St. Olaf College

Local Ecology Research Papers

Comparison of oak tree and understory characteristics in remnant and restored oak savannas

Marcel Hones
2020

Comparison of oak tree and understory characteristics in remnant and restored oak savannas

Marcel Hones

Professor Kathleen Shea

Field Ecology 371

9 December 2020

Abstract

Oak savanna habitats supply vast ecosystem services, yet have historically faced major degradation and decrease in range. Today, remaining oak savannas are either remnant or restored habitat and thus require varying management regimes due to their age and previous management history. The aim of this study was to compare oak tree and understory characteristics of a remnant and restored oak savanna located in southern Minnesota. This comparison was performed by counting and identifying the various oak species between sites, measuring mature oak tree diameters at breast height, identifying understory species and measuring ground coverage of each species. Analysis of variance tests were then used to determine significant differences in these variables between the sites. This study found significantly higher grass coverage at the restored oak savanna site, higher biodiversity at the restored site and more woody understory species at the remnant site. These results are consistent with other literature regarding the ecosystem response to varying histories of fire management and can help inform what sort of regimes must be utilized to maximize biodiversity and resilience within remnant and restored oak savannas.

Introduction

Oak savannas are among the rarest and most biodiverse terrestrial ecosystems remaining in the United States. Oak savannas provide many ecosystem services in regard to agriculture and carbon sequestration. Oak savannas benefit agriculture through runoff prevention, promoting water penetration and providing havens for native pollinators (Oldfield 2019, Letow 2013, Kelly 2020). In terms of carbon sequestration, oak savanna habitats store carbon in plant material above and below the ground. These ecosystems are fire adapted and tolerant to warmer and drier

climates which increases their resilience and ability to continue storing carbon amidst climate change (Dass 2018).

An oak savanna is a plant community in which the oak canopy coverage allows grasses and other herbaceous species to become the dominating characteristic of the understory. (Curtis 1959). Oak savanna ecosystems are native to the Midwest, but have been decreasing in range for roughly the past 200 years. Prior to European settlement in North America, there were roughly 11 to 13 million hectares of oak savanna habitat in the Midwest. In 1985, roughly 2,607 hectares of this habitat remained in the Midwest. This is approximately 0.02% of the previous range (Nuzzo 1986).

Although a large portion of oak savanna habitat has been completely lost due to human activity, some oak savanna remains in the form of remnant habitat. In areas where oak savannas have been completely lost, considerable effort has been made to restore these beneficial habitats. Remnant and restored oak savannas often differ due to the history of their management. Oak savannas are dependent on fire for optimal functioning. Without consistent management, the canopy and understory composition of oak savannas go through various changes (Spencer 2012). It is important to understand the varying oak tree and understory characteristics associated with remnant and restored oak savanna habitats in order to best inform future management. Additionally, understanding these differences can help predict the trajectory of a habitat's biodiversity and overall functioning when prescribed a certain management regime.

This study examined a remnant and restored oak savanna within two sections of the St. Olaf Natural Lands. The following objectives were used to guide this research project, 1) compare the number of oak tree seedlings, saplings and mature trees, oak tree species composition and oak tree size between sites 2) compare understory species composition and the

percent coverage of common species between sites, and 3) determine if there are significant variation in oak tree or understory characteristics between the two sites.

Methods

At the remnant and restored oak savanna sites, two $20m^2$ plots were selected randomly. These $20m^2$ plots were used to count the number of oak seedlings (height<0.5m), saplings (height > 0.5m and DBH <13cm) and mature trees (DBH >13cm). The species of oak seedlings, saplings and mature trees were also identified in the $20m^2$ plots. Additionally, the DBH was recorded for each mature oak tree. These $20m^2$ plots were 30m away from any edges to avoid edge effects. Within each of these $20m^2$ plots, three $1m^2$ plots were randomly selected to measure the biodiversity and percent coverage of understory species.

