Nina Denne

Stuart Wagenius

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Effect of Diversity on *Echinacea angustifolia*

Introduction

Habitat fragmentation of native communities has severely affected prairie habitat throughout the United States, introducing non-native species, decreasing genetic diversity within native species, and decreasing overall species diversity. Studies have shown that habitat fragmentation reduces the viability of native species and lowers their reproductive success (Menges 1991). More diverse plant communities can increase their resistance to external invaders and create a robust, viable community (Naeem et. al, 2000). Unfortunately, pockets of diverse plant communities are becoming smaller as human influence continues to fragment prairie populations. Although negative trends in viability and reproductive success have been documented in many species, it is unclear if habitat fragmentation will affect all native species in the same way.

Echinacea angustifolia, commonly known as purple coneflower, is a native prairie plant in western Minnesota and serves as a model organism for the Midwestern prairie region. Previous studies of *Echinacea* have found that achene count, seed-set, and fecundity are valuable measures of *Echinacea* success (Wagenius 2006). However, *Echinacea* seed-set, fecundity, and achene count have not been compared directly to measures of surrounding plant community diversity. This data could provide a more complete picture of *Echinacea* response to habitat fragmentation and the impact that invasive species may have on *Echinacea*. Finding a correlation

between measures of diversity in *Echinacea* habitat and its success could indicate that *Echinacea* success depends on its community. Additionally, if seed-set is affected more by diversity, this could indicate that pollinator communities are also affected by diversity, since seed-set takes pollination into account. On the other hand, if achene count is effected more greatly, then diversity could affect other resources, but not necessarily the pollinator community.

Materials and Methods

Echinacea angustifolia heads were collected from 24 sites in Douglas county in western Minnesota. Square 2 by 2 meter plots were created in each site, and all species within the plots were identified, whether or not the plant was flowering was recorded, and percent cover was estimated for each species. 91 flowering *Echinacea* heads were collected from the plots and each was given a unique identifier. Each head was cleaned of all achenes, and achenes were separated from other chaff. All achenes from each head were counted and at least $1/6^{th}$ of the achenes were randomly selected for X-raying. Samples were X-rayed for 4 seconds at 12 mV and scans were created to view whether or not achenes had embryos.

Three measures were used to quantify *Echinacea* success: total achene count, seed set and fecundity. Total achene count was the total number of achenes present on each head. Seed set was calculated by dividing the number of full achenes in the X-ray sample by the total number of achenes from the X-ray sample. Fecundity was defined as the seed set multiplied by the total number of achenes on the head. Additionally, plot diversity was quantified in two ways. Species richness was defined as the total number of species present in each plot, but diversity indices were also used to take into account abundance and rarity as well as prevalence of native and nonnative plants. Two specific indices were used: Shannon's and Simpson's diversity indices from the R package 'vegan', version 2.4-5. These diversity indices took into account

percent cover at each plot and calculated a unique diversity score for each plot. In order to analyze the data, RStudio version 1.1.383 was used to create all plots and conduct all statistical analyses.

Results

The histogram of achene count (Figure 1) shows that the number of achenes across all samples followed a fairly normal distribution, although it skewed slightly towards lower numbers of achenes. The mean number of achenes was 148.55, while the median number of achenes was 160. However, both histograms for fecundity and seed-set (Figures 2, 3) show a high frequency of lower fecundity and lower seed-set measures, with many heads having fecundity and seed-set of 0 or close to 0. Additionally, measures of *Echinacea* success were compared directly to one another, as shown in Figures 4 and 5. When comparing achene count and seed-set, a weak relationship was seen when heads with seed-set of 0 were included, but no relationship is found when these values are removed (Figure 4). Heads with seed-set values of 0 had no full achenes in the X-ray samples taken, but not necessarily a complete lack of full achenes on the entire head. When comparing seed-set and fecundity, a very strong relationship was found, as shown in Figure 5, both with and without points where seed-set is 0. There was also a strong relationship between achene count and fecundity ($p=1.458*10^5$, $R^2=0.2105$).

