The effects of deer browsing on species richness and density of an exclosure

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The University of Michigan Biological Station
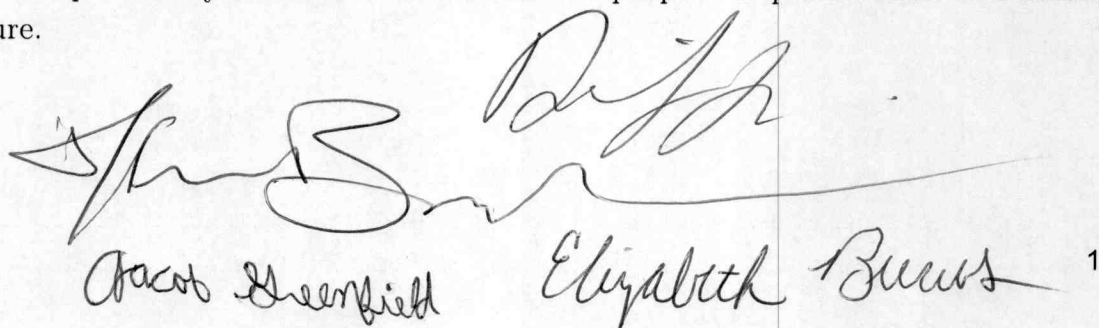EEB 381: General Ecology
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Abstract

In light of the high White-tailed deer (*Odocoileus virginianus*) population density in Michigan, it is important to understand how their browsing habits affect tree, shrub, and groundcover species growth. We hypothesized that areas with significant deer browse would have less species richness and density than areas deer were not able to browse. The forested area we surveyed at the University of Michigan Biological Station in Pellston, Michigan, had a deer exclosure built 17 years ago, which allowed us to compare the effects of deer browse over time with the exclosure area as a control. We recorded groundcover species, tree species density and tree diameter at breast height (DBH) both inside and outside of the deer exclosure. Trees that were browsed outside the exclosure were also identified and recorded. We did not find any statistical difference in woody or herbaceous ground cover species density and richness. We also found that, although certain species of trees were more likely to be browsed than others, the browsing preference at the site did not follow previous research on deer preference.

Signed,

Introduction

Old growth forests in Northern Michigan were destroyed following severe logging and fires in the early 1900's, resulting in vast new open areas. Because of this, an opportunity for new browse resources and edge habitats emerged. This, combined with an expansion of agricultural land area, resulted in a minor drop and then major increase in the populations of many mammals in Northern Michigan, including white-tailed deer (Meyers and Lundrigan, 2010). Furthermore, the extermination of many large predators in the Great Lakes region has led to historically high deer densities (Rooney and Waller, 2003). White-tailed deer densities are twice as high as predicted pre-settlement densities (Doepker et al. 1996). Rooney and Waller (2003) found that deer browsing could limit the regeneration of woody and herbaceous plants and thus alter species distribution. Horsley et al. (2003) concluded that increasing ungulate density could result in changes in the abundance of specific woody and herbaceous plants because of ungulate browsing preference. Ungulate-preferred species usually experience greater mortality over time, as shown by Heinen and Sharik (1990) and Heinen and Currey (1999). The consequences of browsing can be significant, as ungulates have the capacity to alter development and succession patterns of a forest (Laskurain et al., 2012).

The objective of this study was to examine the effect of deer browsing on the richness and density of plant species in a forest at the University of Michigan Biological Station (UMBS), in Pellston, Michigan (Heinen and Vande Kopple, 2003). Data was collected in a forest on UMBS property that naturally burned in 1911. Since then, multiple control burns have been executed to study forest succession. In 1998, the most recent plot was burned and a deer exclosure was built inside it to prevent any deer from browsing in the area. A deer exclosure was built within the 1911 plot (also in 1998) to be used as a control plot to further study the effects of deer browsing in old growth forests compared to a forest beginning to grow. Up until 1998, the area considered to be "within" the exclosure was indistinguishable from the area "outside" the exclosure as there was an 87-year growing period with equal levels of browse after the burn in 1911. This is why our study concerns the effect of deer browsing in the past 18 years, when the two areas have been separated.