R commander, for R 4.0.3 was used to run statistical analysis on the data. In order to analyze the differences between oak tree and understory characteristics between the two sites, several analyses of variance (ANOVA) were performed on the data. ANOVA tests were used on the following variables between the two sites: average number of red oak (*Quercus rubra*) seedlings/saplings/mature trees, bur oak (*Quercus macrocarpa*) seedlings/saplings/mature trees, average percent coverage of grasses, asters and yellow coneflowers. The biodiversity at each site was calculated using the Shannon and Simpson equations.

Results

Table 1 shows a complete list of the understory species found at each site. Grasses, asters and yellow coneflowers were the understory species found at both sites. Figure 1 shows the percent ground coverage of the understory species found at both the Coyote Ponds and Heath

Creek site. An ANOVA test was run on each of these understory species. The ANOVA test for average percent coverage of grass shows significant difference in coverage between the remnant and restored oak savanna sites, P=.018. The ANOVA test for average percent coverage of asters (P=.599) and percent coverage of yellow coneflowers (P=.451) shows insignificant variance between sites. Table 2 shows that the Coyote Pond understory has greater species richness and biodiversity (Richness=10, Shannon H=0.79, Simpson D=0.78) compared to the Heath Creek Understory (Richness=8, Shannon H=0.69, Simpson D=0.75). Table 3 shows the number of each understory species found in each site. The data in this table were used to calculate Shannon and Simpson indices.

Figure 2 and 3 show the average number of bur and red oak mature and seedling/sapling trees found at each site. An ANOVA was run on this data and found insignificant variance between the sites. Figure 4 shows the average DBH of all oak trees found at each site. There was no ANOVA run on the average DBH between the two sites. The average oak tree DBH is greater at Heath Creek (DBH=34.75) compared to those at the Coyote Ponds (DBH=23.43). Additionally, there is a greater range in oak tree DBH at Heath Creek (SD=21.30) than at the Coyote Ponds (SD=10.35). Table 4 shows a complete list of oak tree species found at each site. The oak species found at both sites were red oak and bur oak.

Discussion

This research found that oak tree and understory characteristics differ between the remnant and restored oak savanna habitats. One difference in oak tree characteristics between the two sites is the greater number of total oak species found at Heath Creek site compared to the Coyote Ponds cite. The two species found at both sites were red and bur oak. There was the same

average number of mature red oak trees at the Heath Creek and Coyote Ponds sites, but there was a greater average number of red oak seedlings/saplings at the Coyote Ponds site compared to the Heath Creek site. There was a greater average number of mature bur oak trees and bur oak seedlings/saplings at the Heath Creek site compared to the Coyote Ponds site. These differences could be partially due to the age and management history of each site. The Coyote Ponds site, which is restored, may have been hand planted with seeds and/or seedlings in recent years. The Heath Creek site is an older oak savanna and has primarily been seeded by its existing mature trees, which are mostly bur oaks.

Another important difference in oak tree characteristics between the sites was greater average number of oak trees and greater average DBH at Heath Creek compared to at the Coyote Ponds. Based on the relationship between oak tree DBH and crown radius, written about by Neil (1987), we can use our data to also infer greater percent canopy cover at the Heath Creek site compared to the Coyote Ponds site.

In terms of understory characteristics, we found significantly greater coverage of grasses at the Coyote Ponds site and greater number of woody species in the understory at the Heath Creek site. Heath Creek had a large number of buckthorn seedlings compared to the Coyote Ponds site where there were none. Additionally, the understory of the Coyote Ponds site had greater species richness and biodiversity compared to the Heath Creek site. These findings were consistent with literature from Noble (2020), who found increased presence of woody vegetation in oak savannas with greater canopy cover (>75%) and increased presence of grasses in oak savanna habitats with low canopy (<25%). In this circumstance, the greater canopy cover was associated with the remnant prairie site, where we found greater oak frequency, larger average mature oak DBH and more woody species in the understory. Conversely, lower canopy cover

was associated with the restored site, where we found lower oak frequency, smaller average mature oak DBH and increased grass coverage.