Across all plots, several species had consistently high percent cover, indicating that they are likely associates for *Echinacea.* These species included *Solidago canadensis* and *Amorpha canescens,* which both had >75% cover in some plots, *Solidago rigida, Solidago speciosa, Medicago sativa,* and *Trifolium pratense,* which all had >50% cover in some plots. Several different methods were used to quantify diversity for each plot. The first measure, species richness, was the total number of species in each plot. This measure was calculated twice, once

using all plants and once using only flowering plants identified in each plot. Both types of species richness were compared to seed-set, fecundity, and achene count, but no strong relationships were found across these comparisons.

Another measure of diversity calculated was percent invasive species per plot. The United States Department of Agriculture PLANTS Database contains information about all plants native and non-native to the state of Minnesota, and this database was used to determine native status of all species present in each of the plots. Percent of invasive species was then compared to each measure of success: seed-set, achene count, and fecundity. However, achene count and percent invasive species per plot was the only measure with a relationship, with higher percent invasive species indicating a lower achene count for *Echinacea* (Figure 6). Fecundity and seed-set had no relationship with achene count.

Additionally, Shannon's and Simpson's Diversity Indices were calculated for each plot using R's diversity function. These diversity indices were calculated both using all species identified in each plot and only species that were flowering in each plot. Each of these measures of diversity was used as a predictor for measures of *Echinacea* success, but the only relationships found were between both Shannon's and Simpson's diversity indices and achene count when including all plants (not just flowering plants in each plot), as shown in Figure 7. Seed-set and fecundity did not exhibit any relationship with either diversity index.

Discussion

Although achene count as shown in Figure 1 shows a fairly normal distribution, Figures 2 and 3 show that fecundity and seed-set are clearly skewed towards low seed-set and fecundity values. This suggests that regardless of the number of achenes per head, there was a fairly low number of full achenes per head, which is consistent with other studies (Wagenius 2006).

Additionally, seed-set is a much better predictor of fecundity than achene count, shown in part by Figure 5, although both seed-set and achene count have a strong relationship with fecundity.

Species richness, the total number of species present in a site, was one of the measures of diversity calculated for each plot. Although species richness does not take into account any information on type of species present within each plot, for example whether the species are native or non-native, it is still a valuable measure of diversity. Species richness was calculated twice, once with only flowering plants and once with all plants, but no relationship was found between species richness and any measure of *Echinacea* success. This indicates that the total number of species present in each 2x2 meter plot does not influence *Echinacea* success, and does not provide any information on whether non-native species influence *Echinacea.*

The percent of invasive species was also calculated for each plot, and a weak relationship between percent of invasive species and achene count was identified, but no relationship was found for the other measures of success. Since achene count is affected by invasive species while seed-set and fecundity are not, it is possible that the invasive species are competing with *Echinacea* for nutrients and resources, but the pollinator interactions are not necessarily affected by the invasive species.

Shannon's and Simpson's Diversity Indices were also calculated, both with flowering species only and all total species in each plot. Again, a weak relationship was found between achene count and both diversity indices (but only when all total species per plot were used). This further supports that achene count is more directly influenced by competition within the 2x2 meter plot, while seed-set and fecundity both are affected more by the pollinator community, which could span a much larger area. If a larger plot size were chosen or the entire site surveyed for diversity information, then a more complete picture of diversity could be generated and

compared to seed-set and fecundity information. While there are definitely plants outside of the plots that are affecting pollinator communities, plants within the plots affect achene count, which indicates that they are more directly connected with the nutrients at that location (although nutrient levels could vary across the site as a whole).

However, since this was not an experiment, other variables were not held constant throughout the duration of the study, meaning that these relationships could be a result of confounding factors. Studies and experiments exploring site diversity on a larger scale would be useful in ascertaining the true effects of invasive species and the native community diversity on *Echinacea* success as a whole.

Literature Cited

Naeem, S., Johannes M. H. Knops, Tilman, D., Howe, K., Kennedy, T., & Gale, S. (2000). Plant Diversity Increases Resistance to Invasion in the Absence of Covarying Extrinsic Factors. Oikos, 91(1), 97-108. Retrieved from http://www.jstor.org/stable/3547476

Menges, E. (1991). Seed Germination Percentage Increases with Population Size in a Fragmented Prairie Species. *Conservation Biology, 5*(2), 158-164. Retrieved from http://www.jstor.org/stable/2386189

Wagenius, S. (2006). Scale Dependence of Reproductive Failure in Fragmented Echinacea Populations. Ecology, 87(4), 931-941. Retrieved from http://www.jstor.org/stable/20069023

