The impact of deer browsing on tree growth, plant biomass and biodiversity

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Abstract

Herbivores have a major impact on the ecological communities they inhabit. In the past two decades, deer habitat in Michigan has increased significantly, thus intensifying the effects of herbivory. This study examines the impact of deer browsing on plant growth, abundance, and diversity. We conducted our research at the University of Michigan Biological Station, in a forest plot that was burned in 1998, where part of the site holds an enclosure that inhibits deer browsing. In order to examine the effects that deer have on tree growth, we compared the diameter at breast height and the number of branches below 2 meters for adult trees within and outside of the enclosure. Simultaneously, ground plant species in smaller sample plots were recorded, along with percent coverage. Our results showed that browsing did not have an impact on diameter at breast height, but the number of branches per tree was significantly lower for browsed trees. The data also supported our prediction that plant abundance was significantly lower outside of the deer enclosure. Future research could be done on the effects of browsing on the production of secondary compounds, canopy coverage, and how yearly fluctuations in deer population effect plant growth patterns.

Introduction

Herbivores have a large impact on plant communities and ecosystems (Marquis, 2004). While insects and mammals are the two most prevalent terrestrial herbivores (Huntly, 1991), mammals have a much greater impact because they consume significantly greater plant biomass (Crawley 1989). Gill and Beardall (2001) suggested that deer browsing reduces foliage and stem density, as well as growth of trees. Similarly, Anderson (1994) showed that deer browsing reduces the growth of Trillium, a ground level plant frequently browsed on by deer. Heinen and Currey (2000) suggested that continued browsing by ungulates lowers the abundance of vegetation.

Deer habitat in Michigan has increased significantly in the past two decades as a result of human alteration of the landscape (Waller and Alverson, 1997). With a larger niche to exploit, stricter hunting laws, and a lack of predators, the deer population has become a significant problem for ecological communities (Van Deelen et al., 1997). Increased deer populations have resulted in a large impact on browsed vegetation, as well as non-browsed plant species. An enclosure plot study by Horsley et al. (2003) showed that big tooth aspen, birch, American beech, striped maple and red maple trees were all negatively affected by deer browsing. Specifically, the browsed trees had lower heights and thinner trunk diameters on average, compared to unbrowsed trees. Species richness of browsed plants showed a negative linear trend. Conversely, trees that were not browsed upon by deer, such as black cherry, or species that were more unyielding to deer, were able to thrive outside the plot.

The University of Michigan Biological Station (UMBS) has a series of natural (1901, 1911 and 1923) and experimental (1936, 1948, 1954, 1980 and 1998) burn plots that are used to study plant succession after fire. Each experimental burn plot is around a hectare in size. The 1998 burn plot is particularly interesting because a 50m x 80m deer enclosure fence was established at the same time as the burn. The enclosure allows plants within to grow with minimal interruption from deer.

There have been many studies in different geographic regions that use enclosure plots to examine the effects of herbivores on an ecosystem. In northern Spain, Laskurain et al. (2012) found that enclosure plots inhibit domestic sheep grazing. The study showed that domestic sheep impact the abundance and growth of large-seeded sapling species, such as beech trees. Schultz and Leninger (1990) studied the effects of livestock grazing in north-central Colorado. Their results showed that enclosed areas had greater vegetation and canopy cover than unenclosed areas. Within the enclosure plots, willow trees, pine trees, and several other woody plant species were more abundant. Additionally, the enclosure plots had two times the leaf litter, while areas outside the plots had four times more bare ground. At a forest site in Pennsylvania, Brose et al. (2012) focused their study on oak sapling growth. They found that saplings within an enclosure plot grew to be taller than plants outside the enclosure. The authors attributed the results to the lack of deer browsing within the enclosure plot, since Pennsylvania, like Michigan, has a problem with deer overpopulation.

Given the information available on mammalian browsing and the accessibility of the UMBS enclosure plot, this project aims to study the effects of deer browsing on individual plant growth, as well as how browsing affects the composition and abundance of plants within the ecological community. We hypothesize that deer browsing should significantly limit tree growth and reduce plant biomass and biodiversity. Specifically, we expect that tree growth and both plant biomass and biodiversity to be greater within the enclosure.

