The Effects of the Hemiparasite *Pedicularis lanceolata* on Prairie Diversity, Quality, and Representation.

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Abstract

Swamp Betony (*Pedicularis lanceolata*) is a root hemiparasitic plant that thrives in wet prairie environments. It has been described as an ecosystem engineer due to its ability to stunt the growth of surrounding plants, thereby creating short, open patches for less dominant plants to grow. An observation study was performed to investigate the effects that the quantity of Swamp Betony has on prairie quality, diversity and composition. It was found that Swamp Betony had no influence on the quantities of any of the prairie species recorded in this study, including the sometimes overdominant *Andropogon gerardii, Sorghastrum nutans*, and *Solidago altissima,* although this was not directly tested. There was found to be a strong correlation between *P. lanceolata* cover and an increased Floristic Quality Index (FQI) measured on both the individual plot level and the larger grid level. No direct link between *P. lanceolata* cover and biodiversity was found in this experiment. *Hypericum punctatum, Getntiana andrewsii,* and *Chamaecrista fasciculata* were proposed as potential companion plants as these plants were found in association with Betony on both the small and large scale. Although *P. lanceolata* was not found to decrease quantity of overdominant natives, it was shown to be associated with high quality grasslands and the promotion of subdominant prairie plant species.

Introduction

A self-sustaining and diverse plant community is the final goal for many prairie restoration projects as these factors allow restored communities to thrive with minimal management for the foreseeable future. An issue that is often encountered when restoring a prairie is an overabundance of the dominant, native, warm-season grasses, including *Andropogon gerardii* (Big Bluestem) and *Sorghastrum nutans* (Indian Grass) (McCain et al 2010). These two native species play an essential role in the community composition, biomass accumulation, and food availability of prairies, but their overdominance can be problematic when trying to instill a healthy level of biodiversity in early-stage restored prairies.

One proposed method to both increase prairie biodiversity and stunt the warm-season grasses is to introduce native hemiparasitic plants, such as *Pedicularis* species. It has been shown that *Pedicularis* species exhibit host selection preference (Piehl 1963; Bao et al 2015) and because of this, hemiparasites have been described as ecosystem engineers due to their ability to directly affect the competitiveness of surrounding plant communities (Hatcher et al 2012). They alter their surrounding environments by competing with dominant natives on two fronts, for light and through haustorial root connections. Hemiparasites have been described as weak competitors for light, but strong competitors through their haustorium as parasites (Borowicz 2011). Although this method of introducing native hemiparasites into an early stage prairie restoration has been proposed as a system for increasing prairie biodiversity, it is unknown whether there are any long-term adverse effects of doing so.

Previous studies have shown the effects of *Pedicularis* species on grassland community composition and overall quality of restored grasslands. *Pedicularis kansuensis* was found to preferentially parasitize members of Fabaceae, Rosaceae, and Poaceae and significantly less often parasitize members of Cyperaceae and Asteraceae (Bao 2015). This would allow for members of the group that is less favored by *P. kansuensis* to better compete for resources than plant species in groups more favored by the hemiparasite. In a second study, the occurrence and quantity of *Pedicularis canadensis* was found to have a direct correlation with an increased prairie quality measured using the Floristic Quality Index (DiGiovnni et al 2016). Additionally, several root hemiparasites have been associated with high quality and diversity in temperate grasslands in the Czech Republic (Fibich et al. 2012; DiGiovanni et al. 2016).

Pedicularis lanceolata (Swamp Betony) is a perennial hemiparasite that thrives in wet prairie ecosystems. It is a generalist parasite that propagates through underground rhizomes (Piehl, 1963) and because of its nature, this plant often is found in large patches that colonize an area, creating shorter areas in an otherwise tall prairie due to the plants that are stunted by *P. lanceolata.* It was hypothesized that other less competitive plants will grow in these shorter patches. Also investigated, the amount of *Pedicularis lanceolata* in a well-established prairie will have a positive effect on prairie biodiversity, species richness, and overall quality of the prairie, all of which should be measurable on a small scale. The quality will be measured by FQI.

Methods

The experiment was performed at Litzsinger Road Ecology Center Prairie, a 29 year old restored bottomlands prairie in Ladue, Missouri. The land was previously farmed for an unknown number of years and restoration began in 1988. Sudex, a hybrid cross between Sudan grass or Sorghum, was sown the first year with the intent to outcompete the non-native plants that dominated the field's plant composition (William 2000). These non-native plants included tall fescue (*Festuca arundinacea*), hairy vetch (*Vicia villosa*), sour dock (*Rumex crispus*), bitter dock (*Rumex obtusifolius*) and japanese hops (*Humulus japonicus*). Once the Sudex reached a height of 12 feet, it was mowed before it had a chance to set seed and the grassland was burned the next year. After the burn, the field was planted with a mix of locally collected forb seed from Shaw Arboretum, 35 miles from Litzsinger Road Ecology Center, and grasses purchased from a seed nursery located in northwest Missouri and eastern Kansas. The prairie was burned yearly, immediately followed by both seeding and planting events (William 2000). Once the prairie was established in the early 2000's, burning transitioned to a two to three year schedule.

