not affect plant diversity (van Klink et al, 2015).

One study found similar results with very weak relations of insect diversity to plant diversity and warns about assuming management for plant diversity will also lead to insect diversity (Axmacher, Liu, Wang, Li, & Yu, 2011). In this study they explain that there are many more factors which go into insect diversity besides merely plant diversity (Axmacher et al, 2011). Others have claimed that monitoring plant richness is essential for conservation of insect diversity (Braby and Williams, 2016). Both studies are right, plant diversity can play a very important role in insect diversity but is not the only major factor. The relationship between forb and insect diversity may also have an effect on bird abundance because relationships were seen, but may be explained by certain sites being close to wetlands. Future research should focus on doing more controlled studies of how forb diversity effects insect diversity and bird abundance by attempting to control other possible factors and directly manipulate the forb diversity. A similar approach could be attempted with insect diversity and bird abundance. Since the bunchgrass ecosystem is so dynamic a better understanding of how the insects interact with the plants will help determine ways to manage this precious habitat.

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Literature Cited

Braby, M. F., & Williams, M. R. (2016). Biosystematics and conservation biology: critical scientific disciplines for the management of insect biological diversity. Austral Entomology, 55(1), 1-17. doi:10.1111/aen.12158

Corcos, D., Cerretti, P., Mei, M., Vigna Taglianti, A., Paniccia, D., Santoiemma, G., . . . Marini, L. (2018). Predator and parasitoid insects along elevational gradients: Role of temperature and habitat diversity. Oecologia

Diekötter, T., Crist, T. O., Stewart, A., & Dytham, C. (2013). Quantifying habitat-specific contributions to insect diversity in agricultural mosaic landscapes. Insect Conservation & Diversity, 6(5), 607-618. doi:10.1111/icad.12015

Dolný, A., Harabiš, F., & Mižičová, H. (2014). Home range, movement, and distribution patterns of the threatened dragonfly sympetrum depressiusculum (odonata: Libellulidae): A thousand times greater territory to protect? PLoS One, 9(7)

Elson, A., & Hartnett, D. C. (2017). Bison Increase the Growth and Reproduction of Forbs in Tallgrass Prairie. American Midland Naturalist, 178(2), 245. doi:10.1674/0003-0031-178.2.245

Evans, D. M., Villar, N., Littlewood, N. A., Pakeman, R. J., Evans, S. A., Dennis, P., … Redpath, S. M. (2015). The cascading impacts of livestock grazing in upland ecosystems: A 10-year experiment. *Ecosphere*, *6*(3), 1–15.

Gibbs, M. M., Lambdin, P. L., Grant, J. F., & Saxton, A. M. (2007). DIVERSITY OF GROUND-DWELLING INSECTS IN A MIXED HARDWOOD SOUTHERN APPALACHIAN FOREST IN EASTERN TENNESSEE. Journal Of The Tennessee Academy Of Science, 82(3/4), 49-56.

Gómez-Díaz, J. A., Krömer, T., Kreft, H., Gerold, G., César, I. C., & Heitkamp, F. (2017). Diversity and composition of herbaceous angiosperms along gradients of elevation and forest-use intensity. PLoS One, 12(8)

Hovick, T., Elmore, R., Fuhlendorf, S., Engle, D., & Hamilton, R. (2015). Spatial heterogeneity increases diversity and stability in grassland bird communities. Ecological Applications, 25(3), 662-672.

Koerner, S., & Collins, S. (2014). Interactive effects of grazing, drought, and fire on grassland plant communities in North America and South Africa. Ecology, 95(1), 98-109.

Levine, J. M., & HilleRisLambers, J. (2009). The importance of niches for the maintenance of species diversity. Nature, 461(7261), 254-7.

Milchunas, D., & Lauenroth, W. (1993). Quantitative Effects of Grazing on Vegetation and Soils Over a Global Range of Environments. Ecological Monographs, 63(4), 328-366.

Olff, H., & Ritchie, M. E. (1998). Importance of herbivore type and scale. *Trends in Ecology and Evolution*, *13*(7), 261–265.

