

Factors Influencing Ungulate Barking Patterns of *Populus tremuloides*

Dillon R. Sapena, Montana State University

Mentor: Benjamin Blonder, University of Oxford

Independent Research and Course: Summer 2017

Biotic and abiotic factors may influence ungulate herbivory of the quaking aspen (*Populus tremuloides*). This study aimed to figure out how these factors affected tree selection and herbivory amounts of aspen bark in the East River Valley near Gothic, Colorado. Common forestry methods and reflectance spectrometry were used to test 195 aspen trees over four sites in different elevations. I found that the factors tested did not affect tree selection but some, such as bark reflectance properties, did affect barking amounts.

Introduction

The quaking aspen, *Populus tremuloides*, is one of the most widespread, genetically diverse, and ecologically important tree species in North America (Mitton and Grant 1996). Quaking aspens are a clonal species that can create massive stands that dominate the landscape (DeWoody et al. 2008). However, quaking aspen populations have seen a decline over the last 100 years (Bartos and Campbell 1998). This decline, primarily in the montane west, has been attributed to a number of factors, but predominantly fire suppression, sudden aspen decline (SAD), anthropogenic climate change, and herbivory (Gruell 1980, Houston 1982). Herbivory, in which this study focuses on, is shown through an ungulate feeding method called barking. Barking is the technique in which ungulates, primarily elk, *Cervus elephus nelsoni*, and mule Deer, *Odocoileus hemionus*, use their lower incisors to scrape off and eat the chlorophyll filled bark and cambium of the aspen (MacCracken and Hansen 1986). This usually occurs in the winter,

when their preferred grasses and forbs are covered in snow (Hoffman et al. 1989). This type of herbivory has a large effect on the health of aspen populations. This is because barking can spread tree-to-tree diseases, open entry points for infections, and leave the tree more susceptible to solar radiation damage (Hart and Hart 2001, Rabinowitz et al. 2015). The ungulate browsing of aspens can also play a large role in selecting genetic traits for the aspen and can go as far as changing the chemical composition of whole forests (Bailey et al. 2007).

Now, with a combination of new anthropogenic factors and elk populations recovering from historic over-hunting, the quaking aspen has been barked to the point of decline in many areas (White and Feller 2001). This has produced a need for a clear understanding of ungulate-aspen ecological interactions. Part of understanding these interactions includes recognizing these animal's feeding patterns.

Ungulate feeding patterns on aspens may be linked to a number of factors including tree diameter, slope and other topographic variations, bark reflectance properties, and many others (Kufeld 1973, Covington 1975, Fortin et al. 2005, Geist 1982). These factors have effects on aspens over large spatial extents due to the species' clonal nature (Mock et al. 2008). By understanding these factors and the spatial areas in which they persist, we can begin predicting where the ungulates will browse and creating efficient management plans.

This study aimed to answer these problems. In particular, it looked at one main question: What factors influence ungulate barking on the quaking aspen? The factors looked at were trunk diameter at breast height (130cm), slope, proximity to open areas, NDVI (normalized difference vegetation index) and mean reflectance of the white outer layer bark

and inner green cambium. In order to test these factors and answer the question mentioned above, 7 hypotheses were proposed (Table 1).

<u>Factor</u>	<u>Hypothesis</u>
Diameter at Breast Height of Aspen trees	Due to larger DBH trees having larger trunk surface areas, trees with a larger DBH will be subject to more ungulate barking.
Slope	Due to steeper slopes impeding ungulate movement, trees that are on a steeper slope will be subject to less barking.
Aspen tree's distance to open area	Due to ungulates winter preference for open grassland near forests, trees that are closer to open areas will subject to more ungulate barking.
White outer bark NDVI	Due to greener bark containing higher outer bark chlorophyll and sugars, trees with higher NDVI values will have more barking
White outer bark mean reflectance	Due to whiter bark containing more sloughed cambium cells, trees with lower white bark mean reflectance will be subject to more ungulate barking.
Green cambium NDVI	Due to greener bark containing higher bark chlorophyll and sugars, trees with higher green cork cambium NDVI will be subject to more ungulate barking.
Green cambium mean reflectance	Due to less reflective bark absorbing more light, trees with lower green cork cambium mean reflectance will be subject to more ungulate barking.