Surveying of plant communities took place in mid-July. A transect system was modified from a previous study that looked at for a potential correlation between *Pediculris canadensis* and an increase in FQI. Three total grids were established with a center point starting near various levels of Swamp Betony (low, medium, and high). Each grid was comprised of five transects that extended 10m, the first towards North 0° and each of the others extended equidistantly around the center point. Two, $1m^2$ plots were chosen at random distances along and outward perpendicularly from each transect line, totaling 10 plots per grid, 30 plots total. In

each plot, all plant species were identified and their cover was measured using a consolidating system, 0=0%, 1= <1%, 2=1-5%, 3=5-25%, 4=25-50%, 5= >50%.

Results

An ANOVA was run to determine the significance of results found. An increase in the Floristic Quality was significantly ($p<0.001$) associated with greater levels of *Pedicularis* in each plot. There was found to be no correlation ($p=0.513$) between *Pedicularis* levels and an increased number of unique plants per plot. Finally, there was no relationship between *Pedicularis* and decreased amounts of *Andropogon gerardii* ($R^2=0.19$), *Solidago altissima* ($R^2=0.23$), *Sorghastrum nutans* ($R^2<0.01$), and *Rubus allegheniensis* ($R^2=0.22$). Additionally, potential companion plants to *Pedicularis lanceolata* were recorded. These plants included *Hypericum punctatum* (4 plots, all with *P. lanceolata* >37.5%), *Gentiana andrewsii* (2 plots, both with *P. lanceolata*), and *Chamaecrista fasciulata* (4 plots, 3 with *P. lanceolata* >37.5%).

Discussion

The hypothesis that an increased amount of *Pedicularis lanceolata* would impact prairie diversity and quality was tested. It was found that greater cover levels of Betony per plot resulted in greater prairie quality when measured with the FQI, shown in Figure 1. This increase was measured using the entirety of the 30 plots recorded. The Floristic Quality Index is an objective measure of a natural area's quality that takes into account both an area's diversity as well as the coefficient of conservation value (c) of each of the plants found in that site (Swink &Wilhelm 1994). This value (c) is a rating from 0-10 that considers a plants tolerance to degradation and the narrowness of its ecological growth conditions. Using these parameters, the FQI of any natural area can be measured and compared subjectively to other natural areas evaluated by this system. The average FQI calculated for each grid was found to be greater depending on the amount of Betony recorded in all plots of that grid. These two observations show a strong correlation between prairie quality and Betony representation. These correlations still hold true after *P. lanceolata* was removed from the FQI calculation, showing that the quality increase was in fact in the plants represented in each plot and not due to the high (c) value *P. lanceolata* was given.

Figure 1.