Pryke, J. S., Roets, F., & Samways, M. J. (2016). Wild herbivore grazing enhances insect diversity over livestock grazing in an african grassland system. PLoS One, 11(10)

Ruthven, D. C. (2007). Grazing effects on forb diversity and abundance in a honey mesquite parkland. *Journal of Arid Environments*, *68*(4), 668–677.

Sauer, J. R. (2018). Using Landscape Ecology to Test Hypotheses About Large-Scale Abundance Patterns in Migratory Birds Author (s): Curtis H . Flather and John R . Sauer Published by : Wiley on behalf of the Ecological Society of America, *77*(1), 28–35.

Sutton, K., Carlos, J., & Soto, W. (2017). Cattle rangeland effects on plant heterogeneity and Coleoptera diversity and abundance

van Klink, R., Nolte, S., Mandema, F. S., Lagendijk, D. D. G., WallisDeVries, M. F., Bakker, J. P., … Smit, C. (2016). Effects of grazing management on biodiversity across trophic levels–The importance of livestock species and stocking density in salt marshes. *Agriculture, Ecosystems and Environment*, *235*, 329–339.

van Klink, R., van der Plas, F., van Noordwijk, C. T., WallisDeVries, M. F., & Olff, H. (2015). Effects of large herbivores on grassland arthropod diversity. Biological Reviews Of The Cambridge Philosophical Society, 90(2), 347-366. doi:10.1111/brv.12113