The management history in each site likely had an impact on the canopy closure and understory species composition at each site. The Coyote Ponds site has been managed with 3-5 year burn cycles to control reed canary grass, while the Heath Creek site has only recently been managed in the past two years with a burn. The oak tree and understory characteristics we found are consistent with other research regarding oak savanna response to similar fire regimes. Haney (2008) found that increased frequency of burn cycles results in decreased woody vegetation in the understory. Additionally, his research found more oak trees with DBH>5cm in areas where there was a history of fire suppression. Our research found a greater number of oak stems with DBH>5cm in the site with a history of fire suppression compared to the site with frequent fire management as well.

The increased richness and biodiversity in the restored oak savanna site is consistent with findings from Noble (2020) who found that oak savannas with intermediate canopy cover have the greatest biodiversity. Intermediate canopy was defined by Noble to be 25-50% coverage. Although we did quantify the canopy coverage at each site, Noble's definition of intermediate coverage seems most compatible with the Coyote Ponds site, based on our findings regarding average oak DBHs and the number of oak trees per $20m^2$ plot.

Conclusion

This study found differences in oak tree and understory characteristics between the remnant and restored oak savanna. However, the two oak savannas in this study do not necessarily represent the characteristics of all remnant and restored oak savanna habitats. Two

defining variables of the remnant and restored oak savanna are their ages and their management histories. Based on our research, these variables have an impact on both the oak tree and understory characteristics in each site. An important characteristic that they affect is the biodiversity of each site. In order to manage the Coyote Ponds and Heath Creek sites for maximum biodiversity, we recommend further research to quantify the percent canopy coverage. If the canopy cover is greater than 25-50%, we recommend thinning of the canopy to fall in the intermediate canopy coverage range, defined as 25-50% coverage. If the coverage is less than 25-50% we recommend decreasing burn intensity to promote seedling and sapling recruitment. However, the Heath Creek site requires an intense fire regime until buckthorn competition is reduced for oak seedlings or herbaceous understory species.

A comparison of the Heath Creek and Coyote Ponds oak savanna sheds light on some important ecosystem differences in response to varied management histories. We hope this research can be followed by additional studies on the specific ways that differences in oak tree and understory characteristics affect ecosystem functioning. Additionally, longer term studies should be used to explore how the remnant and restored oak savannas shift over time in response to management prescribed for their individual needs.

Acknowledgments

I would like to thank Kathleen Shea for her support during this project and her guidance in regard to understanding the St. Olaf Natural Lands management history. I would also like to thank Aidan Schoff and Amanda Stagg for their assistance with data collection.

Literature Cited

Curtis, J. T. 1959. The vegetation of Wisconsin. University of Wisconsin Press, Madison.

Nuzzo, V. 1986. Extent and status of midwest oak savanna: presettlement and 1985. Natural areas journal 6.2: 6–36.

Oldfield, O. 2019. Restoring the future. Springer International Publishing, Manhattan, New York.

Lettow, M. 2013. Oak savanna restoration strategies and their effects on light, vegetative cover, flowering forbs, and pollinator communities. ProQuest Dissertations Publishing.

Kelly, E. 2020. Effects of community composition on plant-pollinator interaction networks across a spatial gradient of oak-savanna habitats. Oecologia 193.1: 211–223.

Dass, P. 2018. Grasslands may be more reliable carbon sinks than forests in California. Environmental Research Letters. 13: 74027.

Spencer, J. 2012. An 8,000-year fire and vegetation history of an oak savanna in east central Minnesota. ProQuest Dissertations Publishing.

Neil, I. L. 1987. D.b.h/crown diameter relationships in mixed Appalachian hardwood stands. United States Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.

Noble, S. L. 2020. The influence of canopy cover and canopy heterogeneity on plant diversity within oak savannas. ProQuest Dissertations Publishing, Ann Arbor, Michigan, USA.

Haney, B. 2008. Gradient analysis of an eastern sand savanna's woody vegetation, and its long-term responses to restored fire processes. Forest ecology and management 256.8: 1560–1571.

