Preferred Areas of Deer Browsing in Relation to Canopy Cover and Forest Gaps.

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Abstract

In the absence of natural disturbance and logging, gaps are the major source of shade–intolerant regeneration in forests. This study tested if White-tailed deer (*Odocoileus virginianus*) browsing at the University of Notre Dame Environmental Research Center (UNDERC) impacts gaps more than surrounding forest sites. I identified and measured tree species inside and outside of gaps, and estimated browsing pressure to determine if deer browse preferentially in gaps or in one canopy type over another. Data were collected in five gaps each of three canopy types: sugar maple (*Acer sacharum*) dominated, quaking aspen (*Populus tremuloides*) dominated and balsam fir (*Abies balsamea*) mixed canopy. Each gap was paired with a control of the same canopy type. I found that canopy type does influence sapling size and deer browsing pressure; deer preferentially browsed at maple canopy type as compared to balsam fir or aspen canopy types. However, no significant differences were discovered between stem height in gaps and controls. Because I found that browsing pressure was actually lower in gaps, my research indicates that, currently, deer populations do not significantly impact gap regeneration at UNDERC.

Introduction

The population of white-tailed deer (*Odocoileus virginianus*) in the northern hardwood forests of Michigan's Upper Peninsula has increased over the past 80 – 90 years, reaching levels greater than those present before European settlement (Christensen 1963). This increase followed a period of near extinction at the turn of the 19th century and has been aided by stricter hunting laws and land management practices that favor forests capable of supporting large deer populations (Haufler 1996). The increase in deer population, numbers and density, impacts the abundance, distribution and relative size of many plant species (Fowler et al. 2001).

Deer are able to choose browse based on the plant's ability to provide nutrition and energy (Klein 1970, Berteaux et al. 1998). The documented preference deer show for eastern hemlock (*Tsuga canadensis*) and northern white cedar (*Thuja occidentalis*) over balsam fir (*Abies balsamea*) is an example of this. Because balsam fir is less nutritious and deer can not survive on it as the sole source of browse (Ullrey et al. 1968), it is eaten less often by deer (Borgmann et. al 1999). Another feeding preference shown by deer is the tendency to feed on younger vegetation as well as on vegetation in early successional stands. Young plants are growing vigorously and sequester more nutrients in their tissue, increasing their value as browse for herbivores such as deer (Klein 1970). Disturbed areas receive more light, which facilitates increased plant growth (Kneeshaw and Bergeron 1998). Disturbed areas also have less competition from larger trees for nutrients, increasing the available nutrients for the younger plants. The combination of feeding preferences results in the prediction that deer will feed more in disturbed areas dominated by preferred browse species.

The dominant natural disturbance that once controlled regeneration and succession within the northern hardwood forests of the upper Great Lakes region is gap dynamics. Kneeshaw and Bergeron (1998) define these gaps as the death of a single or multiple trees from the canopy level, resulting in an increase in light reaching the forest's lower levels. Prior to timber harvesting by humans, these forests lacked large-scale disturbance events that reduce the importance of gaps in a forest both by removing older and weaker trees that might create a gap and by recurring at intervals that create large-scale succession that renders gap dynamics a small portion of the regeneration cycle. The absence of large-scale disturbance, recurrence interval is over 1000 years (Frelich et al. 1993), is the reason that gaps were once so important in these forests (Lorimer 1989, Kneeshaw and Bergeron 1998). However, the entire northern hardwoods forest region was clear cut in the early1900's. Periodic timber harvesting now creates areas of regeneration on a regular basis, creating anthropogenic cycles of 'gap' disturbance events that are managed for timber regeneration, reducing the importance of natural gaps (Webb 1998).

UNDERC, however, is a property that is no longer subject to logging, so the importance of gaps here will increase as recovery from previous logging continues. The forests at UNDERC will become dependent upon gaps for the maintenance of pioneer species that grow in areas of disturbance. The regeneration of these pioneer species increases diversity in forest stands by maintaining heterogeneity in forests that are dominated by dense canopy, shade tolerant trees, such as sugar maple (*Acer sacharum*) or eastern hemlock (Frelich et al. 1993). If gaps are the only source of disturbance and deer browse preferentially in disturbed areas, heavy deer browse could impact forest diversity

I proposed to test this idea and see if the gaps at UNDERC suffer from more intense browse pressure than do the surrounding areas of canopy cover. Given the previously mentioned studies, I expect that deer browsing in gaps of northern hardwood forests should be greater than in areas of canopy cover. My study used the number of browsing incidents per cm of stem height as the indicator of browsing pressure. Because increased browsing incidents per cm of stem height are assumed to equate to higher browsing pressure, I predicted the highest rate of bites per cm of stem height to occur in gaps.