In a previous exclosure study, Horsley et al. (2003), found that deer browsing had a negative effect on vegetation even at low densities. This was comparative to the higher densities observed in 2003, indicating that even at low densities deer browse can negatively impact vegetation. An altered trajectory of vegetation development was also observed when comparing the impacts of various deer densities. Specifically, the study concluded that deer browsing had a significantly negative effect on the growth and

abundance of bigtooth aspen (*Populus grandidentata*), American beech (*Fagus grandifolia*), striped maple (*Acer pensylvanicum*), and red maple (*Acer rubrum*). As early as 1961, the U.S. Forest Service was conducting deer exclosure experiments and showed that the area within the exclosures had considerably higher species density (Shafer et al. 1961). Based on this research and previous class labs regarding mammalian browsing behavior, we hypothesize that deer browsing significantly reduces plant richness and density, potentially altering the succession pattern of the forest.

Materials and Methods

For this experiment, our group sampled the original 1911 burn plot. This plot is considered the control plot, and it has not been touched since it burned in 1911, except for the erection of the deer exclosure in 1998. Our experiment had three foci: plant richness and density, tree richness and density, and evidence of deer browse. Data relevant to species richness and density was collected inside and outside the deer exclosure. We began inside the exclosure by gathering data on the ground cover species. We measured two 20m transects making sure to be away from the edges of the exclosure to eliminate any skewing of data due to possible edge effects. Edge effects can include smaller species passing through the fence to eat plants along the edges or species of plants outside blending with the inside due to their close proximity. Along each 20m

transect, we set up ten 1m x 1m quadrats, alternating sides as we moved down each transect. We recorded species of vascular plants, tree seedlings, and tree saplings that were not taller than 1m. Outside the exclosure we performed the same methods with some adjustments to transect size. Two 30m long transects were measured and fifteen 1m x 1m quadrats were placed, alternating sides down the length of each transect. We also recorded species of vascular plants and tree seedlings which we classified as shorter than 1m. In total, data were recorded from 200 1m^2 quadrats in order to measure seedling and sapling density and richness.

Tree richness and density was recorded to determine if there was a difference inside versus outside the exclosure using transects. Inside the exclosure, a 30m transect was laid with six 5m x 5m quadrats alternating sides down the length of each transect. In each quadrat, we recorded tree species and diameter at breast height (DBH). Outside of the exclosure, a 45m transect was laid with nine 5m x 5m quadrats alternating down the length of each transect. Tree species and DBH were also recorded for these trees.

Finally, we collected information about deer browse outside of the deer exclosure. Five circular plots were set up with a radius of 5m. In each circular plot we observed trees and saplings for deer browse. For each type of sapling, we recorded whether or not browse had occurred by examining the terminal buds on the saplings; if the saplings

were missing terminal buds, we would infer that they had been browsed. Since no deer

can enter the exclosure, it was used as a control to compare the level of browse on trees

outside of the exclosure.

Statistical Methods

We calculated plant species density and richness using the following methods; all

statistical tests were computed using R. The element counts, defined as m_i, are

represented by each individual plant species. The element counts, m_i, are obtained from

n independently and randomly selected quadrats, each of area a, along transects of

varying lengths. So

$$\bar{m} = \frac{1}{n} \sum_{i=1}^{n} m_i$$

is an estimator of the number of each plant species per quadrat, and $\hat{\lambda} = \frac{\bar{m}}{a}$ is an

estimator of the number of each plant species per unit area a. It follows that the

variance of $\hat{\lambda}$ can be estimated as:

$$\hat{V}(\hat{\lambda}) = \frac{1}{a^2} \hat{V}(\bar{m}) = \frac{1}{a^2} \frac{s_m^2}{n}$$

where

$$s_m^2 = \frac{\sum_{i=1}^{n}(m_i - \bar{m})^2}{n - 1}$$

Once the average density of each plant species was calculated, we determined

whether or not there was a statistically significant difference between the density inside