Tables and Figures

Table 1. This figure shows a complete list of the understory species found at the Coyote Ponds and Heath Creek site. The three species found at both sites are grasses, asters and yellow coneflowers.

Coyote Pond	**Heath Creek**
Coyote Unknown #1	Heath Unknown #1
Coyote Unknown #2	Heath Unknown #2
Coyote Unknown #3	Heath Unknown #3
Bee Balm	Asters
Goldenrod	Yellow Coneflower
Asters	Black Berry vine
Yellow Coneflower	Annual Sow Thistle
Black Berry vine	Buckthorn Seedling
Annual Sow Thistle	
Queen Anne's Lace	

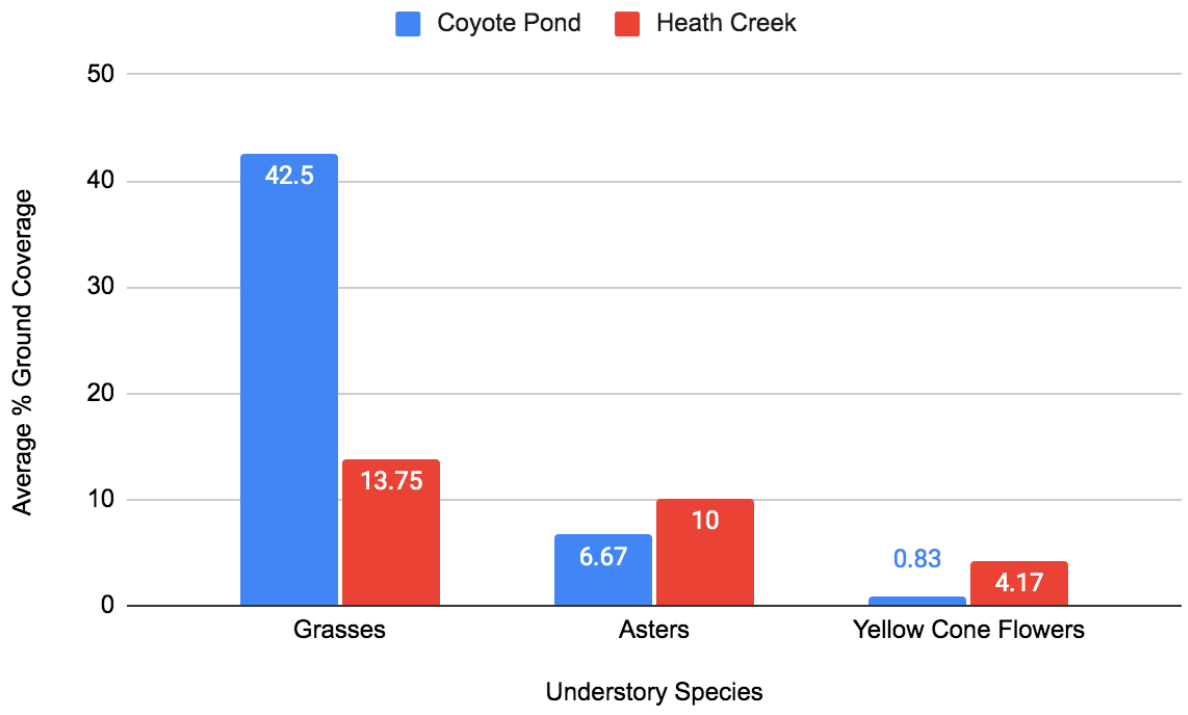

Figure 1. This figure shows the average percent ground coverage per plot of grasses, asters and yellow coneflowers located at the Coyote Ponds and Heath Creek Site (n=6 at each site). There is higher average percent coverage of grasses at the Coyote Ponds site and higher average percent coverage of asters and yellow cornflowers at Heath Creek site. Several analysis of variance tests showed that there is a significant variance in the coverage of grasses (P=0.018) and insignificant variance of asters (P=.599) and yellow coneflowers (P=0.451) between sites.