A second indicator of browsing is sapling (regenerating tree) height. Increased browsing pressure can reduce plant height (Anderson 1994, Rogerson 2005), so I predicted that saplings will be shorter in areas with higher browsing pressure, which I predict are gap habitats. This is the opposite of what is expected of saplings in gaps based on the increased light availability. Increased light should encourage rapid growth resulting in increased sapling height in gaps compared to non-gaps. I also predicted a difference in browsing to exist between forest canopy types. I predicted that the browsing would be greatest in non-balsam fir plots, maple or aspen (*Populus tremuloides*), which contain the more nutritious browse deer prefer, leading to reduced tree height and increased browsing incidents in maple and plots.

Materials and Methods

Study Site

I conducted the study at UNDERC during a 10 week summer course in June-July of 2006. The property is approximately 7500 acres in Vilas Co., Wisconsin and Gogebic Co. Michigan. The property is comprised of numerous open water lakes and bogs, as well as areas of northern hardwood forests. The forests on the property are second or third growth forests, regenerating from periodic logging events beginning in 1900 and ending in the late 1960's. The dominant hardwood species include sugar maple, birch (*Betula* spp.), and quaking aspen (*Populus tremuloidess*). The dominant conifer is by far balsam fir, with white pine (*Pinus strobes*), red pine (*Pinus resinosa*) and spruce (*Picea* spp.) also present. Eastern hemlock and northern white cedar are present in select areas bur are not abundant across the entire property (http://www.nd.edu/~underc/east/about/, Osborne, personal observation.).

Sampling procedure

I found the gaps for this study in a variety of ways. Anne Chouinard, a teaching assistant at UNDERC, 2005 and 2006, had personal knowledge of multiple gap locations and aided me in finding them. I also used ArcView 3.3 (ESRI, Redlands CA) data layering software containing information on UNDERC habitat types (Francl, unpublished data) to determine areas of target canopy species in which to search for gaps. I marked GPS coordinates for each gap upon its location and selection for use (table 2). I determined GPS coordinates using a Garmin 12 GPS hand-held unit (Garmin Int. Inc., Olathe KS)

I measured stems in five gaps each of three canopy types: sugar maple dominated, quaking aspen dominated and balsam mixed canopy. I had planned on measuring gaps of medium, but finding enough suitably sized gaps proved to be challenging, so I accepted gaps of any apparent age. Gap size was not collected and gaps were included in the study base on their ability to hold sufficient sub-plots. Each gap contained circular sub-plots with a 2-m radius. The number of sub-plots per gap varied due to stem densities in the gap. All gaps had a minimum of two sub-plots, and up to four sub-plots were used in less dense gaps, in order to measure a minimum of thirty stems in each gap. I placed the first sub-plot in the center of each gap. I placed the subsequent sub-plots at random compass directions with seven meters between the center of the first sub-plot to the center of the subsequent sub-plots.

I measured the height and recorded species type for all stems in a specific height range and of target woody species within the sub-plots of each gap. The lower limit was 30cm in height and the upper limit was 200cm (2m), because stems in this range are subject to browse pressure by deer. They are also larger than what snowshoe hares (*Lepus americanus*) and eastern cottontails (*Sylvilagus floridanus*) are capable of reaching.   The target species were chosen based on relative abundance across the property in hopes most species were present at a majority of sites. The target species were balsam fir, quaking aspen, sugar maple, red maple (*Acer rubrum*), and beaked hazelnut (*Corylus cornuta*). I also recorded the number of apparent browsing incidents each stem had suffered, both from this season and from past years. I considered all unevenly-broken branches and twigs to be incidents of deer browse. I also recorded missing leaves as incidents of deer browse (Rogerson 2005). I divided the incidents of deer browse into the height of each stem to obtain my quantitative measure of browse pressure: browse incidents per cm of stem height.