Table 1: Hypotheses for how each factor effects barking

Methods

The study was conducted using four sites in the East River Valley of Gunnison County, Colorado (Figure 1). Sites were chosen at different elevations and locations due to the quaking aspen's clonal nature. Because the trees are clonal, multiple sites would ensure multiple clones were

being tested and see if the factors being tested had different effects in different areas. The first site was at an elevation of 3000 meters. It was a 1-hectare plot with 25, 20x20 meter subplots within. In the 1-hectare plot, I randomly selected 5 subplots using a random number generator. Then within each selected subplot, I randomly selected 15 aspen trees to test. The other 3 sites were transects with elevations of 2900-3100 meters, 3000-3200 meters, and 3100-3300 meters. Each transect had 5, 20 square meter subplots, 40 meters apart. Within each transect subplot, 10 trees were selected by choosing the closest trees to the center of the subplot. All trees in all sites had a minimum DBH of 7 cm to ensure accurate barking was measured.

For each tree, I first measured the diameter at breast height (130 cm from the base of the tree) by wrapping diameter tape around the trunk of the tree. Next, the slope of the ground at the base of the tree was measured using a LaserTech TruPulse 360R laser range finder. The slope was taken within 30 cm of the trunk on the south facing side of the tree (downhill side). Next, the distance from the nearest open area was recorded. An “open area” was defined as a spot with an area of 25m², containing no trees larger than 7 cm DBH. This was done by firing the laser range finder at the closest point on the perimeter of the open area and recording the horizontal distance.

For each tree, I also estimated the total area of bark herbivory. I looked at ungulate herbivory damage on all sides of the tree. I only looked at barking that was green and not blackened, indicating recent barking damage of less than 2 years. I calculated the amount of barking on each tree using a ruler to measure the length of the scar at its longest point and the width of each scar at its widest point. I then multiplied the two values to estimate an area to the nearest centimeter. All the scars on the tree were then added up to make a total barking

area for each tree. Finally, on each tree I collected a 5x5x2 cm bark sample 130cm up from the base on the south facing side of the tree. This was done using a knife sterilized with isopropyl alcohol to prevent tree-to-tree infection. The samples were then kept cool and moist until they were analyzed in the lab.

The analyzing of the bark samples was done using an ASD HandHeld 2 Reflectance Spectrometer. First the instrument was referenced to both black and white, then optimized and calibrated. Once calibrated, each sample was measured 3 times for reflectance and averaged. Both the white outer bark and the inner green cork cambium layer of each sample was measured. The reflectance was measured on from 325nm to 1075nm wavelengths. Each spectra set was then merged and matched to its corresponding tree and bark type (white or green) and the data was plotted. Next, 2 NDVI and 2 mean reflectance values were calculated for each tree, one for the white bark and one for green. NDVI was calculated in R using the equation: $NDVI = \frac{NIR-RED}{NIR+RED}$. The wavelengths used in the calculation of NDVI were 700nm-1075nm for NIR (near infrared), and 400nm-700nm for red wavelengths. Mean reflectance was also calculated by averaging the reflectance of all the wavelengths measured in a sample.

Once collected, all the data was entered into R for analysis. All variables were ran through a zero-hurdle regression model and a count regression model. The zero-hurdle regression model showed the relationships between the independent variables and if barking was present on a tree. If there was barking on a tree, the count regression model showed the relationships between the independent variables and the amount of barking on a tree. Finally, each variable was plotted with bark scarring and visualized using a linear trend line.

Results

The Zero-Hurdle Model (table 3) showed no statistical significance ($P < .05$) in the relationship between any of the variables and the presence of barking. The closest variable to having significance was the NDVI of white bark ($P = .07$). The other variable close to having significance in the Zero-Hurdle was slope ($P = 0.09$).

The Count Model (table 2) did show significance ($P < .05$) in the relationship between 4 of the independent variables and the amount of barking per tree. I found that more barking occurred on trees with higher DBH ($p = 6.16e-14$) (Figure 2) and trees closer to open areas ($p = 0.003$) (Figure 4). I also found significant correlations in the reflectance properties of the bark. Trees with higher white bark NDVI and mean reflectance values tended to have more barking (Figure 5, Figure 6).

The plot (figure 2) of Diameter at Breast Height vs. the Amount of Bark Scarring (Barking) shows a slightly positive relationship, however the majority of barking instances appear to be toward the middle and lower end of DBH values. The plot (figure 3) of Slope vs. Amount of Bark Scarring (Barking) shows a negative slope with the majority of barking instances appear to be toward the middle range of slope values. The plot (figure 4) of Distance to Open Area vs. Amount of Bark Scarring (Barking) shows a slightly negative slope with many of the trees a distance of 0 to the nearest open area indicating they are positioned on the perimeter

of the open area. The next plots (figure 5, figure 6) show the relationship between NDVI for white and green bark vs. the amount of barking on each tree. More barking appears to be concentrated on trees with lower (0.3-0.5) white bark NDVI and higher (0.6-0.8) green bark NDVI. The last two figures (figure 7 and figure 8) show the plotting of the relationship between mean reflectance for white and green bark vs. the amount of barking on each tree. Both plots contain all of the trees in the reflectance range of 0.3-0.6. The elevation model shows a positive relationship between the amount of barking and the elevation of the tree in the Avery peak site and in both Deer Creek sites. However, the Judd Falls site shows a negative relationship.