Methods

Field Methods

Within the 1998 burn plot, we took several measures to compare tree growth and plant biomass and biodiversity (BMBD) inside and outside of the deer enclosure. To measure tree growth, we randomly sampled 20 5m x 5m plots within the enclosure and 20 5m x 5m plots outside of the enclosure (see Figure 3 for a map of the locations). We identified and measured the diameter at breast height (DBH) for all adult trees, as well as length of each branch below a stem height of 2m in order to obtain the best estimate of tree growth. We expected DBH to be lower outside of the enclosure, considering that heavily browsed trees will place less energy into somatic growth and will instead divert energy into forming secondary compounds to combat herbivores (Swain, 1977). Number of branches and branch length were recorded as indicators of browsing levels, since branches in heavily browsed areas should take longer to grow if the apical meristem has been removed during browsing (Kribel et al., 2011). We measured branches at or below 2 m because branches above this height on the tree are presumably out of reach of the deer.

To measure plant BMBD, we sampled 48 1m x 1m plots within the enclosure and 48 1m x 1m plots outside of the enclosure along 32 30m transects. We identified the number of species and estimated the percentage of plant coverage for each of these plots. Species richness and abundance were measured to observe the extent to which deer browsing limits plant regeneration and affects overall biodiversity and composition of an ecosystem.

Statistical Methods

Five independent sample t-tests and a Chi-squared test were performed on the resulting data. The average DBH of trees from within the enclosure was tested against the average DBH from trees outside the enclosure using a t-test. Similarly, tree species density, average branch length, number of branches, and percent coverage of plant biomass were compared using t-tests. The Chi-squared test was used to examine the distribution and diversity of ground plants in each sample plot.

Results

The data supported our hypotheses that plant BMBD and number of tree branches would be lower outside of the enclosure. There was a significant difference between the BMBD outside of the enclosure and within the enclosure ($p < 0.05$); this result was supported by both the Chi square test and t-test. There was a significant difference in the average number of tree branches between the inside and outside of the enclosure ($p < 0.05$). Our other three hypotheses—that tree DBH would be lower outside of the enclosure, tree species density would be lower, and average branch length would be lower–were not supported by the data, as there was no statistical significance ($p > 0.05$).

Discussion

Our findings lead us to reject three of our hypotheses. The hypotheses not supported by our data were those that predicted deer browsing would lead to a significant reduction in tree diameter, average branch length, and tree species richness outside of the enclosure. However, our results support three of our hypotheses—that deer browsing reduces the number of tree branches and the abundance and species richness (plant BMBD) of ground cover plants outside of the enclosure.

The number of branches on each tree was used as an indication of tree growth. In periods of stress, trees have been shown to forego branch growth and focus primarily on stem growth (Logan, 1965). When environmental stressors are low, trees grow in a normal fashion; when stress levels are high, energy is focused towards stem development (Schoengart et al., 2002). Therefore, we would expect trees within the enclosure plot to grow more branches, since they are not faced with the stress of deer herbivory. For trees outside of the enclosure at the UMBS burn plot, the optimal time to put energy towards branch growth would be when deer populations are at their lowest point in the yearly cycle. Deer populations are lowest in early spring, as a result of the die out that occurs during the winter months when resources are scarce. Once vegetation is in full bloom in late spring and early summer, deer populations are able to increase along with the increase in nutrients available, and by late autumn deer populations are at their peak. At the time of this experiment, deer populations in northern Michigan were still not at peak numbers (Rudolph, 2013). To see an even more staggering difference in number of branches, sampling again later in the year might maximize the difference between areas inside and outside of the enclosure, since at that point in the year trees outside of the enclosure would be devoting limited energy to branch growth.

Our test results showed plant BMBD to be significantly lower outside of the enclosure. Braken ferns (*Pteridium aquilinum*), wintergreen (*Gaultheria procumbens*), and blueberries (*Vaccinium* sp.) were the three most common plant species observed at the study site, both inside and outside the enclosure. Each of these plants was more heavily abundant inside of the enclosure plot (see Figures 1 and 2), which we attribute to a preference of deer to browse upon herbaceous plant matter as opposed to trees. In a study by Hygnstrom et al. (2009), researchers found that deer prefer to browse on non-timber forest products such as food, as opposed to trees and other woody plants. This is consistent with our results that deer have an impact on BMBD, since they prefer the non-timber species of the burn plots, such as blueberries and wintergreen. In addition, Wakeland and Swihart (2009) suggested that deer prefer to browse on oak trees over other species. As there were a limited number of oak trees within the burn plot, it is possible that the deer chose to browse on ground plants instead of the trees present. It is also possible that the level of secondary compounds produced by trees may be higher—and thus more toxic to deer—than those produced by the herbaceous plants within the site (Robins et al., 1987). Further study is necessary to determine how secondary compounds may affect deer browsing within our sample area.