Figures

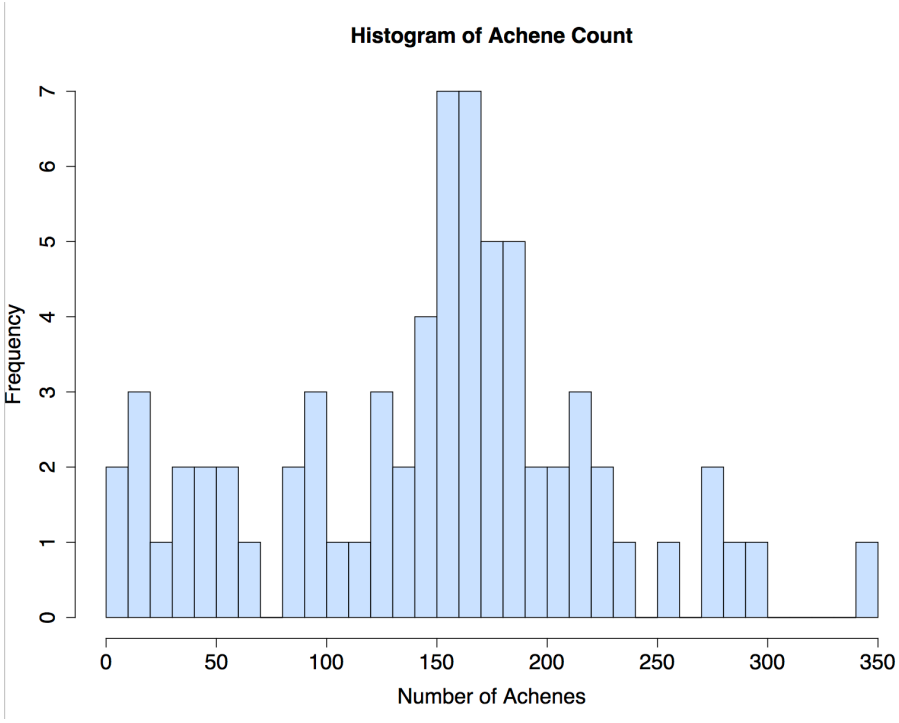

Figure 1. Frequency of achene count per head. This histogram shows the frequency of different numbers of achenes per head across all heads sampled.

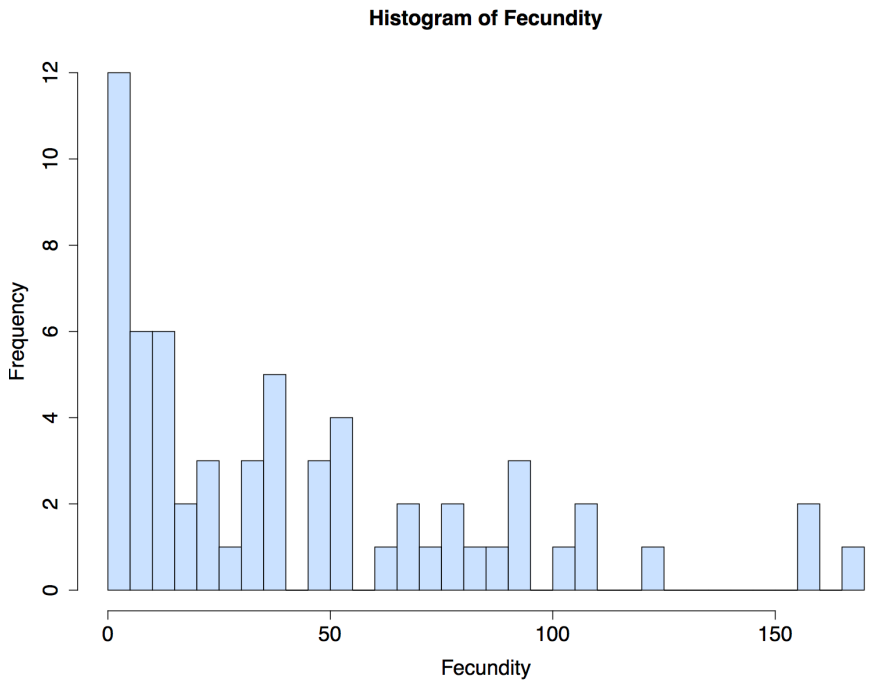

Figure 2. Frequency of fecundity per head. Fecundity is the number of achenes per head multiplied by the head's seed-set. This histogram shows the frequency of specific fecundity levels across the sample.