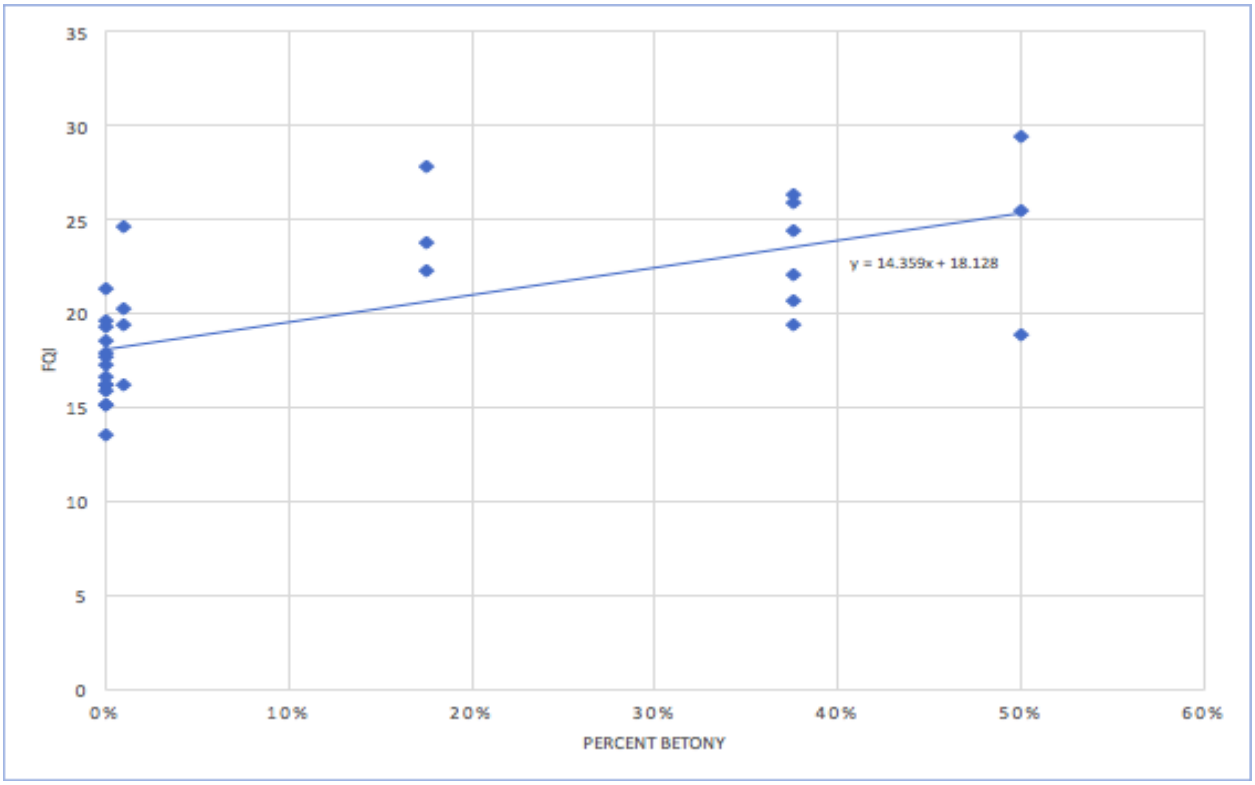

Figure 1. FQI values vs percent cover of *P. lanceolata* combined for the three total grids measured in this study. FQI values presented here include *P. lanceolata* in the calculation, but excluding it from the calculation provides similar results. Since starting grid points were selected for surrounding Betony levels, it is important that their exclusion from the FQI values still result in significant values.

Overall prairie diversity was measured in relation to *Pedicularis lanceolata*, shown in Figure 2. There was found to be no correlation between increased concentrations of Betony and an increased number of plant species per plot. This is a result that was not expected, as it was hypothesized that Betony would create open patches where more plant species should grow compared to the more dense, competitive spaces without Betony; however, this result makes sense. *P. lanceolata* is colonial hemiparasite, so the amount of extra open space it generates by stunting surrounding plants is then immediately taken by this plant through rhizomes, leaving little extra space for other plants trying to colonize an area. There is most likely also a maximum

to the number of unique plant species that can grow within a $1m^2$ area. The maximum number of unique species per plot recorded in this study was 17 (recorded three times) and this cap probably varies based on the history of the prairie (Polley 2005). A slight correlation was found between grids with high levels of *P. lanceolata* and grids with lower levels of it, but there were not enough data points to provide any statistical correlation. More testing is needed to strengthen this relationship between *P. lanceolata* and diversity.

Figure 2.