Significance for BMBD may also stem from the fact that ground plants are smaller in size and lower to the ground than trees. Therefore, it is easier for deer to browse them as opposed to trees with higher foliage (Kribel et al., 2011). Additionally, due to the size of the herbaceous plants, they are more at risk of being over-browsed or completely uprooted by deer. Browsing damage for trees occurs by removing the meristem, and repeated browsing and removal needs to occur before there is significant damage (Kribel et al., 2011).

According to our data, there was no significant difference in tree DBH inside and outside of the enclosure, which may reflect the fact that trees invest the most energy into growing leaves towards the top of the canopy, since this is the portion that receives the most direct sunlight (Terjung & Louie, 1973). Canopy-level leaves most efficiently perform photosynthesis. Large enough trees have canopies that are too high up for deer to access. Therefore, once trees reach a certain height, they are able to photosynthesize even while being browsed upon. Thus, tall trees are still able to obtain sufficient nutrients to increase trunk girth, regardless of the presence of mammalian herbivores (Hartnett et al., 2012).

Our hypothesis that average branch length would be significantly lower outside of the enclosure was not supported by our data. Average branch length may in fact not be a suitable measure to observe deer browsing effects on trees. Branches of small saplings are likely to be completely removed if browsed upon, and thus would not have been included in our data set. Moreover, when deer browse upon mature trees they tend to defoliate the branches but leave the woody plant matter intact. Therefore, branch length may not be as relevant a measurement record as initially believed. If the experiment were repeated we would not include this variable in the experimental design.

Test results for tree species richness inside and outside of the enclosure showed no significant difference. This result might be explained by the young age of the burn plot forest. The controlled burn for the site was performed less than a decade ago, and the plot is still in its primary successional stage. Therefore, tree species richness can be expected to be inherently low, with or without occurrences of deer browsing (Moral, 2007). If a similar experiment were performed once several decades had passed, we would expect to observe a more drastic level of variation for woody plant species richness.

Possible sources of error for this study may include misreading of DBH, measuring trees outside of the designated plots, measuring stems multiple times in the clusters, and under or overestimation of percent coverage. If this experiment were repeated, we could reduce these possibilities of error by marking out the borders of each plot with string, in order to eliminate any confusion about which trees to include. We could also mark each branch that has been measured in order to avoid recounting or skipping over branches.

If this experiment were replicated, it would be useful to measure the concentrations of secondary compounds in each plant species at the burn plot. Measuring this additional variable would give us an indication of whether secondary compound levels were partially responsible for the observed preference deer had for herbaceous plant matter. Another possible change in the experimental design would be to alter the timing of data collection. Sampling in late autumn may lead to different results, since deer populations are at their peak in October and November (Rudolph, 2013).

Canopy coverage is another variable that could be measured in future studies, in order to examine how browsing affects tree development and foliage levels. At the time of our experiment, the leaves had not flushed out enough to measure canopy coverage. However, this would be a valuable measure to add to the experimental design. Canopy density determines the level of light that reaches the forest floor. Therefore, wooded areas that are heavily browsed would be expected to have more sun-tolerant groundcover plants; shade-tolerant plants, on the other hand, may be expected in wooded areas with less animal herbivory (Hubbell et al., 1999).