The overall reflectance data showed differences between the white bark and the green bark data, but overall had similar patterns (figure 9). Both white and green barks had high reflectance in the 300nm-400nm range. Then in the 400-600nm green bark has much higher reflectance. Both barks reflectance drops largely in the 600nm-700nm range, then rises very quickly to high levels in the 700nm-1100nm range.

Discussion

Summary

Overall, ungulates tree selection was not influenced by the factors tested. However, some of the factors did influence how much bark was eaten on aspen trees. Ungulates tended to eat more bark on trees with larger diameters and trees closer to open areas. Amount of bark eaten was also influenced by bark reflectance properties. They ate more bark on trees with higher mean reflectance and NDVI values. Ungulates also tended to do slightly more barking on trees

in higher elevations with the exception of the Judd Falls site. However, there is very weak evidence for this correlation.

Abiotic Variables

In the Zero-Hurdle Model, none of the abiotic factors had significance in their relationship with barking. Slope and the distance to open areas did not affect ungulates selection of which trees to feed on. Although more barking seemed to occur on intermediate slopes, this is probably just due to the fact that the study sites were set up on mostly intermediate slopes. This indicates that the ungulate tree selection is random or another variable that this study did not test, is a controlling factor. Other abiotic factors that may affect tree selection could be proximity to water sources, soil substrates, and/or over-story coverage. Further research would be needed to test these potential factors. In the Count Model, only one of the abiotic factors, distance to open areas, had significance. The relationship was slightly negative meaning the closer a tree is from an open area (25m² area with no trees larger than 7cm DBH), the more bark is eaten. This indicates that when ungulates decide to feed on an aspens bark, the amount of bark that is eaten is correlated with how far that tree is from an open area. This is consistent with the hypothesis that trees that are closer to open areas will subject to more ungulate barking. This could be due to multiple factors. One may be due to ungulates preference for more open areas in the winter (Grover and Thompson 1986). More research is needed to confirm this notion. Because slope had no significance, the hypothesis that trees that are on a steeper slope will be subject to more ungulate barking, is rejected. The

secondary factor of elevation was plotted against bark scarring and no statistical models were ran for the variable. This was due to the sample size and variation of elevation being too small. Although the plot shows a positive correlation between amount of barking and the elevation of the tree, more testing would have to be done to confirm this relationship.

Biotic Variables

Like the abiotic factors, in the Zero-Hurdle Model, none of the biotic factors had significance or a correlation with the presence of barking on a tree. However, white bark NDVI was fairly close to having significance with a P value of .07. A larger sample size may enable a more robust test for significance for this variable. If significance is later shown, the sign of the correlation between this variable and the presence of barking would be positive indicating that trees with higher white bark NDVI values are more likely to have ungulate herbivory present on their bark. This may be due to trees with higher NDVI values containing more bark chlorophyll and its accompanying sugars, and therefore being more nutritious to ungulates (Kufeld 1973). In the Count Model, 3 of the Biotic factors, DBH, white NDVI and white bark mean reflectance, showed significance and therefore correlations with the amount of barking. DBH had a positive correlation which is consistent with the hypothesis that trees with a larger DBH will be subject to more ungulate barking. This is probably due to the simple fact that larger DBH trees have more surface area for barking. White bark NDVI also had a positive correlation with the amount of barking on a tree. This is consistent the hypothesis that trees with higher white bark NDVI will be subject to more ungulate barking. The reason for this correlation, as stated above, may be due to the fact that trees with higher NDVI values contain more bark chlorophyll and its

accompanying sugars, and therefore being more nutritious to ungulates (Kufeld 1973). Along with white bark NDVI, white bark mean reflectance also had a positive correlation with the amount of barking. This disproves the hypothesis that trees with lower white bark mean reflectance will be subject to more ungulate barking. This may have to do with the white powder on the outermost layer of the bark. The powder is made of sloughed cork cambium cells and is highly reflective (Rabinowitz et al. 2015). I speculate there may be something in the powder that is beneficial to ungulates. Both hypotheses, that trees with higher green cork cambium NDVI will be subject to more ungulate barking, and that trees with lower green cork cambium NDVI will be subject to more ungulate barking, are rejected. There is no correlation between green bark reflectance properties and the presence or amount of barking. This is probably due to the fact that ungulates cannot see this layer of bark and therefore cannot select trees to feed on based on this factor.