Appendix

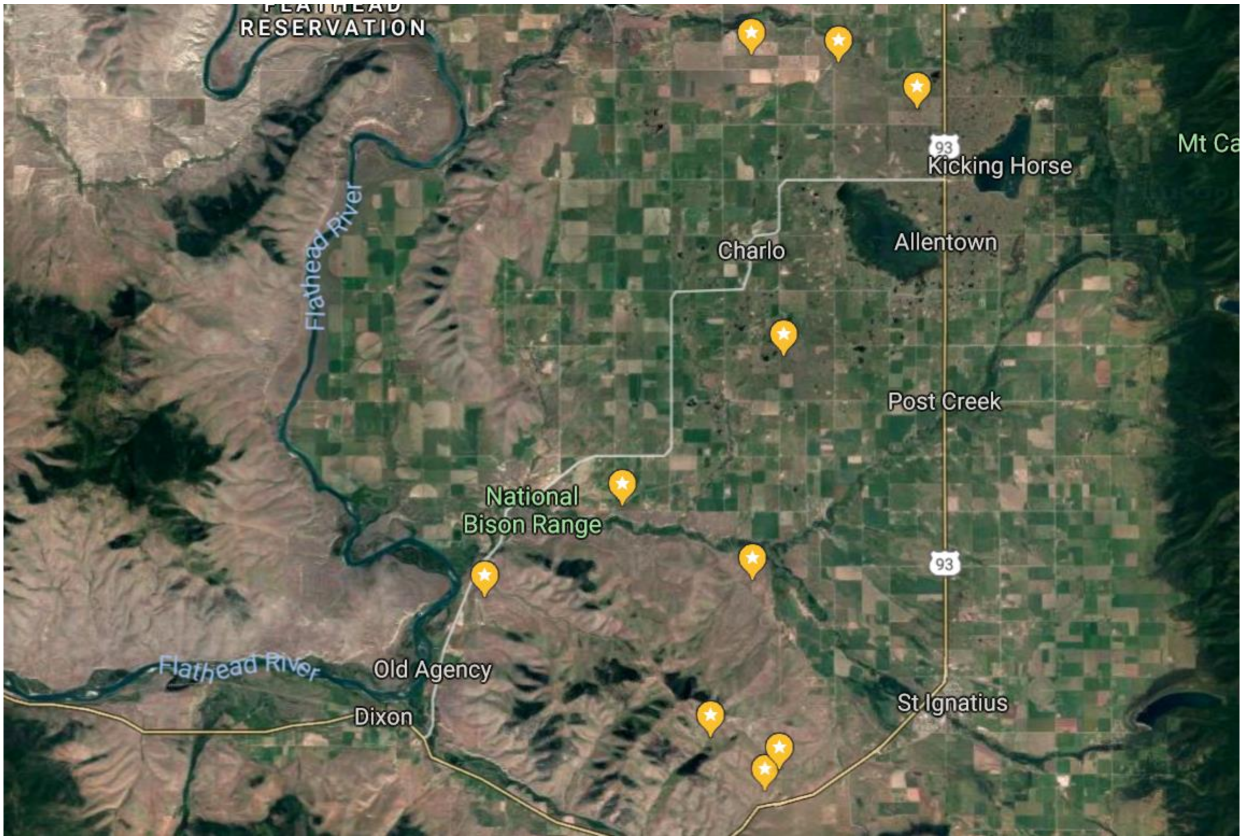

Figure 1. Map of the ten sites used for sampling. Pauline (47.348396, -114.276064), Triangle (47.35025, -114.17213), Trisky (47.310343, -114.188360), Ravalli (47.295033, -114.166978), Turkey Woman (47.3091447, -114.1623544), North Boundary (47.309145, -114.162354), Duck Haven (47.473071, -114.1067166), Anderson (47.486001, -114.138257), Crow (47.487074, -114.172000), and Sandsmark (47.4085140, -114.1590370)

Table 1. The average forb, pitfall insect family, and sweep net insect family diversity for the ten sample site.

Site	*Average Forb Diversity*	*Average Pitfall Insect Family Diversity*	*Average Sweep Net Insect Family Diversity*
Pauline	1.004505701	1.64956844	1.956067767
Triangle	1.359082869	1.376590725	2.126514833
North Boundary	1.360407602	1.72885872	1.421840733
Ravalli	1.340897687	1.65612256	1.911463267
Anderson	1.228188332	1.78360116	2.0122996
Duck Haven	1.373193386	0.93986408	1.7937732
Turkey Woman	1.64593062	1.47992205	1.165850667
Crow	0.966814119	1.32098808	1.7072077
Sandsmark	0.510741776	1.60786164	2.186821867
Trisky	1.687628329	1.845245	1.991804067