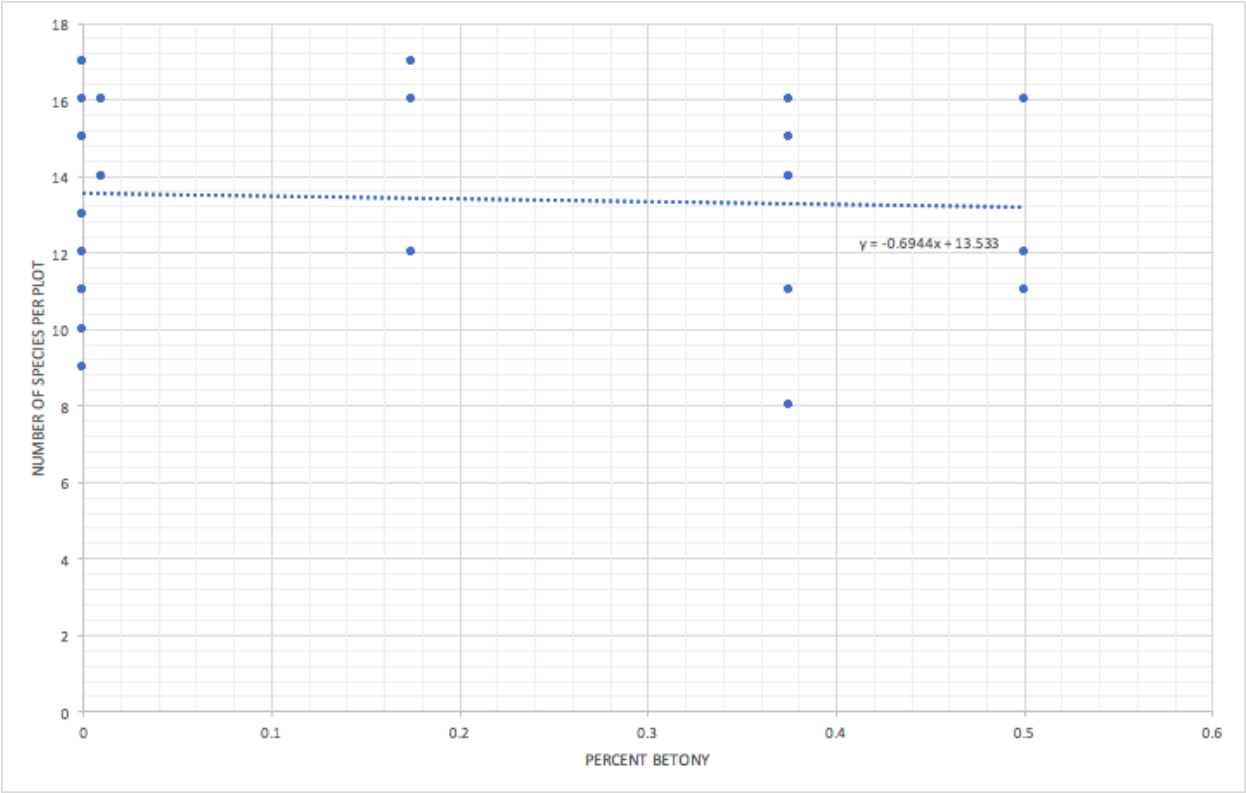

Figure 2. No correlation was found between cover levels of *P. lanceolata* and greater plot diversity. The data evaluated includes the three grids measured, all with varying levels of the hemiparasite. It is shown that *P. lanceolata* has no effect on the number of plant species per plot, which may be hindered by some external cap not measured here.

There was no evidence found to support the idea that *Pedicularis lanceolata* has an excluding effect on any prairie species recorded in this study, dominant or otherwise. No correlation was found between high density measures of *P. lanceolata* and lower density measures of *Andropogon gerardii, Sorghastrum nutans,* or *Solidago altissima*. Anecdotally, it

was noted that grids containing large percentages of Betony were shorter than surrounding prairie, but no data was recorded showing this trend. Although no data was shown supporting the idea that hemiparasites show excluding tendencies, this idea was not directly tested. It may be that *P. lanceolata* subsequently excludes particular prairie species due to the hemiparasite's ability to alter its surrounding environment towards one that is unfavorable to particular plants, whether that be a decrease in aboveground biomass, increased amounts of light, or other unknown factors.

The ability for hemiparasites to alter their surrounding environment may support a more diverse plant community within the shorter patches of Betony. In this study, several species were found only in grids containing large percent covers of *Pedicularis lanceolata.* Those species include *Hypericum punctatum* (Spotted St. John's Wort)*, Gentiana andrewsii* (Bottle Gentian)*,* and *Chamaecrista fasciculata* (Partridge pea). These three species are low growing, the tallest growing slightly under 1m at maximum height. They can be easily outcompeted by the taller, more dominant species that thrive in the LREC prairie and were only found in plots containing medium-high percent covers of Betony. The annual plant Partridge Pea, while often dominant in early stage restoration, is more rarely seen in established prairie restoration and in much smaller quantities. This data suggests that Partridge Pea, along with the other two potential companion plants, have made an association with the Betony in this prairie and is dependent on it to endure.

One potential source of error in this study could be that one half of the prairie was burned in February of this year while the other half was left unburned and two of the three total plots were in the unburned half of the prairie. There is the potential that this could alter community composition as different species do react differently toward fire (Howe 1994 & Morrison et al. 1995). It is for this reason that no data was taken on photic conditions or plant height, as these factors vary greatly between an area that has been burned and one that has not been.

It will always be a goal of prairie restoration projects to create sustainable, healthy, diverse prairies. This experiment suggests that *Pedicularis lanceolata*, along with other native hemiparasites, have the ability to instill this healthy level of biodiversity through their ability to alter their surroundings. This species has the potential to create shorter patches in an otherwise tallgrass prairie with minimal maintenance. Managers of tallgrass prairie restorations should

consider using native *Pedicularis* species in their prairies for their ability to create sustainable, healthy, biodiverse natural areas.

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