Overall reflectance

The overall trend of reflectance follows what would be expected. The reflectance values for almost every tree jumps around 550nm and dips around 700nm. This is due to the bark containing high amounts of chlorophyll which is the pigment that reflects green light and absorbs red light (Kharouk et al. 1995). Both bark types (white and green) reflected large amounts of near infrared light (NIR). This is probably due to the high amounts of water in the bark and water's NIR attenuating properties (Kharouk et al. 1995). The major variation between the two bark types in the 400nm-700nm range is probably due to the white powder that resides on the outside of the bark. The powder has been found to be very reflective of many

wavelengths of light (Rabinowitz et al. 2015). This would explain why white bark has a higher reflectance values in this range.

Conclusions

Ungulates did seem to select trees to bark based on the variables tested. However, they did tend to eat more bark on trees with larger diameters, trees closer to open areas, and trees with high mean reflectance and NDVI values. The findings of this study hopefully will help improve understanding of the ecological interactions taking place with these species. Based on my results, it is clear that more studies on this topic are needed to fully comprehend the factors that influence ungulate bark herbivory of the quaking aspen. Other herbivores and factors must be studied for their patterns and effects on aspen bark. Also, experiments with broader spatial scales and sample sizes may be able to conclude if these factors' effects are continuous over large areas. I speculate that due to the quaking aspen clonal nature, findings in one area may be applicable to others. However, an explicit understanding how individual clones both repress and react to herbivory is imperative before looking deeper into these larger, spatial scopes. Studies like this one and the ones mentioned above are needed in order to produce efficient and effective management plans for not just the quaking aspen, but all species involved in these complex and intriguing interactions.

References

Aschan, G., Wittmann, C. & Pfanz, H. Trees (2001) 15: 431. doi:10.1007/s004680100120

Bailey, Joseph K., Jennifer A. Schweitzer, Brian J. Rehill, Duncan J. Irschick, Thomas G. Whitham, and Richard L. Lindroth. "Rapid shifts in the chemical composition of aspen forests: an introduced herbivore as an agent of natural selection." *Biological Invasions* 9, no. 6 (2007): 715-722.

Bartos, Dale L., and Robert B. Campbell. "Decline of quaking aspen in the interior West--examples from Utah." *Rangelands Archives* 20, no. 1 (1998): 17-24.

Covington, W. W. (1975), Altitudinal Variation of Chlorophyll Concentration and Reflectance of the Bark of *Populus tremuloides*. *Ecology*, 56: 715–720. doi:10.2307/1935507

DeWoody, Jennifer, Carol A. Rowe, Valerie D. Hipkins, and Karen E. Mock. "'Pando' lives: molecular genetic evidence of a giant aspen clone in central Utah." *Western North American Naturalist* 68, no. 4 (2008): 493-497.

Fortin, Daniel, Hawthorne Beyer, Mark Boyce, Douglas Smith, Thierry Duchesne, and Julie Mao. "Wolves Influence Elk Movements: Behavior Shapes: A Trophic Cascade in Yellowstone National Park." *Ecology* 86, no. 5 (2005): 1320-330.

Grover, Karl E., and Michael J. Thompson. "Factors Influencing Spring Feeding Site Selection by Elk in the Elkhorn Mountains, Montana." *The Journal of Wildlife Management* 50, no. 3 (1986): 466-70. doi:10.2307/3801107.

Gruell, G. E. 1980. Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Wyoming. Volume 1: Photographic record and analysis. Res. Pap. INT-235. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 207 p.

Hart, John H., and D. L. Hart. "Interaction among cervids, fungi, and aspen in northwest Wyoming." (2001).

Hoffman, George R., Norbert V. Debyle, and Robert P. Winokur. "Aspen Ecology and Management." *Journal of Range Management* 42, no. 4 (1989): 349. doi:10.2307/3899509.

Houston, D. B. 1982. "The northern Yellowstone elk: ecology and management." New York, NY: MacMillan. 474 p.

Kharouk, V. I., E. M. Middleton, S. L. Spencer, B. N. Rock, and D. L. Williams. "Aspen bark photosynthesis and its significance to remote sensing and carbon budget estimates in the boreal ecosystem." In *Boreal Forests and Global Change*, pp. 483-497. Springer, Dordrecht, 1995.

Kufeld, Roland C. "Foods Eaten by the Rocky Mountain Elk." *Journal of Range Management* 26, no. 2 (1973): 106. doi:10.2307/3896463.

Maccracken, James G., and Richard M. Hansen. "Diets of Domestic Sheep and Other Large Herbivores in Southcentral Colorado." *Journal of Range Management* 34, no. 3 (1981): 242. doi:10.2307/3898054.