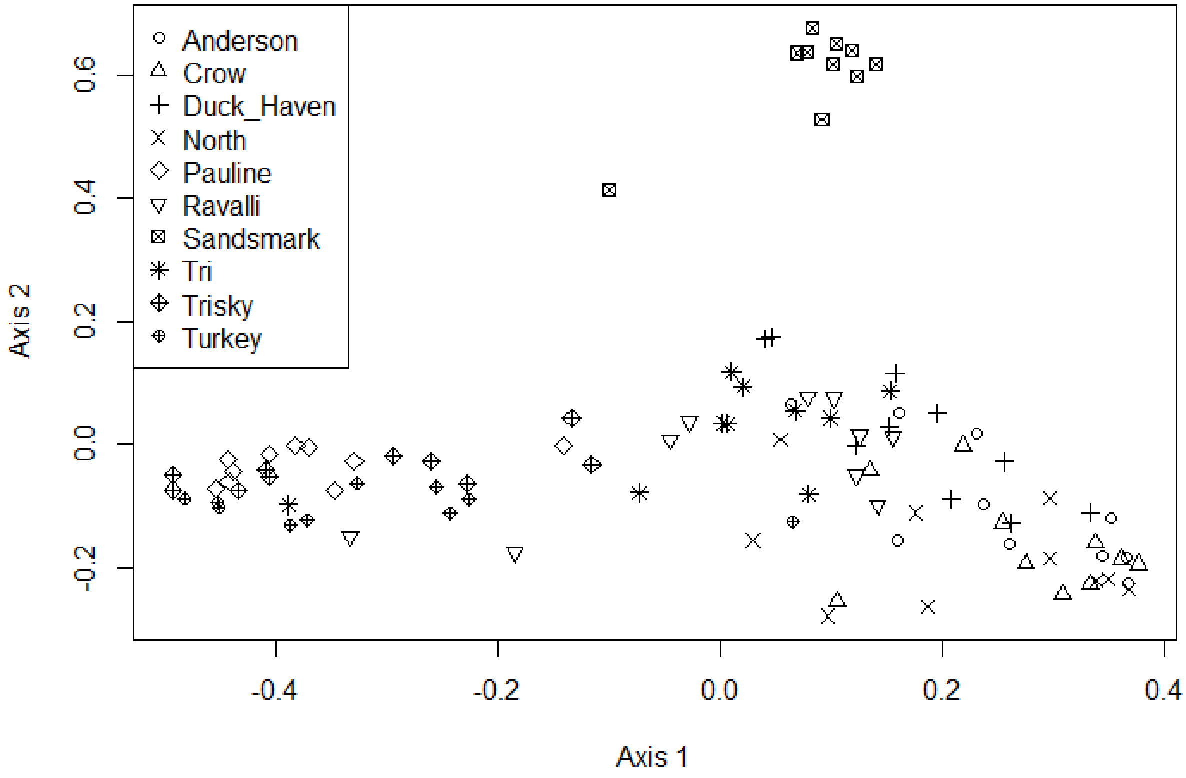

Figure 2. A Principal Coordination Analysis for the ten sites based on forb community.

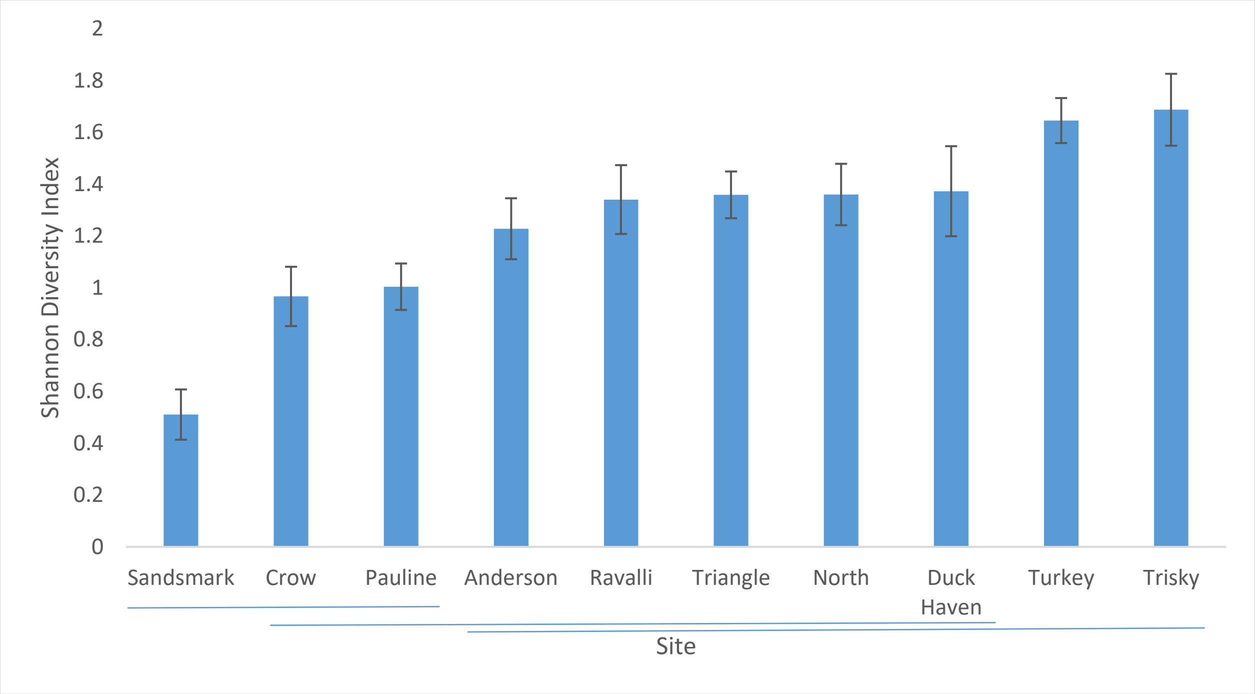

Figure 3. Average Shannon Diversity for forbs of the ten sites with standard error bars (df = 9, F = 7.66, p < .001).