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Tables and Figures

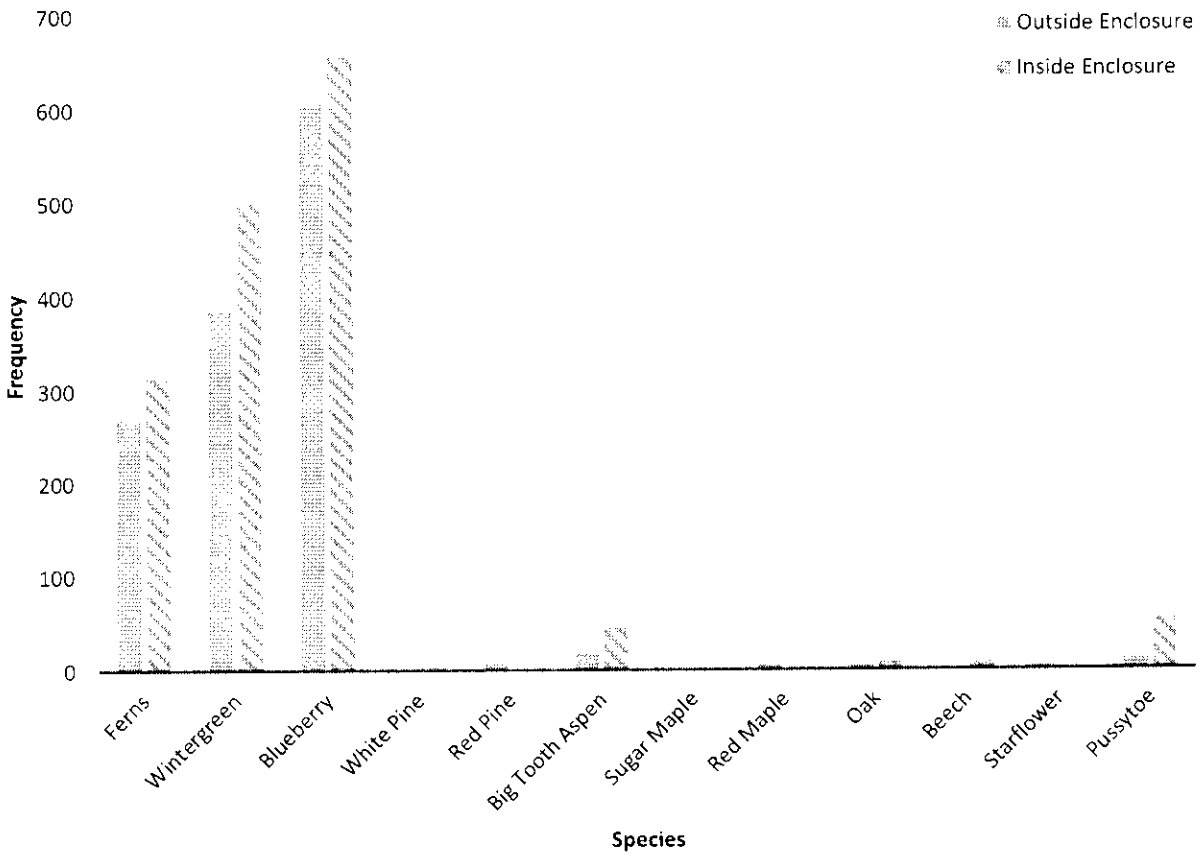

Figure 1: Distribution of Ground Plants/Saplings at the 1998 burn plot