I repeated all measurements in paired control plots of the same canopy cover type located 30-50m from the center of the gap, in a random compass direction. I located the control plot 30 to 50 meters from the center of the gap. Each control had the same number of subplots as its equivalent gap. One control plot, Aspen 4, only had sufficient surrounding habitat for two control plots. Because the two sub-plots at this control contained no stems of recordable height, I did not alter the methods at this site, and used only two sub-plots.

Analysis

The data returned were not of normal distribution, requiring the use of non-parametric statistical techniques. All statistics utilized the Kruskal-Wallis analysis, a non parametric analysis of variance. I tested the height of stems against gap and non-gap, canopy type and finally gap and non gap grouped by canopy type. I also used the browse incidents per cm of stem height to test against the canopy type, gap/non gap and gap/non-gap grouped by canopy type. I used SYSTAT 11.0 (SYSTAT Software, Inc. Point Richmond CA) for the statistical analysis of all data.

Results

Maple gaps averaged the shortest stem height when compared to all other gaps and controls, and maple controls show the shortest mean stem height of all control types. Balsam fir controls had the tallest mean stem height of any plot type, gap or control, and balsam fir gaps had the tallest mean height of all gap types. The aspen control and gap plots fell in the middle in mean stem height, but the difference between the control and gap average height is greatest in the aspen gaps (Table 1.). The largest mean browsing incidents per cm of stem height occurred in maple plots, followed by aspen plots and lastly balsam fir plots had the lowest browse per cm of stem height (figure 1).

I tested the differences in browsing incidents per cm of stem across canopy types and found that a significant difference exists between browsing in the three canopy types (p-value <0.0001, K-W=302.306,). When comparing browsing incidents to canopy type with a grouping by gap/control, I found significant differences for both the gap (p-value < 0.0001, K-W = 261.9) and control (p < 0.0001, K-W = 86.5) groups. In both cases, the heaviest browsing pressure was recorded in maple plots, followed by aspen plots (Figure 1).

The Kruskal-Wallis test comparing bites per cm of stem height and gap/control also shows a significant difference (p-value <0.0001, U= 216,850), with the control plots suffering more intense browsing (figure 2). The test comparing gap/control to bites per cm of stem when grouped by canopy type returned significant differences between gaps and controls for aspen (p-value = .025 U = 30,080), balsam fir (p-value < 0.001 U = 13,709), and maple (p-value < 0.0001 U = 31,968) plots. For all three canopy types, the control plots show more intense browsing then gaps (Figure 2).

The test comparing the height of stems to canopy type indicates a statistical difference (p-value < 0.0001, K-W= 227.3) in height between the three canopy types. The data showed balsam fir had the highest average height and maple the lowest (figure 3). When grouping by gap/control and comparing canopy type to stem height, gaps showed significant difference (p-value < 0.0001, K-W= 192.6) across canopy types. Controls also had a significant difference (p-value < 0.0001 K-W= 35.0) across canopy types. In both gaps and controls balsam fir stands had the highest average height and maple had the lowest (figures 3).

The test comparing gap/control to average stem height did not show a significant difference in height from gaps to control. When grouped by canopy type, the comparison of gaps/controls to stem height did not return any statistically significant values for any of the three canopy types.

Discussion

Because sapling heights were not statistically different between gaps and non-gaps, I reject my original prediction that I would find shorter trees in the gaps. A possible explanation for this lack of height difference is advance regeneration. This would mean that the stems dominating the gap are the same age and approximate size as the ones found in the surrounding forest, because they were present prior to gap formation. In this case, we can not infer deer browsing from height since stems in the gap and forest have not grown their entire lives in gap habitat. Uhl et al. (1988) found a similar trend in their study of tropical systems.