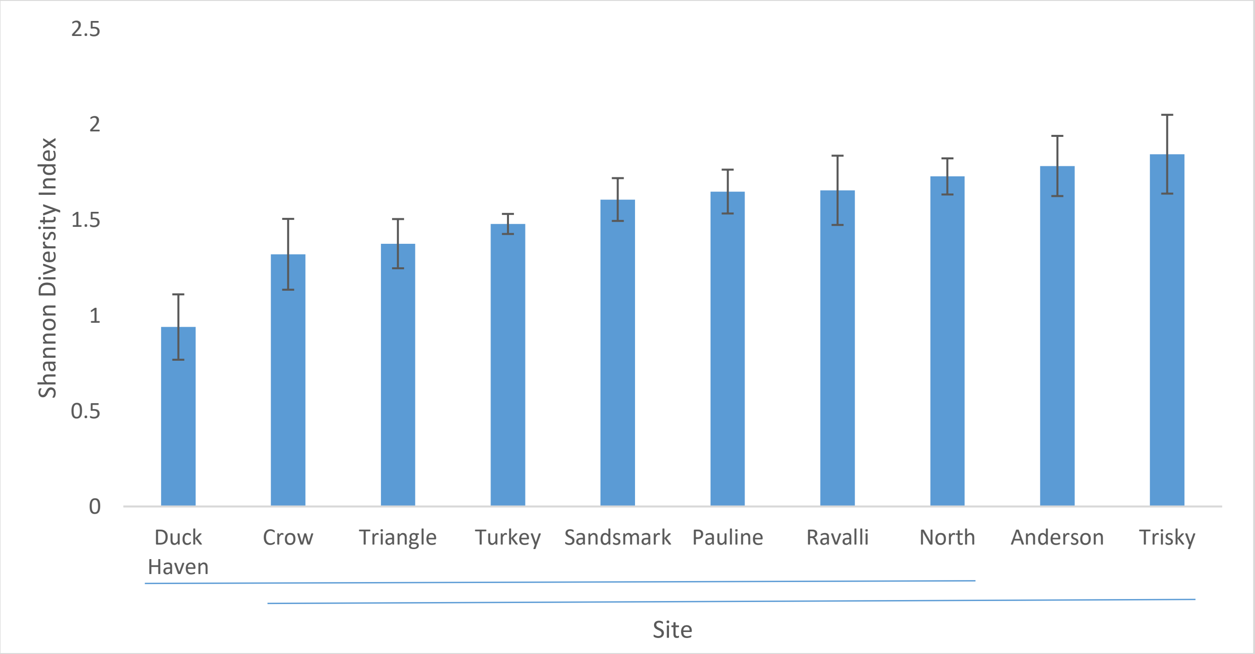

Figure 4. Average Shannon Diversity of insect families collected in pitfall traps with standard error bars (df = 9, F = 2.485, p = 0.0243).