Table 2. This table shows the richness, Shannon and Simpson indices and variance in Simpson indices for each site. The Coyote Ponds site has greater richness and biodiversity compared to the Heath Creek site. No ANOVA was used to analyze the variance of richness and biodiversity between sites.

	Coyote Ponds	**Heath Creek**
richness	10	8
Shannon H	0.79	0.69
Simpson D	0.78	0.75
Variance of Ds	0.004702	0.001742

Table 3. This table shows the number of understory species found within each site. This data was used to calculate Shannon and Simpson indices.

	Coyote Pond 1			**Coyote Pond 2**		
Species	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3
Coyote Unknown #1		1	1			
Coyote Unknown #2			6	2		4
Coyote Unknown #3			3	1		
Bee Balm	2	5		3		3
GoldenRod	15	11	20	7	13	11
Asters		1		5	3	0
Yellow Coneflower						1
Black Berry vine						1

Annual Sow Thistle						1
Queen Anne's Lace		1				
	Heath Creek 1			**Heath Pond 2**		
Species	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3
Heath Unknown #1	3					
Heath Unknown #2		1				
Heath Unknown #3						2
Asters		7	11	10		1
Yellow Coneflower		11				
Black Berry vine	1					
Annual Sow Thistle						1
Buckthorn Seedling	33	10	3	23	6	30

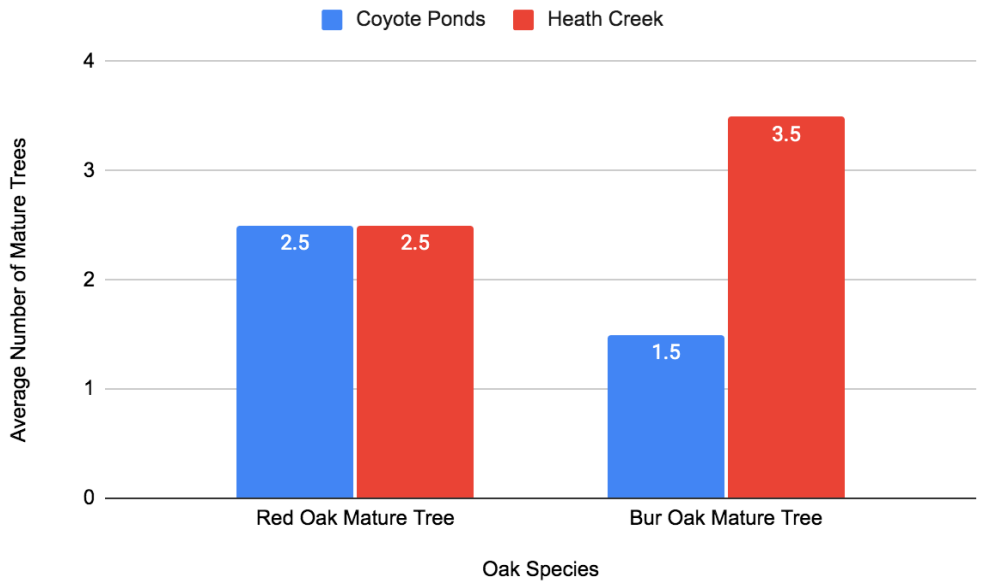

Figure 2. This figure is the average number of red and bur oak mature trees per plot at the Coyote Ponds and Heath Creek site (n=2 at each site). An ANOVA test showed no significant difference

in the average number of mature red or bur oak trees between sites, P=1.000 and P=0.106 respectively.