It is also possible that deer do not preferentially browse in gaps. The canopy habitats could contain browse that is of sufficient quality and quantity such that, at current deer population levels, there is no real incentive for deer to browse more in gaps than in canopy habitats. Future changes in population levels could change this result. If deer populations increase, a difference in browsing between gaps and forested areas may appear, so long as there is a difference in food is available (stem densities) between gaps and controls. This requires that future studies include quantitative measures of stem density inside and out of gaps

Because I found greater browsing incidents per cm of stem height in controls than gaps, there is higher browsing pressure on plants in control plots. This initially looks like a preference for browsing in non-gap areas. However, this result could be due to the number of stems in the control areas being lower. Assuming there is no pressure for deer to browse more frequently in gaps vs. non-gaps (based on previous results), higher stem densities in gaps make it less likely each additional browsing incident will be on a sapling that has already been browsed. The pressure for browsing can be higher in non-gap areas without indicating a preference for these are by deer. In fact, if stem densities are high enough in gaps, more browsing could take place and the intensity measure could still be lower. An accurate comparison of stem densities between the gaps and control plots is needed to truly determine if these results indicate a preference for browsing in one habitat over the other.

The results for heights and browse incidents both support my predictions that balsam fir stands are not utilized as deer browse as highly as maple and aspen plots. The balsam fir gaps surveyed ranged in balsam fir composition from 97% down to 3.2%, so it is possible that even a small amount of balsam fir can deter deer. In those stands with low (3.2%) balsam fir composition, another unpalatable species such as spruce could make up a large portion of the saplings. This would serve the same function as a large percentage of balsam fir. I did not measure spruce stems, so including them in future studies could answer the question of why deer do not use sites with even relatively low balsam fir composition.

Another factor that could be at work in the balsam fir stands is the large amount of woody debris. In my personal observations, I noted that the woody debris in the balsam fir gaps was much denser than at other gap types. Large areas of woody debris have been correlated to increased sapling height of aspen in Yellowstone National Park. In this setting the woody debris acts as a refuge from elk browsing (Ripple and Larson 2001). It is possible that the gaps with higher levels of woody debris act as areas of refugia from white-tailed deer in northern hardwood forests. The result would be taller saplings and less intense levels of browsing. A study quantifying the density of woody debris and comparing it to sapling height and browsing pressure could determine if woody debris in gaps acts as deer refugia on the UNDERC property.

Given my results, I believe that at UNDERC, gap habitats are not any more heavily browsed by deer than surrounding forest areas. The control plots have more browsing pressure per stem and heights of stems do not vary between gaps and controls. This lack of heavy browse pressure may prove beneficial for forest regeneration. However, if deer shift their focus to gaps, a source of forest diversity and one of the few places for shade-intolerant species to persist in the forest, could be harmed. Changes in deer populations could result in such a shift, especially towards the under utilized balsam fir gaps containing less preferred browse species (Klein 1970). Second, my results show that balsam fir stands are less preferred by deer than aspen and far less preferred than maple. Future studies could be done to determine if these less desirable browsing areas act as refugia from deer browsing for species struggling for regeneration, such as eastern hemlock (Borgmann et al. 1999).

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Tables

Table 1. Stem height data for gaps and control plots grouped by canopy

Canopy	Type	Shortest stem(cm)	Tallest stem(cm)	Average stem(cm)	Standard Deviation
Aspen	Control	30	180	72.93	40.0
Aspen	Gap	30	200	66.52	38.6
Balsam	Control	30	195	86.04	48.2
Balsam	Gap	30	197	85.03)	40.5
Maple	Control	30	162	53.85	31.2
Maple	Gap	30	171	49.24	24.3

Table 2. GPS coordinates of gaps on UTM grid, all plots in zone 16 North

Plot	X Coordinate	Y Coordinate
Aspen 1	0302526	5123459
Aspen 2	0302399	5123340
Aspen 3	0307727	5122611
Aspen 4	0307613	5122708
Aspen 5	0305606	5121982
Balsam Fir 1	0307796	5119998
Balsam Fir 2	0309016	5120323
Balsam Fir 3	0307140	5121656
Balsam Fir 4	0309517	5120274
Balsam Fir 5	0304429	5123951
Maple 1	0306077	5121122
Maple 2	0306531	5123481
Maple 3	0306916	5122124
Maple 4	0306609	5120963
Maple 5	0305674	5121517