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and outside of the deer exclosure. We attached a bound on error of estimation, which

was estimated by:

$$B = 2 * \sqrt{\hat{V}(\hat{\lambda})}$$

We had to state a probability, $(1 - \alpha)$, that would specify the proportion of times

sampling would have to be repeated until the error of estimation was less than B. When

we estimated the average density of a plant species inside and outside the deer

exclosure, we added and subtracted the bound on error of estimation to each estimator,

and formed two 95% confidence intervals; if the intervals had overlapped, our results

were not significant at the 5% level. It seems here that there is no difference between

our statistical methods and a paired t-test comparison. However, the elements we

measured were distributed randomly over the area of the burn plot. We simplified our

results by taking into account the randomness of the elements (we are assuming the

elements m_i to have a Poisson distribution). The assumption of randomly disbursed

elements allows us to operate with the above estimators (Scheaffer et. al. 2006).

Results

As shown in Table 1, with the exception of *Cyanococcus* and *Gaultheria*, the

species for which we created estimators were not statistically significant at the 5% level.

We failed to reject our null hypothesis, which predicted a higher species density inside

the exclosure than outside. There was no difference between species density inside and outside of the exclosure except for blueberries and wintergreen, which were significant inside and outside of the exclosure respectively. This can be seen visually in Figure 1, where we see large differences in blueberry and wintergreen densities, and small density differences in other species. Since the deer exclosure is relatively new compared to the age of the forest, we did not observe any significant differences in adult tree abundance, or DBH.

Although it was not found to be statistically significant, our data showed that white pine was the least browsed of the tree species, and maples were not highly browsed either. Beech was shown to be the highest browsed tree species, despite beech being labeled 'browse resistant' by the Department of Natural Resources (see Table 2 and Figure 3; Department of Natural Resources, 2015) Also, there were several observations of deer pellets during our data collection.

Figure 2 shows the composition of species outside the exclosure by percentage. This, when compared to Figure 4 (Michaelson et al., 1996), shows the continued succession of the 1911 burn plot. Table 2 and Figure 3 show the comparison of high versus low browsing for different species of tree within the 1911 burn plot.

Table 1: *Average Density of Plant Species in 1911 Burn Plot*

(*)- Indicates significant difference

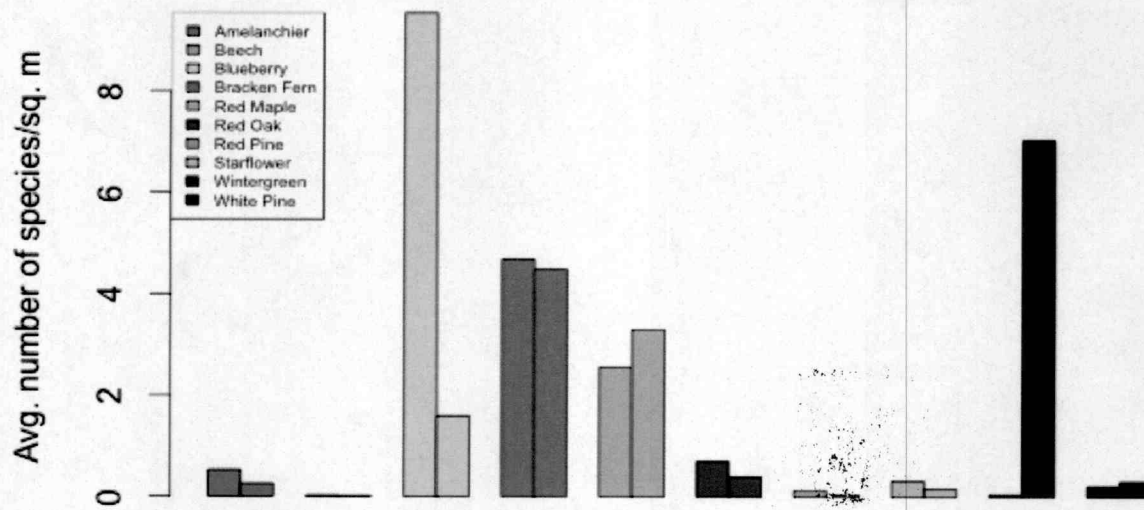| Species	Density inside the exclosure	Density outside the exclosure
Amelanchier (Serviceberry)	.525	.258
Fagus Grandifolia (Beech)	.025	.017
Cyanococcus (Blueberry)	9.562*	1.6
Pteridium (Bracken Fern)	4.688	4.492
Acer Rubrum (Red Maple)	2.563	3.3
Quercus Rubra (Red Oak)	.7	.392
Pinus Resinosa (Red Pine)	.125	.042
Ipheion Uniflorum (Starflower)	.313	.158
Gaultheria (Wintergreen)	.05	7.05*
Pinus Resinosa (White Pine)	.213	.3