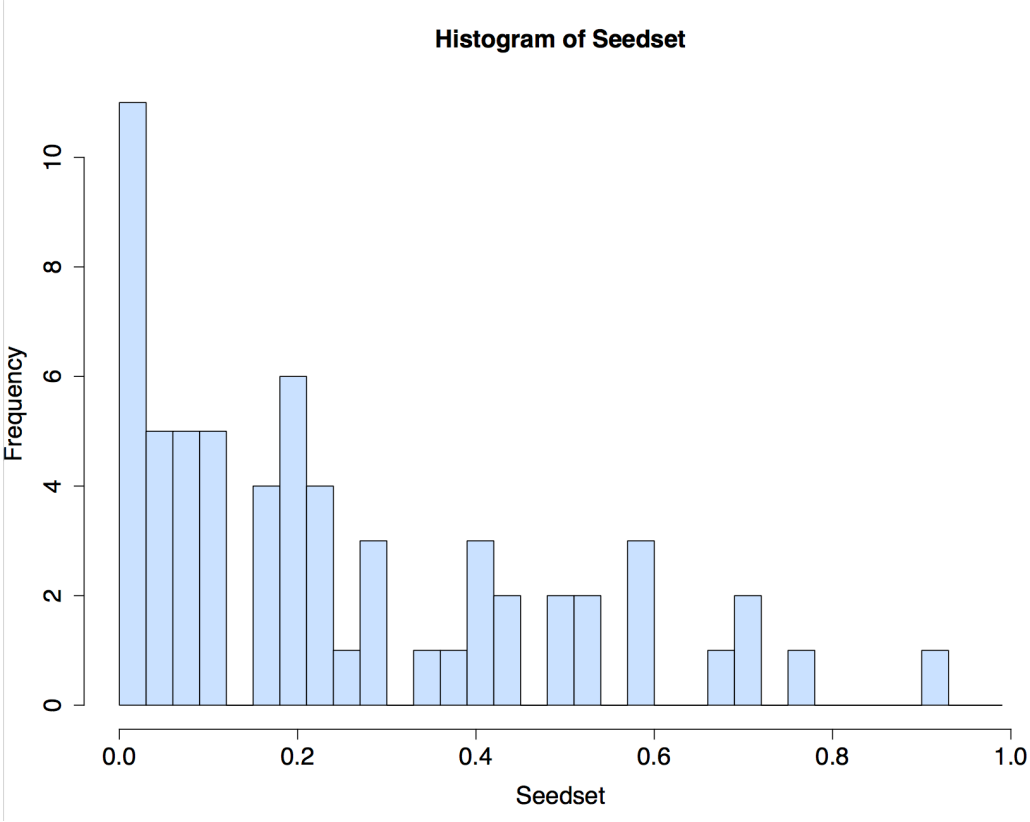

Figure 3. Frequency of seed-set per head. This histogram shows the frequency of specific seed-set levels across all heads measured.