Figures

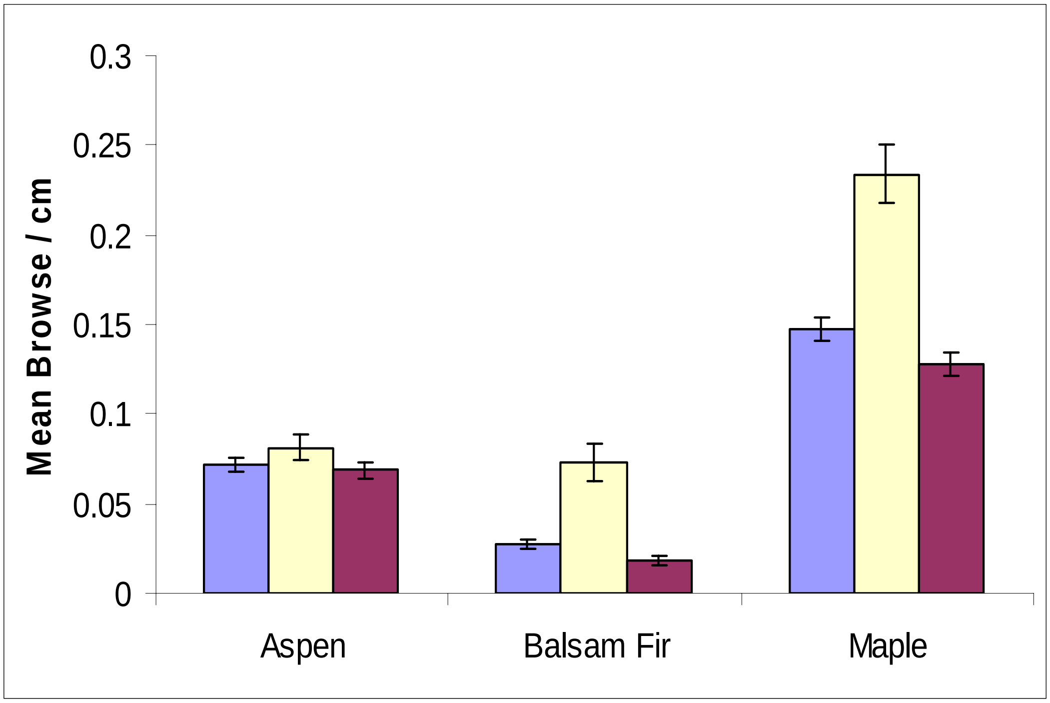

Figure 1. Canopy type vs. mean browsing/cm of stem height, showing gaps and controls (blue), controls (cream) and gaps (maroon). Maple gaps exhibited the highest browse pressure when gaps and controls were combined (p-value <0.0001, K-W=302.306,), in gaps alone (p-value < 0.0001, K-W = 261.9) , and in control plots alone (p < 0.0001, K-W = 86.5). Error bars represent standard error.