Figure 1: *Average Density of Plant Species in 1911 Burn Plot (Left Column is inside the Exclosure)*
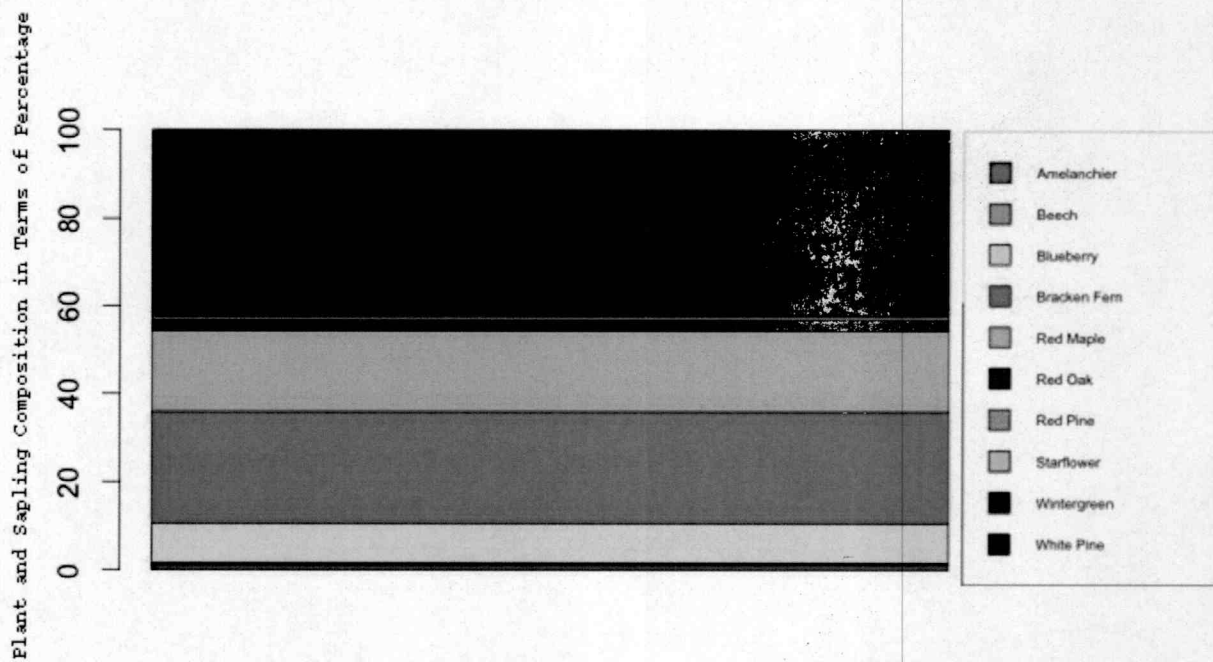

Figure 2: Composition of Herbaceous Species, Tree Seedlings and Tree Saplings (outside the exclosure)