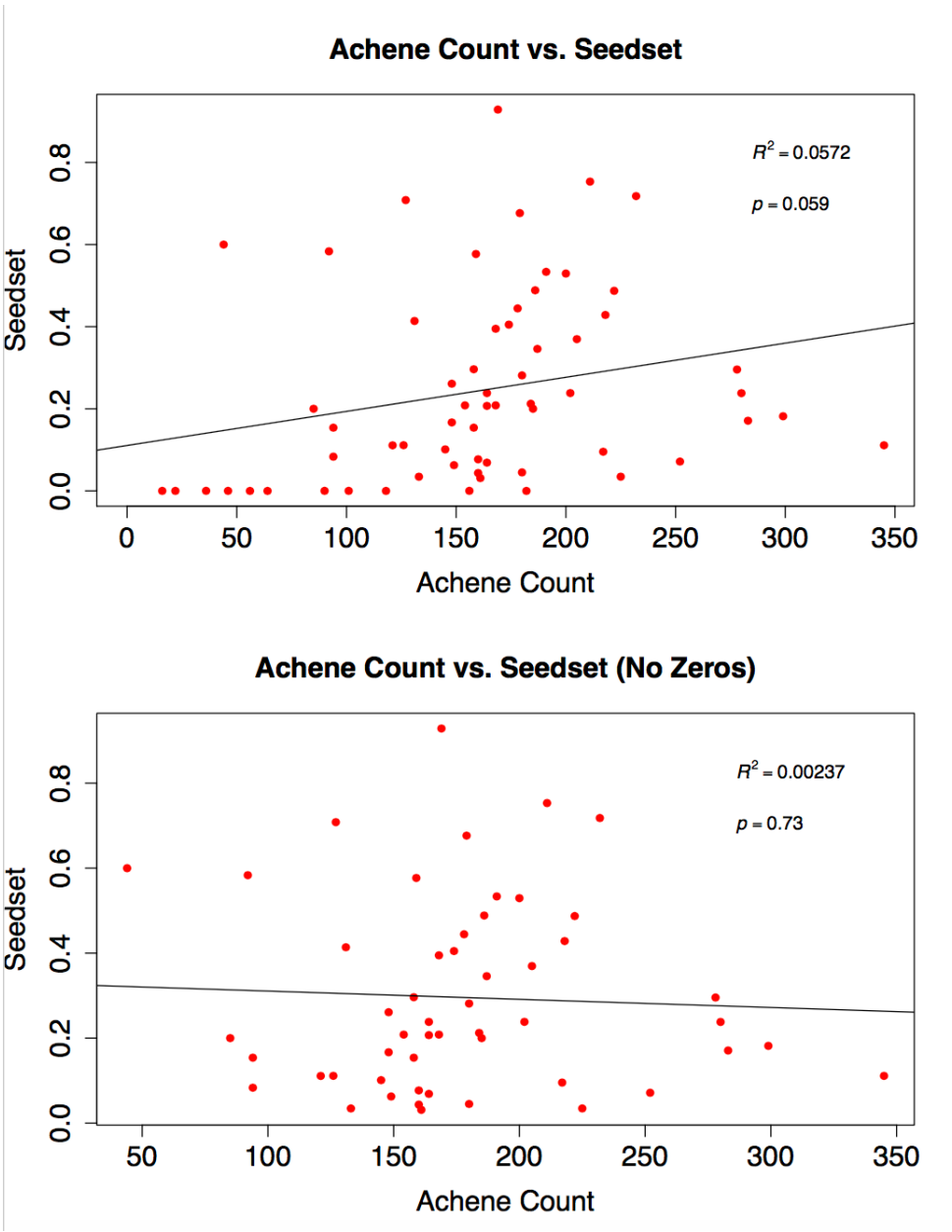

Figure 4. Achene Count vs. Seed-set. The top scatterplot includes data points where seed-set was 0, while those points are removed in the bottom scatterplot. The top scatterplot shows a weak relationship between achene count and seed-set, but there is no relationship once those points are removed.