Marchetti, Suzanne Bethers, James J. Worrall, and Thomas Eager. "Secondary insects and diseases contribute to sudden aspen decline in southwestern Colorado, USA." *Canadian Journal of Forest Research* 41, no. 12 (2011): 2315-2325.

Mitton, Jeffry B., and Michael C. Grant. "Genetic Variation and the Natural History of Quaking Aspen." *BioScience* 46, no. 1 (1996): 25-31. doi:10.2307/1312652.

Mock, Karen E., C. A. Rowe, Mevin B. Hooten, J. Dewoody, and V. D. Hipkins. "Clonal dynamics in western North American aspen (*Populus tremuloides*)." *Molecular Ecology* 17, no. 22 (2008): 4827-4844.

Loope, Lloyd L., and George E. Gruell. "The Ecological Role of Fire in the Jackson Hole area, Northwestern Wyoming." *Quaternary Research* 3, no. 03 (1973): 425-43. doi:10.1016/0033-5894(73)90007-0.

Rabinowitz, Oren, and Erin A. Tripp. "A Note on the Observable Bark Coloration of Quaking Aspen (*Populus tremuloides*)." *Western North American Naturalist* 75, no. 3 (2015): 364-69. doi:10.3398/064.075.0313.

Weber, William A., and Ronald C. Wittmann. *Colorado Flora: Eastern Slope, A Field Guide to the Vascular Plants*. University Press of Colorado, 2012.

White, Clifford A., and Michael C. Feller. "Predation risk and elk-aspen foraging patterns." (2001).

Figures

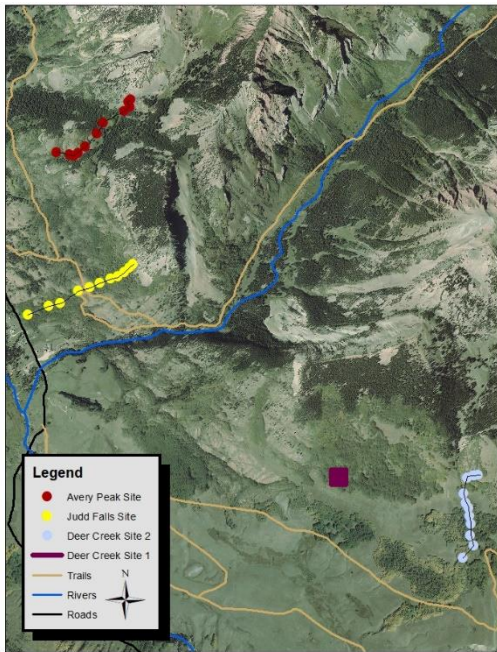


Figure 1: Map of study sites near Gothic, CO

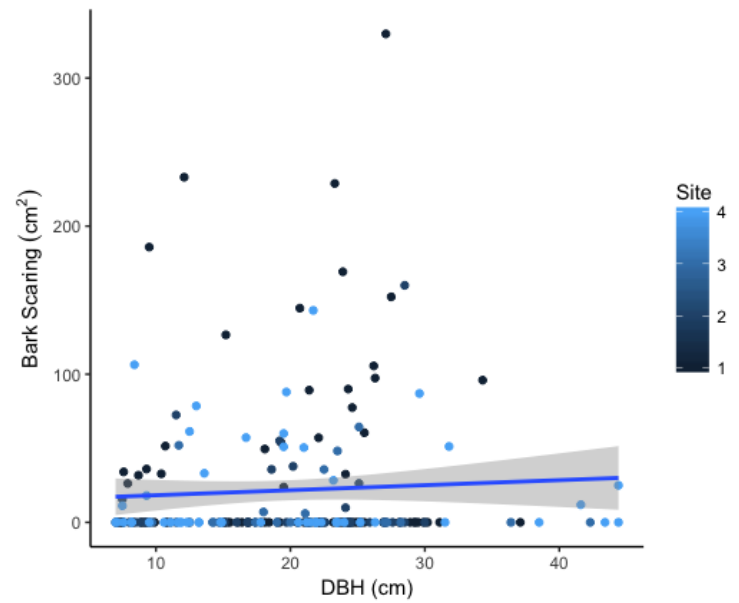


Figure 2: The Y axis shows cm^2 of barking vs DBH of each tree. Each point represents an individual tree. The colors correspond to the site number.