in Terms of Percentage, Observed in 2015

Table 2: *Browsing Levels by Species*

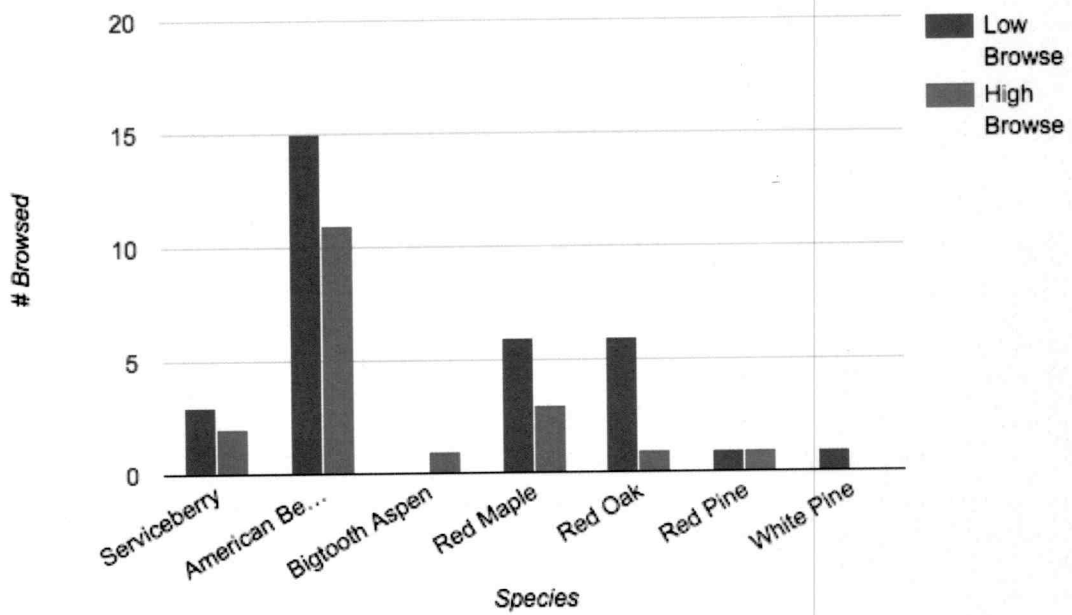|	Low Browse	High Browse
Amelanchier (Serviceberry)	3	2
Fagus Grandifolia (American Beech)	15	11
Populus Grandidentata (Bigtooth Aspen)	0	1
Acer Rubrum (Red Maple)	6	3
Quercus Ruba (Red Oak)	6	1
Pinus Resinosa (Red Pine)	1	1
Pinus Resinosa (White Pine)	1	0

Figure 3: High versus low browse comparison for tree species in the 1911 UMBS burn plot.

Discussion

Due to this forest (both inside and outside the exclosure) being mostly a late secondary successional area, many of the bigtooth aspens, the deer's preferential browse species (Heinen & Sharik, 1990), were either too tall for a deer to be able to browse or in the process of dying. It is likely to find different species such as American beech and red maple to appear to be browsed more, however we only observed this without testing for significance. (See Table 2 and Figure 3). There were no statistically significant results regarding which of these different species was browsed the highest or lowest, but it is apparent that bigtooth aspens are no longer a staple of the deer diet within the 1911 plot.

However, this does not appear to have always been the case. As we can see in Figure 4, the tree species graph (on the right) shows an early successional abundance of bigtooth aspen, and later years show successional distributions with smaller and smaller bigtooth aspen populations. These graphs, created by Michaelson et al., were a result of a 1996 study observing the species composition of three burn plots. The third column (85 years since burn) demonstrates the composition of species in the 1911 burn plot. The graph on the left of Figure 4 shows the composition of herbaceous ground cover. The addition of our data in Figure 2, despite our addition of seedlings as groundcover species, does not elucidate any significant trends in herbaceous plant species over time

and succession. We can see, however, that the trees in Figure 4 are seeing a decrease in bigtooth aspen, amelanchier, and red oak, whereas white pine numbers are increasing. We also suspect that the red pine population that we observed in the burn plot has also been increasing. Unfortunately, Michaelson et al. did not include red pine in their study, in spite of the presence of very old red pines in the 1911 burn plot, some with a DBH greater than 30cm.
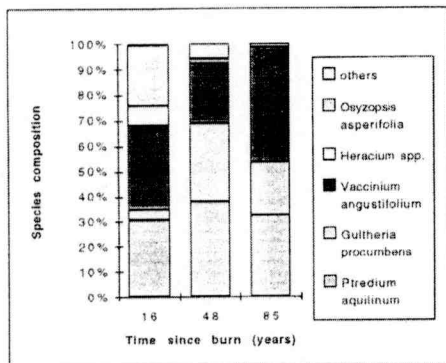