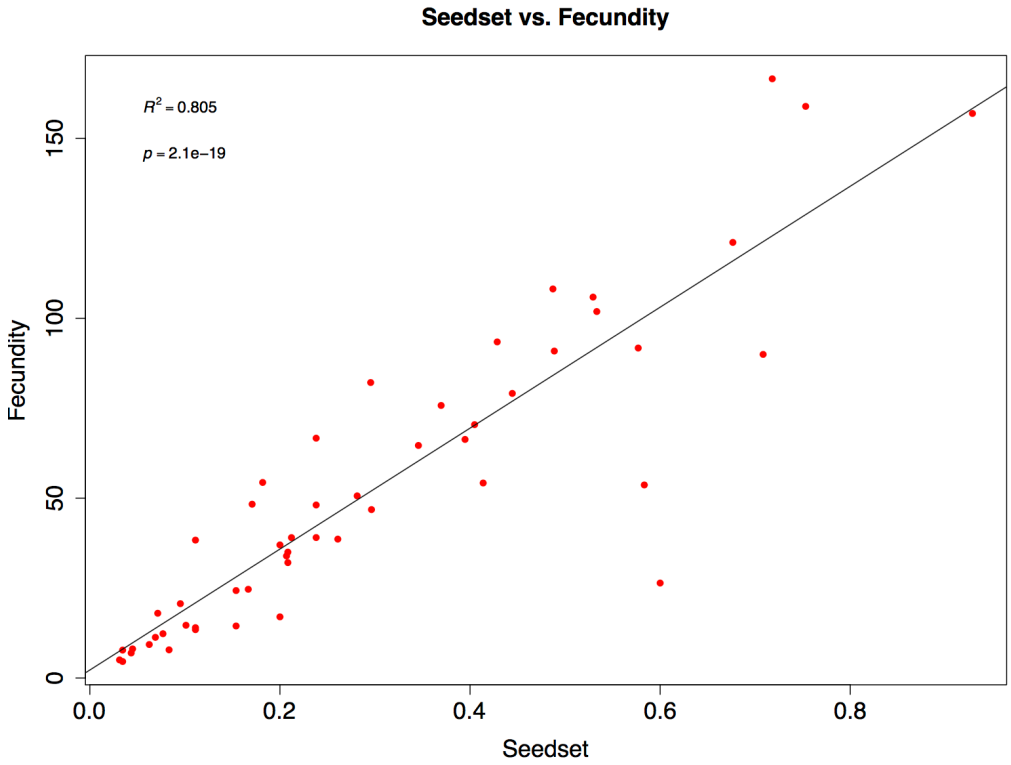

Figure 5. Seed-set vs. Fecundity. This scatterplot shows a strong relationship between seed-set and fecundity. Points where seed-set and fecundity are 0 have been removed from this graph, but the relationship is strong with and without those points.

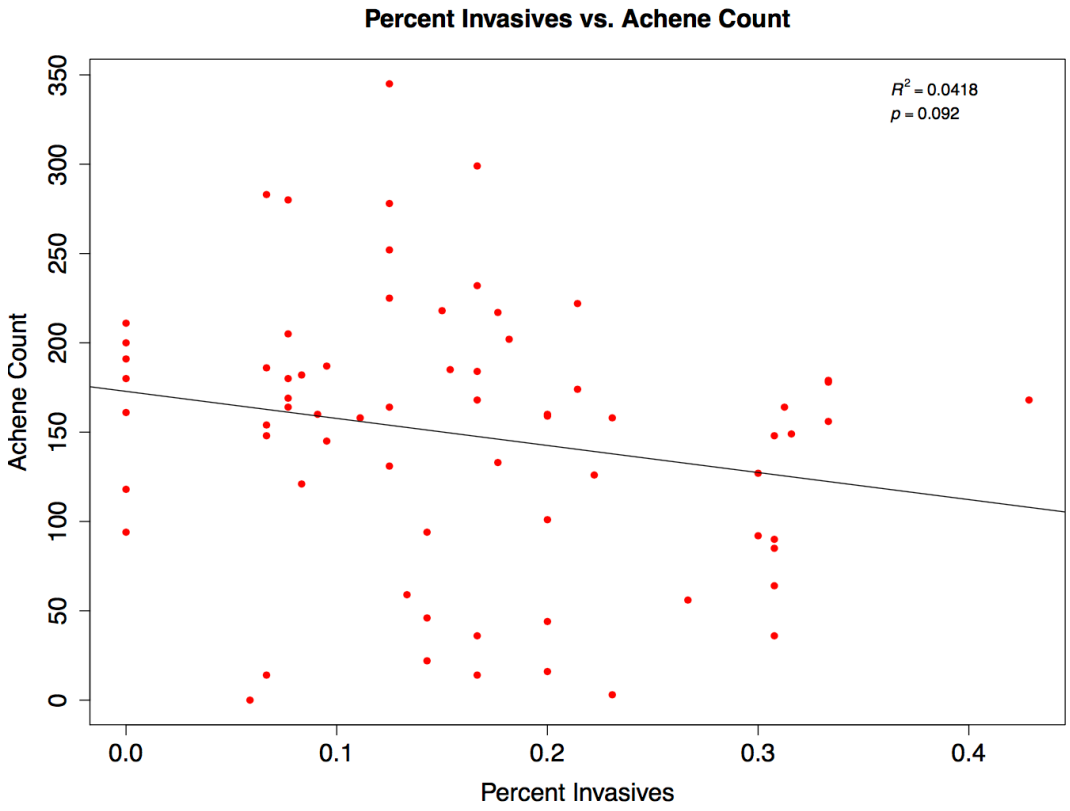

Figure 6. Percent invasive species vs. achene count. Percent invasive species was calculated for each plot and this scatterplot demonstrates a weak relationship between percent invasives and achene count, showing that the higher the percent invasives, the lower the achene count for *Echinacea.*