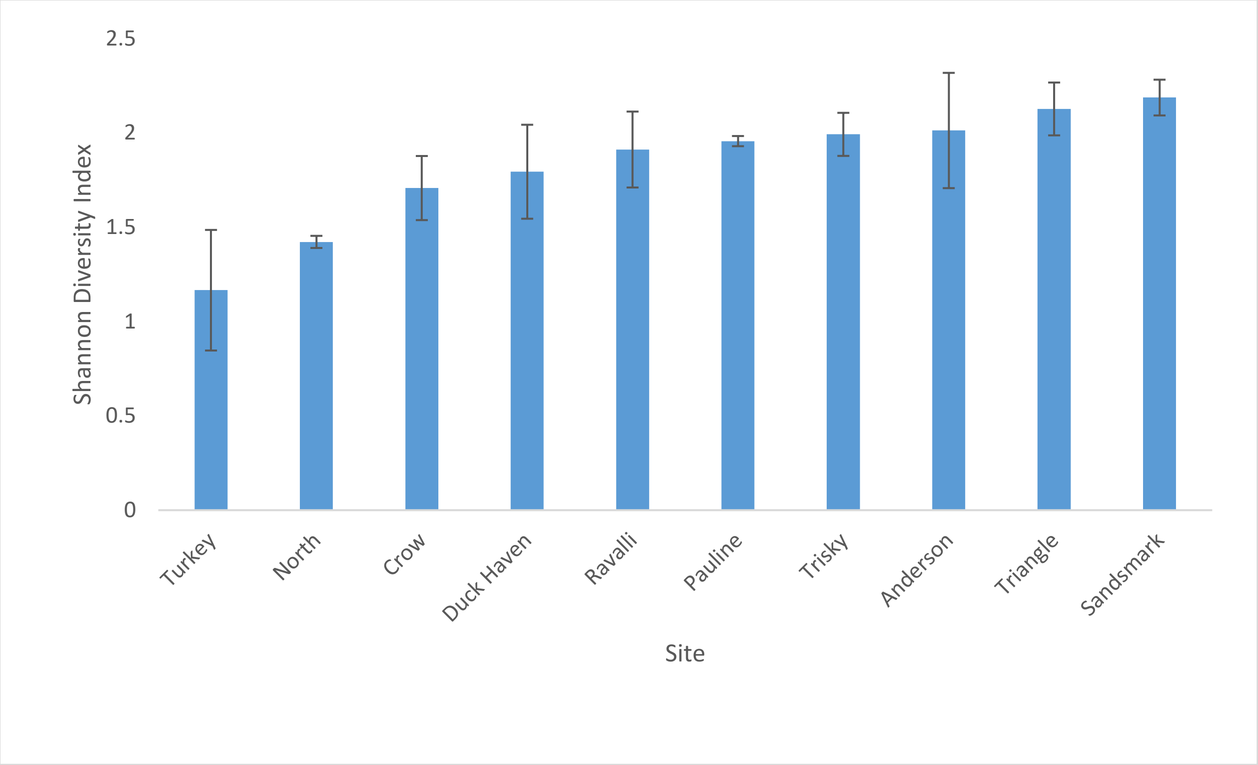

Figure 5. The average Shannon Diversity for insect families caught in the sweep net (df = 9, F = 1.844, p = 0.122)

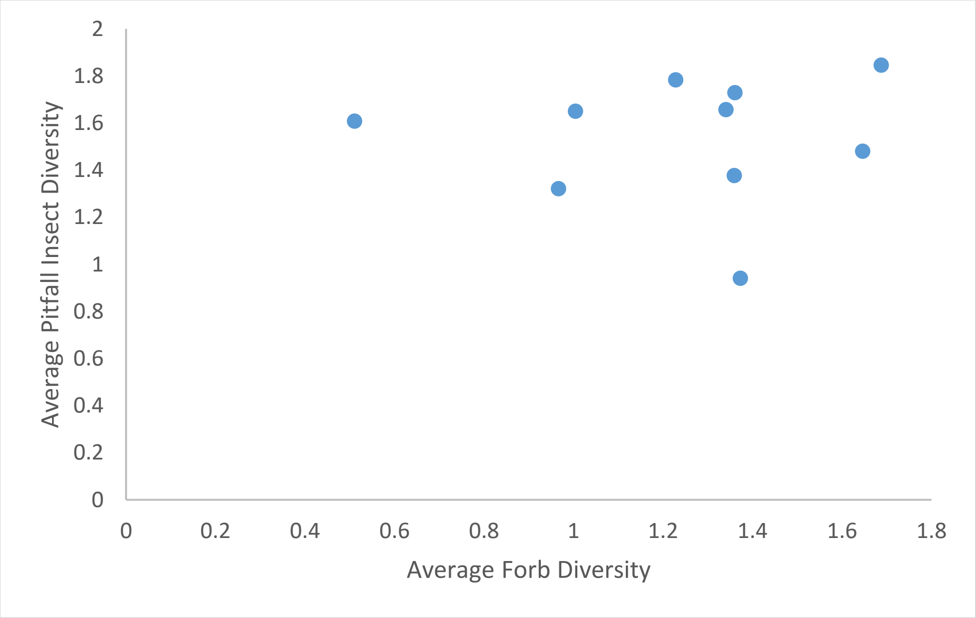

Figure 6. Average Shannon Diversity Index of forbs plotted against average Shannon Diversity of insects caught in pitfall trap (df = 1, F ratio = .908, p = 0. .368).