Figure 2. Composition of herbaceous vegetation with increased time since the plot was burned (X^2=955, df=12, p<0.001).
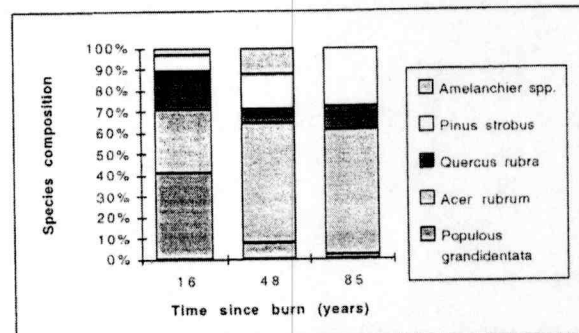

Figure 1. Composition of woody vegetation with increased time since the plot was burned (X^2=179, df=8, p<0.001).

Figure 4: Historical Species Composition in the UMBS Burn Plots. (Courtesy of Michaelson et. al. 1996)

According to the Michigan Department of Natural Resources (DNR), deer prefer maples and white pines to many other species. Interestingly, our data showed almost the opposite (Table 2, Figure 3). The DNR listed aspen and oaks as medium browse preferences; these species also had little evidence of browse.

As shown in our results, the species we found to have the highest levels of browse was beech. According to the DNR, this species is a "starvation food" because it is only consumed when other preferred foods are no longer available. Beech is considered a browse-resistant tree species, as they are not highly preferred by deer, yet in the 1911 plot this is the highest browsed species. High levels of oaks, red maples and white pines—deer's preferred food sources, were available, but the deer still chose to eat the beeches. One possible explanation for this is height of the beech saplings. Many of the maples and oaks we observed were seedlings and remained untouched. The beech saplings we found were usually between 1m and 2m tall, possibly indicating a browse height preference. More studies would need to be done to explore the relationship between browse preference and its relationship to browse height.

While sampling in the 1911 burn plot, the presence of deer pellets indicates an active presence of deer. While we could say that deer browsing between data collections could have led to error in our results, we do not believe this constitutes a legitimate source of error because we are examining different levels of species richness and density, which is not likely to change significantly in the span of a few days.

Mistaken identification of browse may have complicated our results, especially young red or white pine. It was often difficult to distinguish between a browsed pine and a young pine that has perhaps begun aborting its lowest branches. Also, the

presence of cottontail rabbits (*Sylvilagus floridanus*) and snowshoe hares (*Lepus americanus*) could have led us to misidentify the browse of plants as solely deer browse. Over the winter season, cottontails and snowshoe hares browse woody and herbaceous understory growth (Mikita, 1999). We do not believe this was a factor for many of the tree saplings, but the short height of the *Amelanchier* may have been attractive to cottontails and hares wintering in the area.

Because the exclosure was built in 1998, 87 years after the burn took place, many of the species within the exclosure plot already had time to establish themselves prior to it being built. While there were generally more numbers of each species within the exclosure, there was not a large enough difference to consider the results statistically significant. The deer may have an effect on the density of species outside the exclosure but we cannot confirm this, perhaps due to the short time between when the exclosure was built and the present (17 years). With more time it is likely that the density of species within the exclosure will increase significantly versus outside the exclosure as deer continue to browse on the undergrowth. Species diversity could be affected as well if a certain species is continually browsed on and is forced out of the plot by competitive exclusion. Also, because the established trees at the site create new seeds every year, there will likely be seedlings of these species each spring, making the forest more resilient to browse disturbance.

Although Heinen and Currey (1999) showed that increased browsing on preferred species increases mortality over time, our results do not show a significant difference in species distribution, indicating that there has not been a significant increase in mortality in species outside the exclosure since the exclosure was built, despite the obvious browsing. Lyon and Sharpe (2007) conducted an experiment using deer exclosures on a clear cut, and concluded that deer browse did not result in a significant difference in species distribution or mortality. A significant relationship between species richness and soil chemistry was discovered, where forests with nutrient and mineral content conducive to species growth would have greater species richness. This leads us to suggest that a further study in the area should include soil chemistry analysis. It may follow, as Lyon and Sharpe speculate, that the soil chemistry influences species richness more than deer browse. Soil chemistry is likely to be the same inside and outside the exclosure due to the 87 years after the burn in which there was no ecological divide or exclosure. A factor that could have affected the soil chemistry in our study areas is the presence of deer pellets. At our site we observed many instances of deer pellets. Future chemistry soil analysis should take this into account and perhaps test specifically for nutrients present in deer feces.