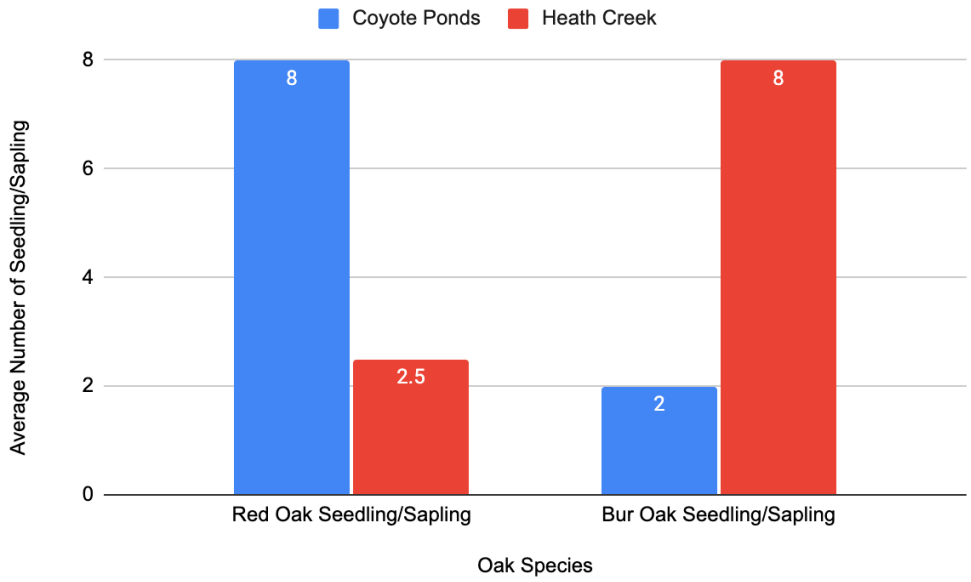

Figure 3. This figure is the average number of red and bur oak seedlings/saplings per plot at the Coyote Ponds and Heath Creek site (n=2 at each site). An ANOVA test showed no significant difference in the average number of red or bur oak seedling/saplings between sites. Red oak P=0.294 and bur oak P=0.272.

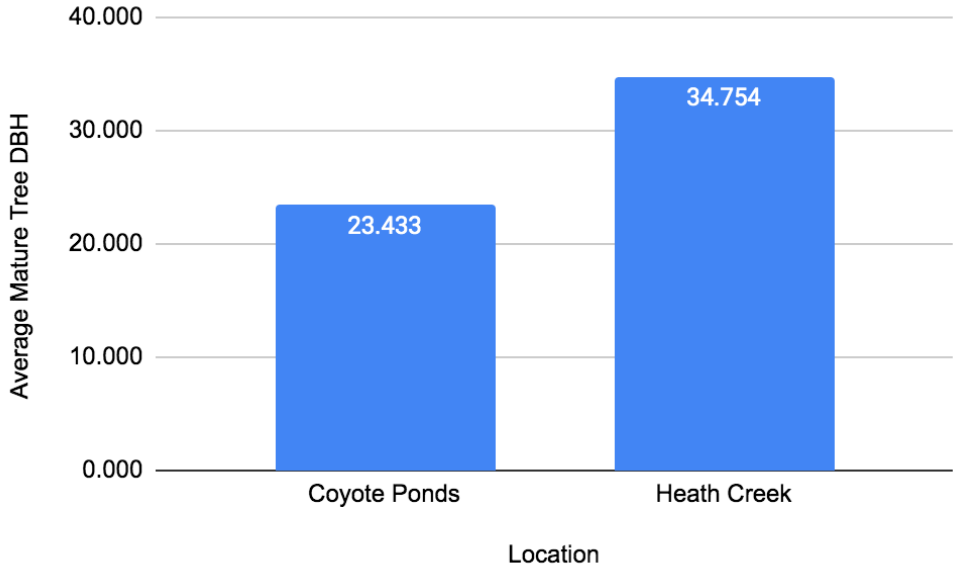

Figure 4. This figure shows the average mature oak tree DBH at the Coyote Pond (n=9) and Heath Creek site (n=13). Additionally, the standard deviation for average DBH is 10.35 at the

Coyote Pond site and 21.30 at the Heath Creek site. This shows that Heath Creek has larger average oak tree DBH and greater range of oak tree DBHs compared to the Coyote Ponds site.

Table 4. This figure shows a complete list of the oak species found at the Coyote Ponds and Heath Creek site.

Coyote Pond	**Heath Creek**
Red Oak	Red Oak
Bur Oak	Bur Oak
Chinkapin Oak	Pin Oak
	White Oak