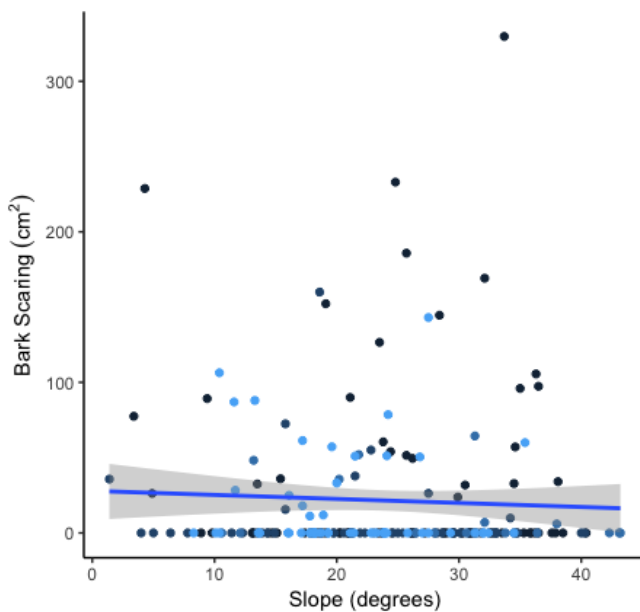


Figure 3: The Y axis shows area of barking and the X axis shows the slope of each tree. Each point represents an individual tree. The colors correspond to the site number

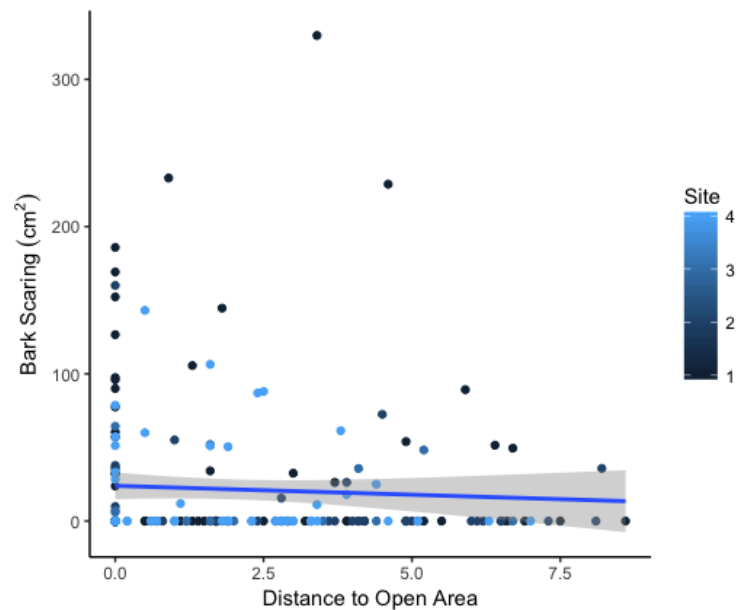


Figure 4: The Y axis shows area of barking vs. the distance from each tree to the nearest open area. Each point represents an individual tree. The colors correspond to the site number.

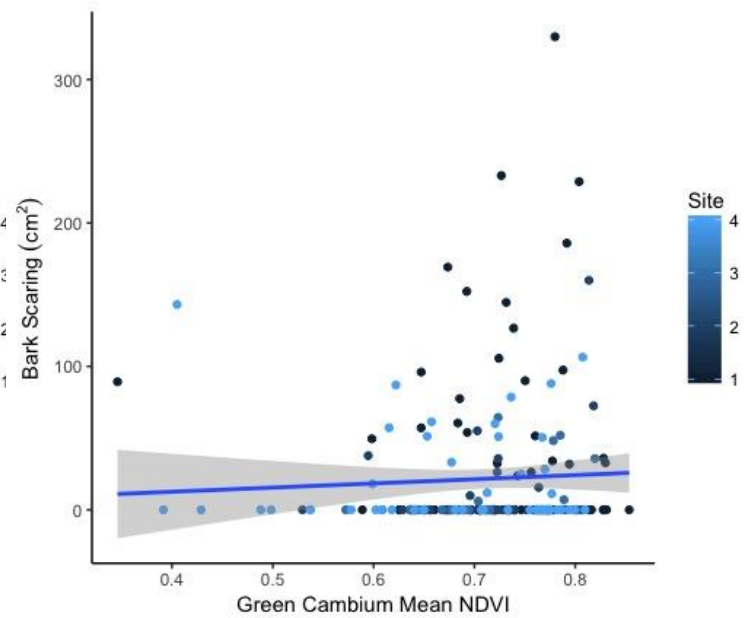
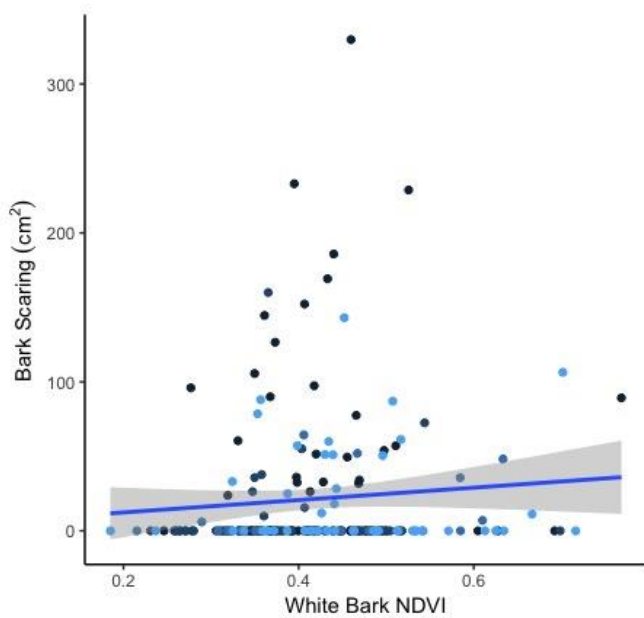