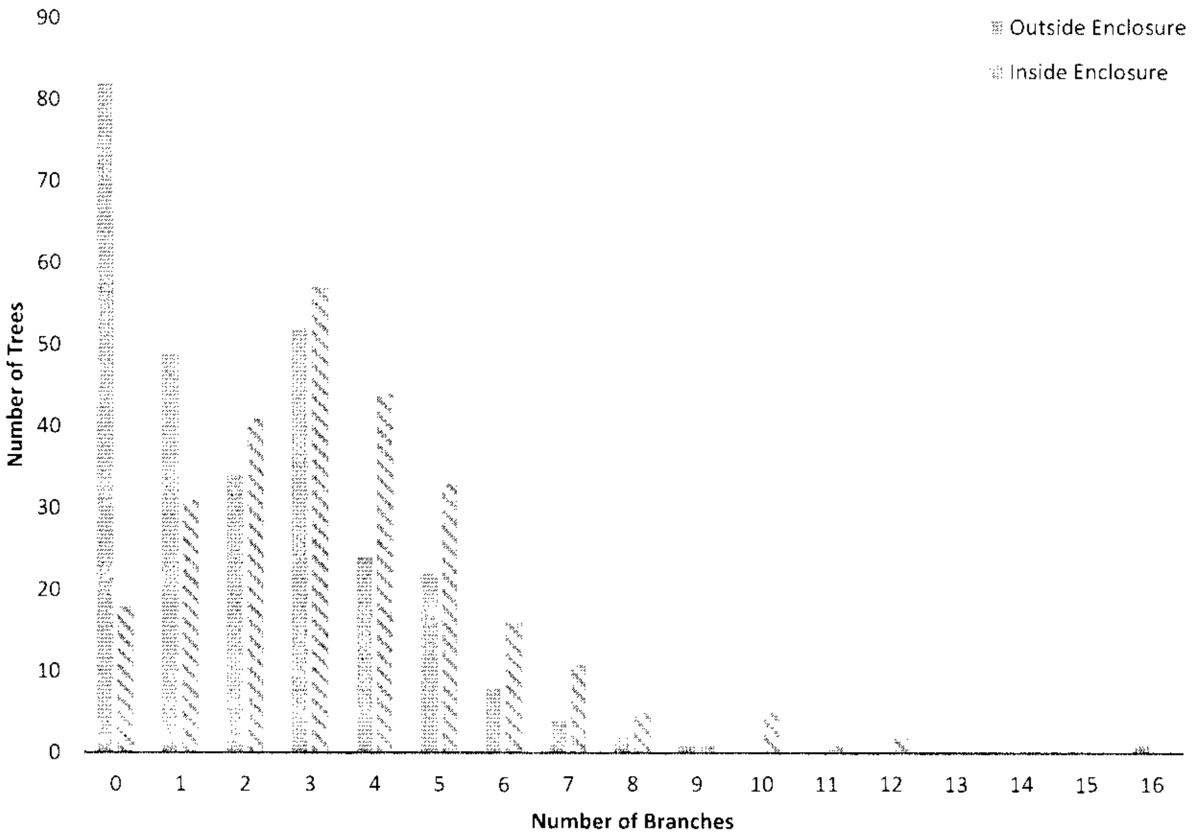

Figure 2: Frequency of trees by number of branches at the 1998 burn plots

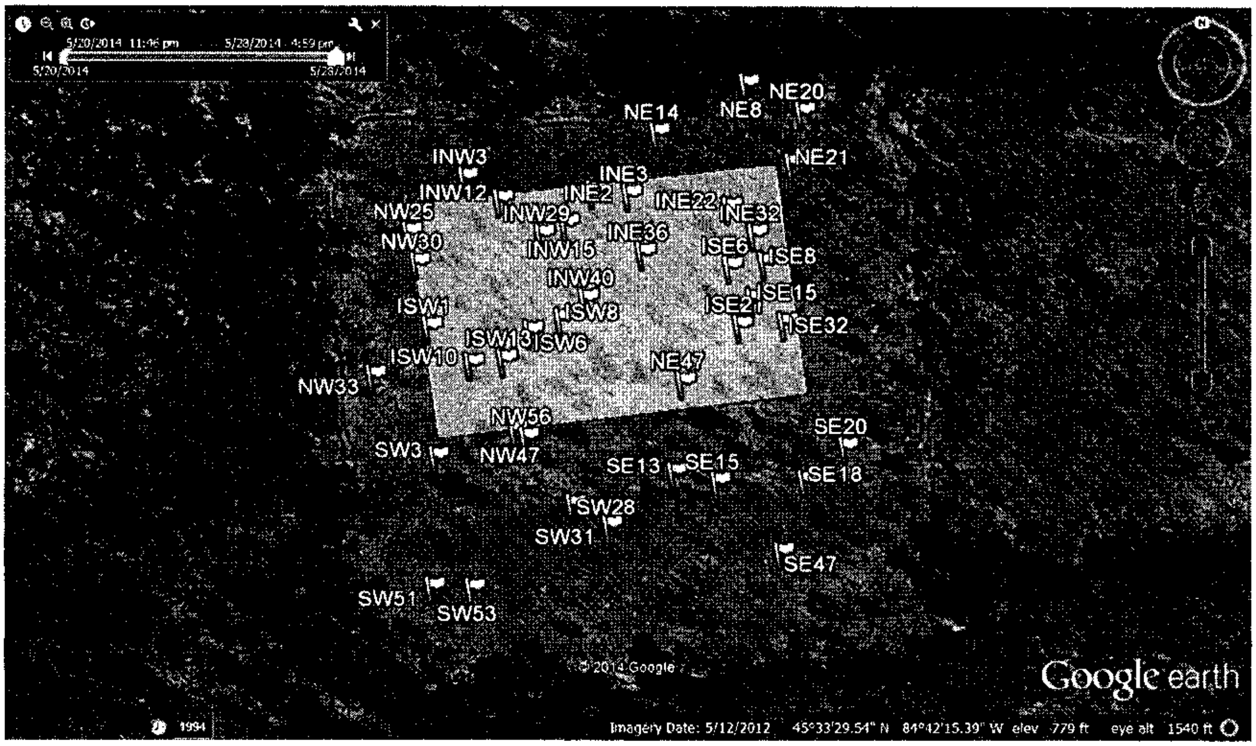

Figure 3: Sample plots at the 1998 burn plots, each measuring 5m x 5m