We had a statistically significant value of more wintergreen present outside the exclosure compared to inside the exclosure, but the presence of wintergreen was

observably patchy and sporadic in both areas; this difference can most likely be accounted for by the uneven distribution of wintergreen. This error is most likely a result of the transect placement, where transects outside the exclosure intersected some of the very dense wintergreen patches, while transects inside the exclosure did not, despite the presence of similarly dense patches of wintergreen. This may have caused us to under-sample the wintergreen population inside the exclosure, biasing our results. Wintergreen are often found in acidic soils where large numbers of pines grow, and can also be found in high numbers where there is a healthy population of oak trees (Sullivan, 1983). Our plot location is becoming an old growth pine forest with an abundance of red and white pines. We also observed many oak seedlings inside and outside of the deer exclosure, creating a habitat conducive to wintergreen growth. However, we should have expected more wintergreen within the exclosure if deer are likely to browse them, especially during winter months. We did not find any evidence of browse on wintergreens outside of the exclosure. Sullivan (1983) does note that some seed dispersal of wintergreens can be attributed to deer, but more research would need to be conducted to draw a more definitive conclusion.

While surveying transects inside the deer exclosure, we came upon unknown species of plants we were unable to identify. We later found that these plants were solomon's seal (*Polygonatum biflorum*) and *maianthemum canadense*. We did not

include the samples in our data due to the fact that we did not know what these plants were and the small sample size of both species. Upon further research, we found that solomon's seal and maianthemum are considered to be indicator species in areas of high density deer populations (Holmes 2002). Holmes (2002) found that solomon's seal and maianthemum are more abundant in areas where there is little evidence of deer browse. We recorded solomon's seal and maianthemum within the deer exclosure, but we did not find any solomon's seal, and we found very little maianthemum outside of the deer exclosure along our transect plots. This is congruent with Holmes' (2002) experimental results. The lack of solomon's seal and maianthemum outside of the deer exclosure is further indication that deer are present, and are having an effect on the vegetation.

In general, white-tailed deer tend to prefer early successional habitats that have high amounts of brush, shrubs, and grasses (Rawinski, 2014). The adjacent 1998 plot, because it was burned so recently, is preferential for food because of the availability of these types of plants, especially *Populus Grandidentata,* a preferred early successional species (Heinen and Currey, 1999; Garthe et al., 2014). Between the 1911 and 1998 burn plots is a dividing area with less plant density due to the clearing made in preparation of the 1998 burn. This has likely created an edge effect along the east side of the 1911 plot. Deer may be browsing along the boundary of the two plots because there are fewer large trees and more shrubs and brush. We did not measure this area

due to the edge effect possibility. However, because this plot is an old growth forest, deer may prefer these nearby areas of earlier successional growth. Data comparing the 1911 plot and the 1998 plot could be considered for future studies and may clear up this question.

Lastly, although deer densities have largely increased since the mid-1800's (Meyers and Lundrigan, 2010) we do not know the deer density in our particular area. Without knowing how often deer frequent our area, our results cannot serve as conclusive results for the region, but rather an interesting examination of the UMBS study site.

While the adverse effects of deer browse on species richness and distribution has been shown in numerous studies (Heinen and Sharik, 1990; Rooney and Waller, 2002; Garthe et al., 2014), our results show little evidence for this at the 1911 UMBS burn plot. This may be due to soil characteristics, the old age of the forest, unknown deer density, areas of higher browse preference in the vicinity, or the relatively young age of the exclosure. Future studies in this area would do well to take some or all of these considerations into account, and experimental results could increase confidence that deer browsing does have a significant effect on species density and richness.

Citations

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