Figure 5 (Left) and Figure 6 (right): The Y axes show area of barking vs. NDVI of each tree. Each point represents an individual tree. The colors correspond to the site number.

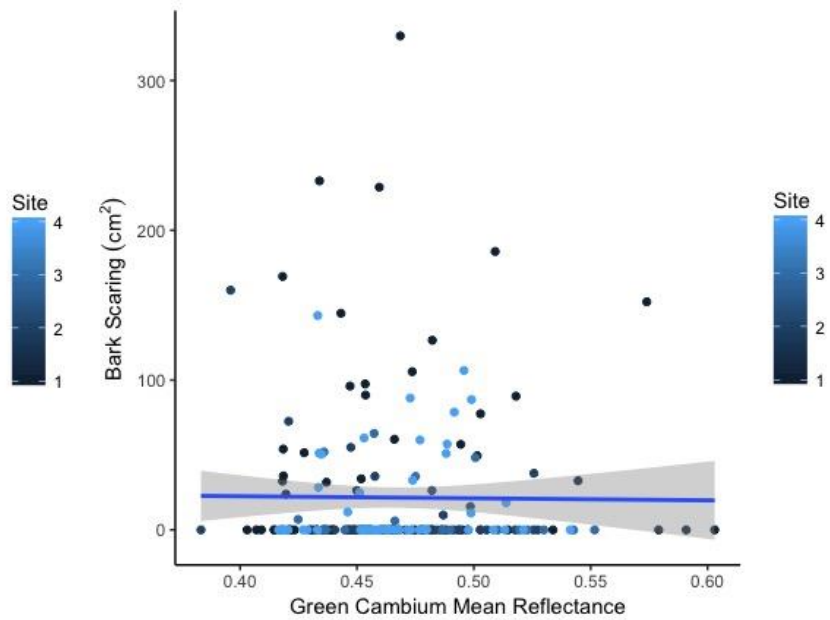
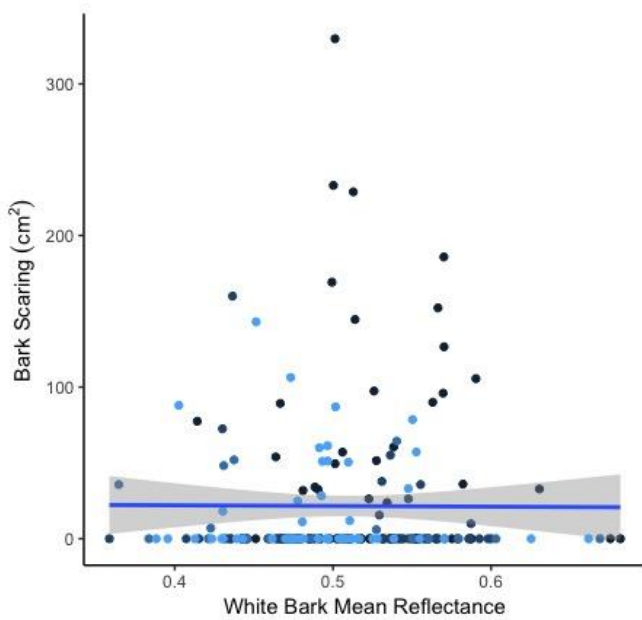


Figure 7 (left) and Figure 8 (right): The Y axes show area of barking vs. mean reflectance of each tree. Each point represents an individual tree. The colors correspond to the site number.