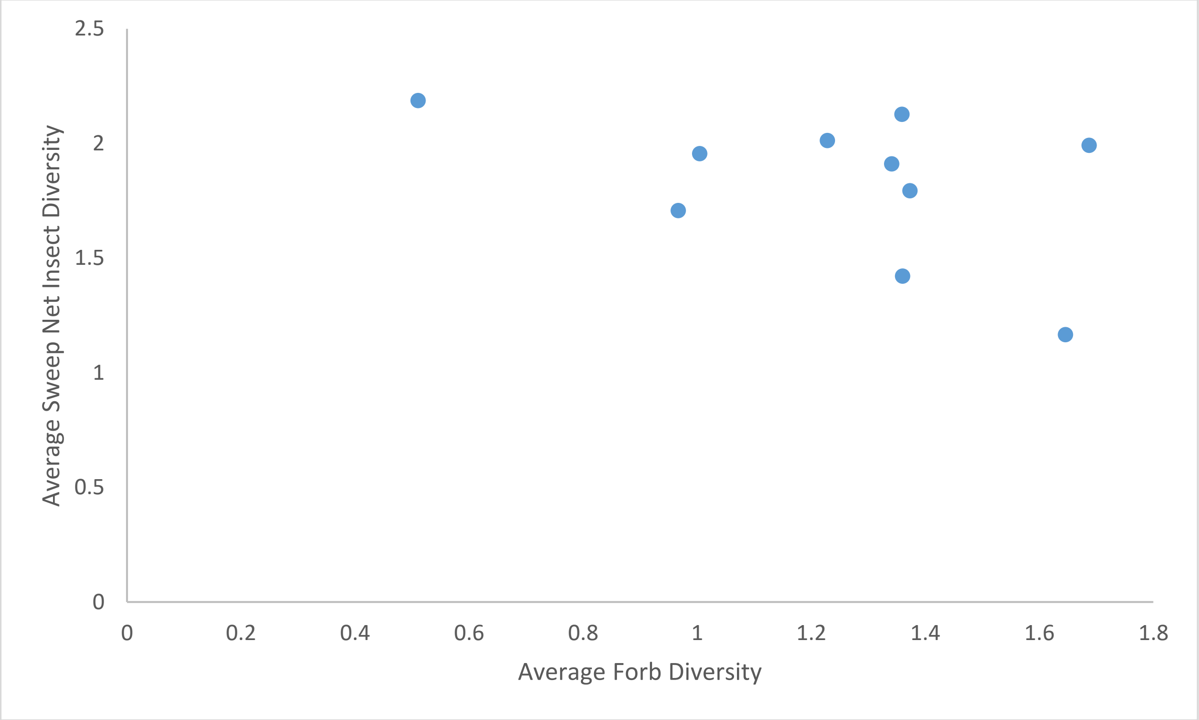

Figure 7. Average Shannon Diversity of forbs versus average Shannon Diversity of insect families caught in sweep nets (df = 1, F = 2.224, p = .174).

