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Effects of Buckthorn (Rhamnus Cathartica and Rhamnus Frangula) on Native Flora Functional Traits

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EFFECTS OF BUCKTHORN (*RHAMNUS CATHARTICA* AND *RHAMNUS FRANGULA*) ON NATIVE FLORA FUNCTIONAL TRAITS

by

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Abstract:

Invasive plant species are currently a threat to native species and communities, and two major challenges facing scientists today are trying to figure out how to deal with the invasive plants and trying to pinpoint their effects on the native communities. While some methods of removal have been effective, it is still unclear how the invasive plants affect the natives. Two species of the shrub buckthorn are invasive in the United States and both are causing problems in the state of Maine. I studied the native plants in areas with and without buckthorn to determine the effects of buckthorn on native plants. The sites without buckthorn served as models of what the natural environment should look like and were compared to the sites influenced by buckthorn to determine if buckthorn affected the structure of the community. To establish the structure of the communities I measured the functional traits of the native plants. The distributions of plant height, chlorophyll, and SLA values all shifted in response to buckthorn, resulting in plants that were taller and had thinner leaves with less chlorophyll. I also assessed changed in species richness and evenness. This study showed that the presence of buckthorn resulted in a change in the community. Invasive plant species are changing the way natural communities look by altering the size and shape of the available trait space, which could lead to exclusion of non-adaptive species or lead to growth constraints.

Table of Contents:

Introduction:

Dealing with invasive plant species is a major problem currently facing botanists and ecologists in much of the United States (Reardon and Skinner, 2009). Invasive plant species are plants that are not native to their current environment; they are transported by humans either intentionally for landscape and agriculture purposes, or accidentally alongside some intended transported product (Mooney and Hobbs, 2000). Invasive plant species are also defined as plants whose presence may cause economic, environmental, or human harm, therefore some species can be identified as 'not native' while also not being considered 'invasive' if they do not pose a threat to native plants or human health (Maine.gov, 2013). Invasive plants tend to thrive in their new environments due to lack of natural predators or competitors, and they often continue spreading after being introduced (Callaway and Aschehoug, 2000). The Maine Department of Agriculture, Conservation, and Forestry currently lists nineteen plant species within the state of Maine that are considered to be invasive with an additional twenty-nine species that have the potential to be invasive in Maine (Maine.gov, 2013).

Due to their immobile lifestyle, plants can only increase their ranges through seed dispersal or root systems, meaning that up until human involvement plants were unable to expand their ranges quickly. Invasive species were rare before modern times because species competition and abiotic factors controlled where species were able to survive (Sexton et al, 2009). Today humans can easily transport plants and seeds into new environments, bringing about species interactions that have never existed before; these introduced species become invasive without natural predators or competitors to control them, and they outcompete native plants and reduce biodiversity (Callaway and Aschehoug, 2000). Ecologists today are trying to figure out what these new species interactions will look like and how they will affect the health of the individual species as well as the entire structure of the community before too much damage is done to the native ecosystems (Reardon and Skinner, 2009).

Two species of the shrub buckthorn (*Rhamnus cathartica* and *Rhamnus frangula*) were introduced to the United States in the 1800's as ornamental plants and have since entered the natural ecosystem and are currently outcompeting native plant species (Night et al, 2007 and Qaderi et al, 2009). While Maine is currently home to nineteen invasive species, the two species of buckthorn were used for this experiment because they are common and easy to locate in Orono, Maine, and because they are both currently posing a major threat to the natural environment (Campbell et al, 1995 and Qaderi et al, 2009). Buckthorn is so successful due to its long growing season, rapid growth, early leaf-out, large quantities of seeds, vegetative root propagation, and habitat tolerance; the shrubs can survive in a wide range of habitats and are very successful at growing on disturbed lands such as roadsides and forest edges (Gleason and Cronquist, 1963). In addition to harming other plant species, buckthorn is also dangerous for foraging birds due to the berries having low protein levels and some laxative-like effects (Izhaki and Safriel, 1989 and Reardon and Skinner, 2009). If buckthorn were to outcompete native food sources, foraging birds would have to rely more on the buckthorn berries and could suffer malnutrition. Hand-removal practices can be successful in removing buckthorn, but can be labor-intensive and are only practical for small areas (Qaderi et al, 2009). Due to all of these factors it is important for us to know what effect buckthorn has on the native environments.

In order to understand exactly what the effects of invasive species are, we need to compare an invaded environment to a natural, un-invaded one. This can be done by using measurable properties that are able to assess differences, such as functional traits and species diversity. Once the properties of the natural environment have been established it is possible to identify the changes caused by an invasive.

Functional traits are phenotypic characteristics of an organism that show life-strategy tradeoffs and determine their role in the environment/ ecosystem (Wright et al, 2006 and Diaz et al, 2013). Such traits can tell us information about biotic and abiotic interactions within a community (Lebrija-Trjos et al, 2010), and the amount of variation in every trait can show the amount of plasticity or niche space allowed in the community. For this experiment I measured plant height, leaf area, chlorophyll content, and specific leaf area (SLA). SLA is calculated by dividing the area of the leaf by the leaf dry mass, meaning thinner leaves yield high SLA values and thicker leaves yield low SLA values (Cornelissen et al, 2003). Plant height can be a response to competition or herbivory, leaf area can be a response to a large number of factors such as drought, chlorophyll content can be a response to light availability, and SLA can be a response to growth rate, leaf lifespan, and nutrient availability (Cornelissen et al, 2003 and Wright et al, 2006). In addition, all four of these traits are useful to determine a plant's light-capture and competitive abilities (Lavorel and Garnier, 2002). These life history strategies are the most useful when looking at the ways buckthorn competes with other plants (leafing out early and growing dense root systems). A shift in values for these functional traits can show us that the community is responding to changing levels of available sunlight or to reduced nutrient uptake.