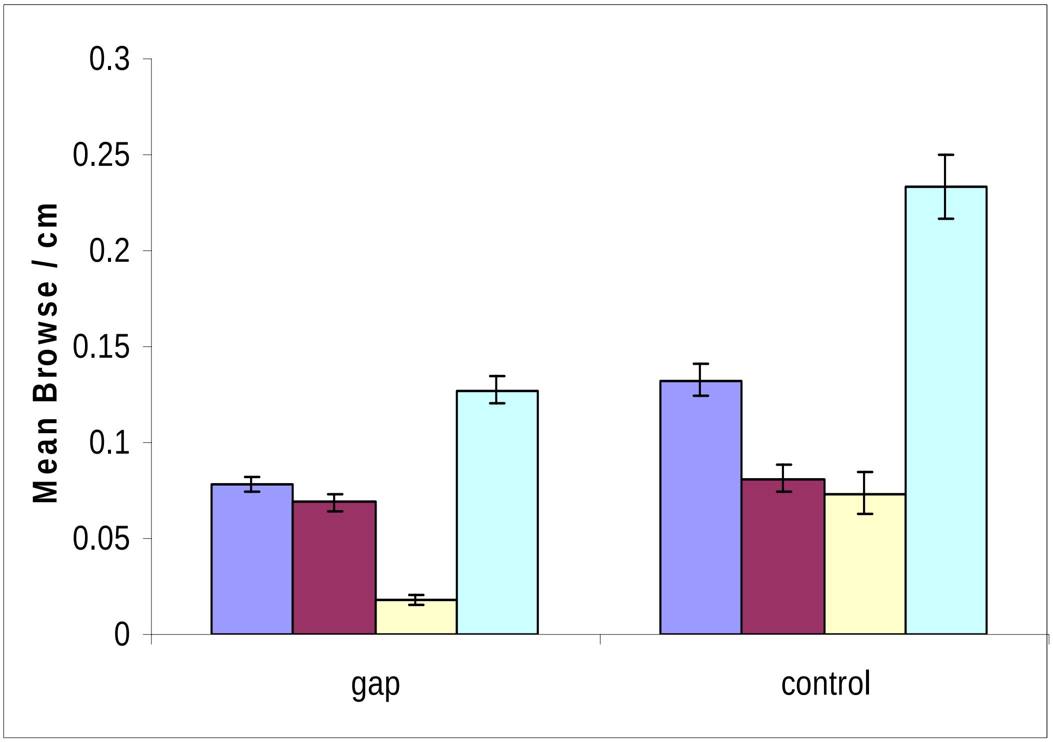

Figure 2. Gap and control plots vs. mean browsing/cm of stem height, showing all canopies combined (blue), aspen (maroon), balsam fir (cream) and maple (aqua). Control plots showed more intense browsing pressure in aspen canopy (p-value = .025 U = 30,080), balsam fir canopy (p-value < 0.001 U = 13,709), maple canopy (p-value < 0.0001 U = 31,968) and all canopies combined (p-value <0.0001, K-W= 216,850). Error bars represent standard error.

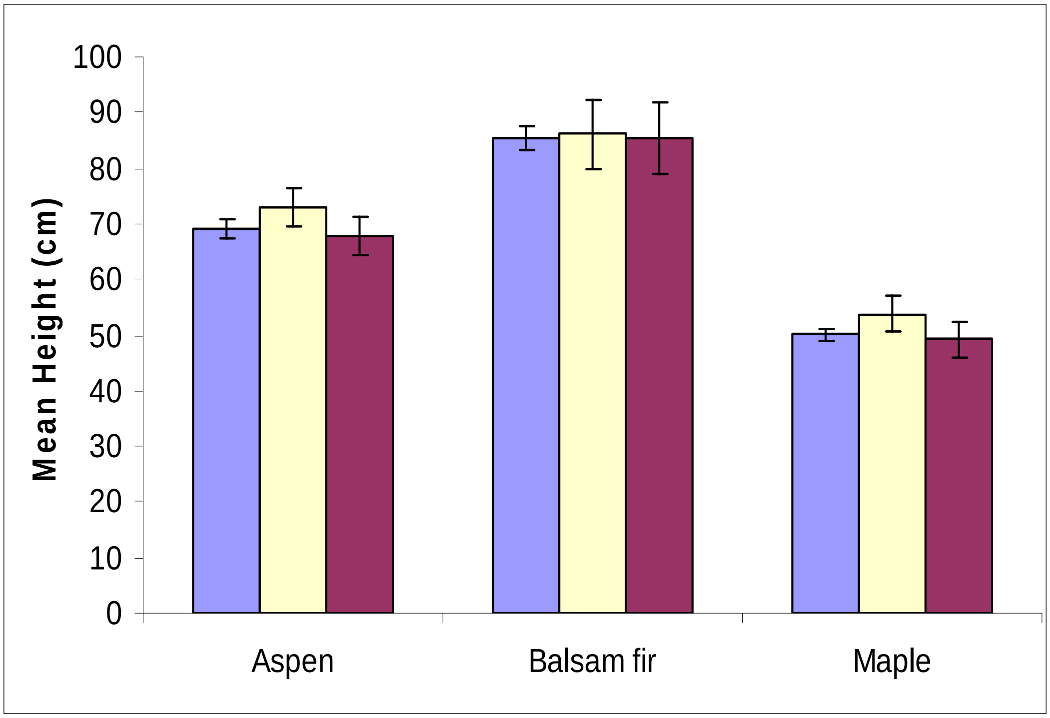

Figure 3. Canopy type vs. mean stem height, showing gaps and controls (blue), controls (cream) and gaps (maroon). Balsam fir stands exhibited the highest mean stem height in gaps (p-value < 0.0001, K-W= 192.6), controls (p-value < 0.0001 K-W= 35.0) and gaps and controls combined (p-value < 0.0001, K-W= 227.3). Error bars represent standard error.