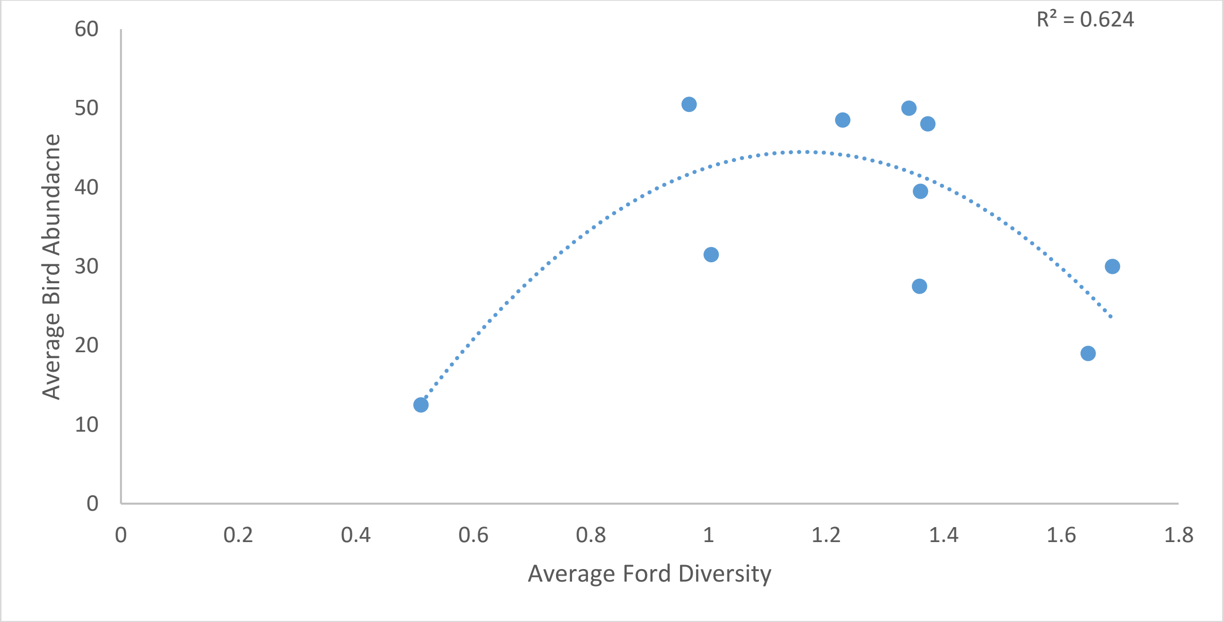

Figure 8. Plot of average bird abundance versus average Shannon diversity of forbs with a 2nd order polynomial trend line ($R^2 = 0.624$).

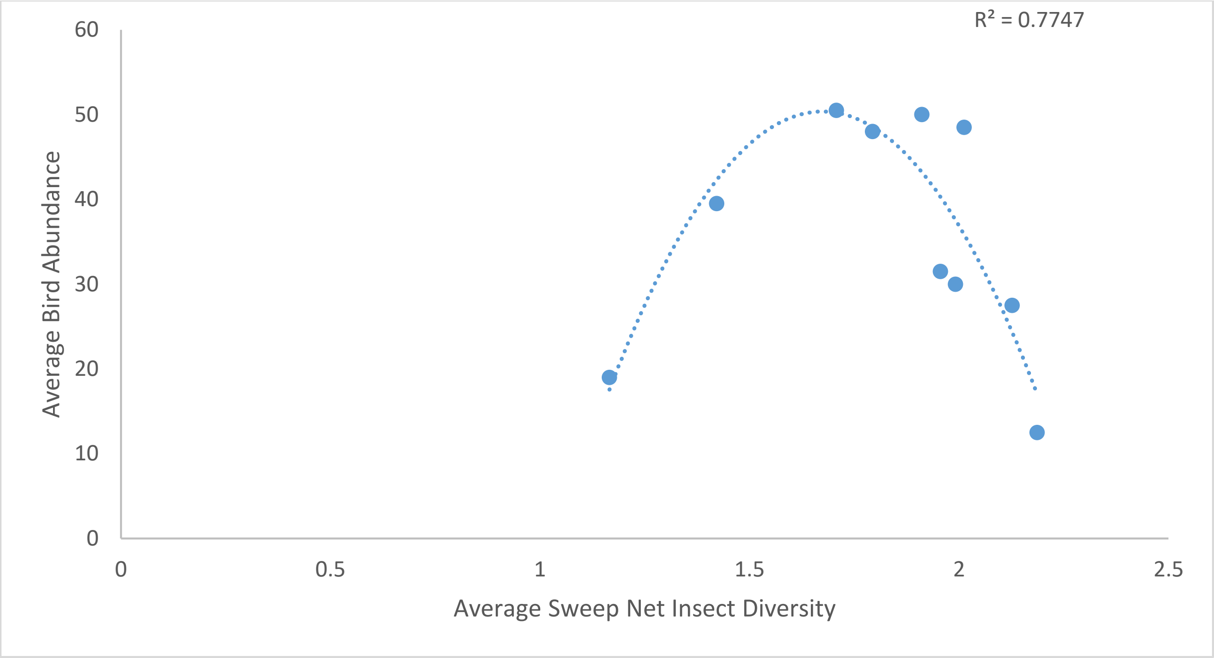

Figure 9. Plot of bird abundance versus average Shannon diversity of insect families caught in sweep nets with a 2nd order polynomial trend line ($R^2 = 0.7747$).