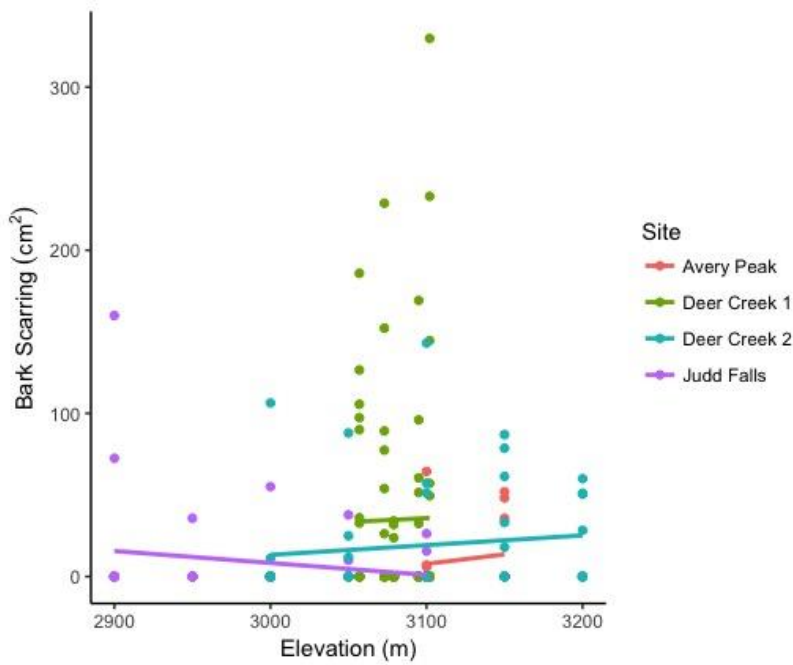


Figure 9: Y axis represents area of barking and X axis represents elevation of the tree. A trend line is shown for each study site

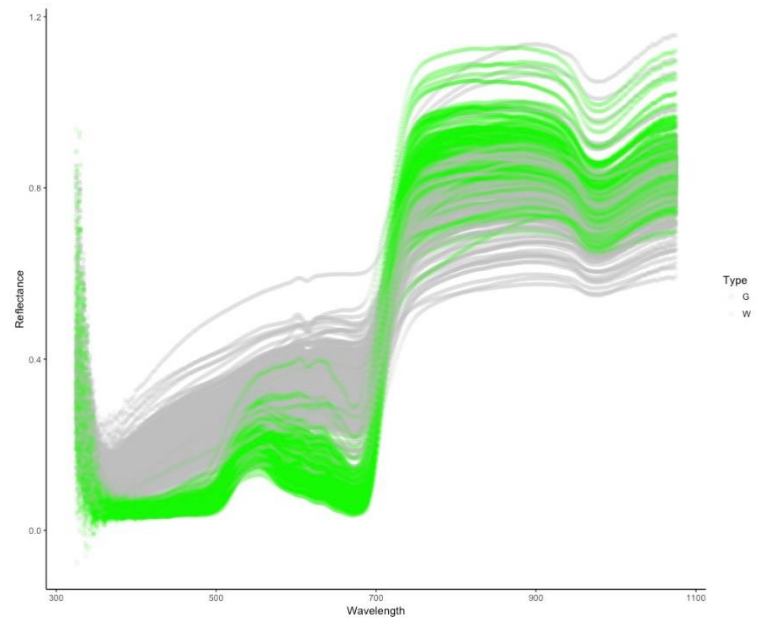


Figure 10: The Y axis shows reflectance from 0-1 (0%-100%) and X axis shows wavelengths from 350nm-1075nm. The green indicates green bark and the grey indicates white bark.

Tables

Count Model	Estimate	Standard Error	Z value	P value
DBH	0.014969	0.0019951	7.505	6.16e-14
Slope	0.002188	0.001945	1.125	0.26069
Distance to Open Area	-0.026114	0.008763	-2.980	0.00288
NDVI White	1.131075	0.216996	5.212	1.86e-07
NDVI Green	0.266390	0.185014	1.440	0.14991
Mean Reflectance White	1.310327	0.406217	3.226	0.00126
Mean Reflectance Green	-0.779325	0.502869	-1.550	0.12120

Zero-Hurdle Model	Estimate	Standard Error	Z value	P value
DBH	0.02196	0.02086	1.052	0.2926
Slope	-0.03406	0.02013	1.692	0.0906
Distance to Open Area	-0.13000	0.08347	-1.557	0.1194
NDVI White	3.72238	2.06097	1.806	0.0709
NDVI Green	2.18172	2.13165	1.023	0.3061
Mean Reflectance White	2.03965	3.72058	0.548	0.5836
Mean Reflectance Green	-0.74716	5.19423	-0.144	0.8856

Table 2 (left) and Table 3 (right) show the Count model and Zero-Hurdle model. P Value indicates significance, Estimate indicates whether the correlation is positive or negative, and the Standard Error shows the amount of error the Estimate could be off by.