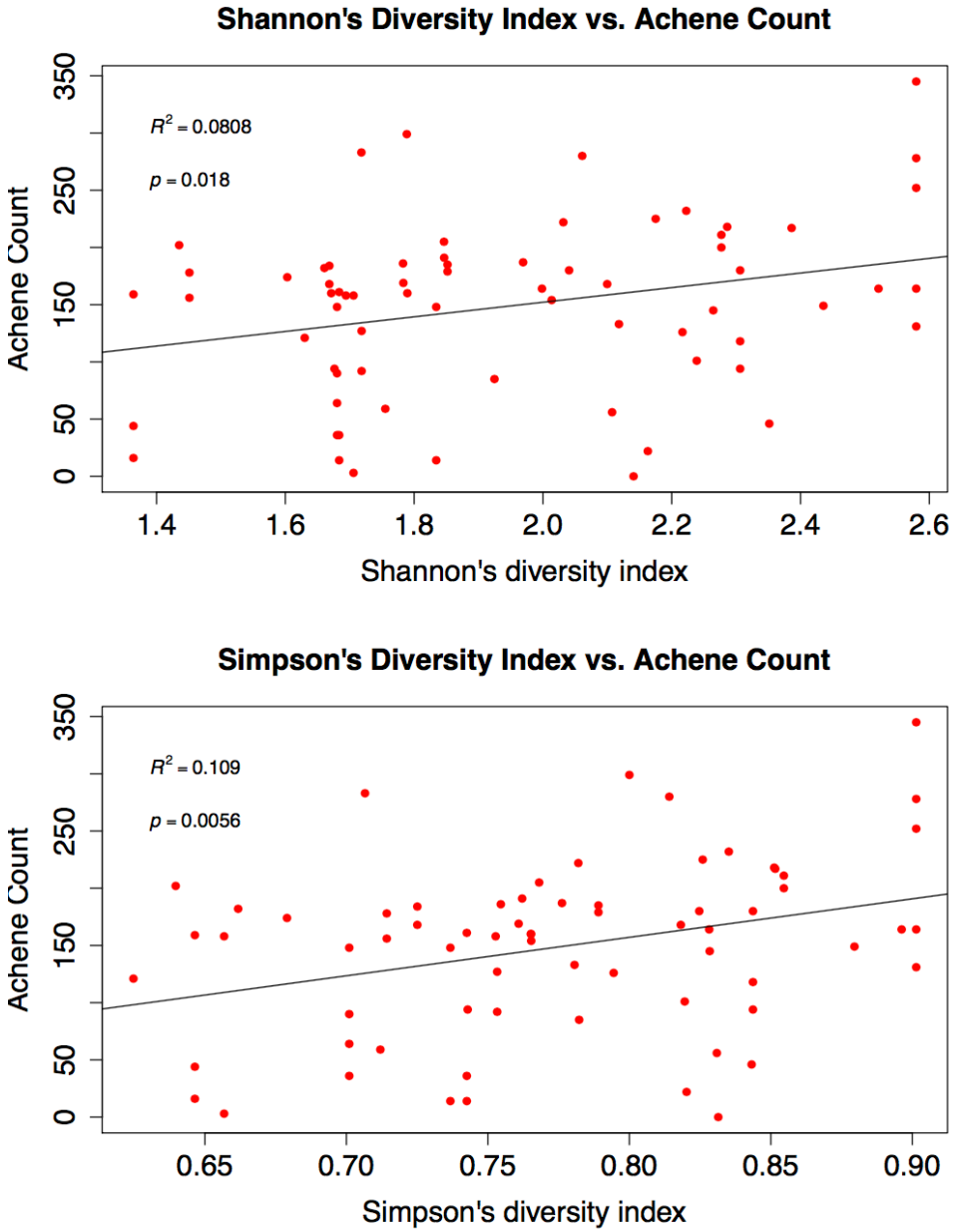

Figure 7. Diversity indices vs. Achene count. These scatter plots show a relationship between both Shannon's and Simpson's diversity indices and achene count. Diversity indices were calculated using all information about plants collected from each plot, not just flowering plants.