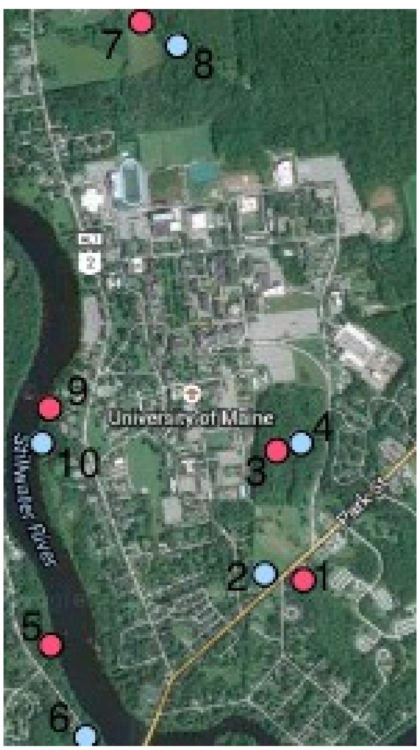
Unlike functional traits which do not look at species identity, species composition shows the presence and relative abundance of the species in an area. This information gives us species richness and species evenness, and it can determine if any species are disappearing or thriving in the presence of an invasive. This could help ecologists target some specific species that are vulnerable to buckthorn invasion. This type of information can be extremely useful but it only shows a small portion of what a community looks like; knowing species diversity and the functional trait space of a community are both important in order to pinpoint the effects of invasive species.

Other studies have been conducted that look at the effect of buckthorn on native communities, but none have compared the functional trait space of native communities to invaded ones. Many sources have reported on buckthorn's ability to crowd out species by creating dense thickets, and one experiment by Klionsky and colleagues determined that buckthorn can shade out understory plants and alter soil chemistry which was observed to delay or prevent germination (Klionsky et al, 2011). This study by Klionsky and colleagues describes how buckthorn alters the environment that other species have to grow in and how this can affect the early stages of plant growth. My study examines the later stages of plant growth by observing how native species respond to these changes using the functional trait space and species composition of mature communities.

This study aims to determine if buckthorn restricts the growth of the native plants by measuring how the functional trait space and species composition of native communities are altered when buckthorn is present.

Methods:

Site Choice: For this experiment I began by locating ten field sites, five with buckthorn and five without. All the sites were in Orono, Maine, a town dominated by mixed hardwood-conifer forests and moderate human development. To minimize the effects of other variables the sites were paired to be as similar as possible; while the paired sites are not exactly the same in all aspects, they are very similar except for the presence or absence of buckthorn shrubs. All paired sites were at the same elevation, equal proximity to water, and equal canopy cover as observed by visual inspection.



Field sites 1 and 2: Backyards: mostly dirt and grass on the edge of a wooded area with a canopy cover of 30-40%.

Field sites 3 and 4: University of Maine Forest Preserve: wooded area along a small stream with a canopy cover of 90-100%.

Field sites 5 and 6: Orono River Trail: close to the Stillwater River and along a dirt walking trail with canopy cover of 90-100%.

Field sites 7 and 8: University of Maine Bike Path: along a paved path and along a forest edge with canopy cover of 35-55%.

Field sites 9 and 10: Fay Hayland Botanical Garden: close to the Stillwater river and along a grass walking path with a canopy cover of 25-35%.

Figure 1 Map of the ten field sites in Orono, Maine. Red sites indicate buckthorn present, blue sites indicate buckthorn absent.

Sampling Design: Within each site one hundred individuals were measured (except for sites 3 and 4 which only had seventy-five individuals due to plant sparsity) and only the understory plants were measured (excluded mature and immature trees along with grasses). The sample size was chosen to be large enough to make inferences about the population while not being too time-consuming. Before any plant was measured it was photographed and identified. Plants were measured at random beginning at a central point in the field site and expanding outward in order to capture an unbiased sample of the relative species abundance. The size of the sites differed due to the density of the understory vegetation; sites that were more dense were smaller in area but all paired sites contained the same number of individuals.

Five different functional traits were measured for each individual plant: height, chlorophyll content, leaf area, leaf weight, and SLA. Plant height and chlorophyll content were measured directly in the field. Height was measured with a meter stick beginning at the bare ground up to the tallest point on the plant-- plants were held upright to capture full height even if the stem was bent or twisted. Chlorophyll content was measured using an atLeaf+ chlorophyll meter which shoots a beam of light through the leaf and records the amount of light that is able to pass through the leaf. The meter then converts this value into amount of light absorbed by the leaf (Zhu et al, 2012). Leaves were kept flat in individual leaf envelopes and were scanned within two hours after being taken from the plants to ensure they maintained shape and did not dry out. Leaf area was calculated using scanned images of a single leaf for each individual plant in the program ImageJ. Leaf weight was taken using a laboratory scale after the leaves were dried in a convection laboratory drying oven for over a week. SLA was calculated by dividing the calculated leaf area by the dry weight of each leaf, making the two variables correlated. Due to this correlation, SLA values were analyzed and leaf weight values were not in order to avoid redundancy.

Species Diversity: All measured plants were identified to species if possible, otherwise they were identified to genus. Identifications were guided by the website GoBotany.com and professional assistance.

Data Analysis: All of the measurements taken for the 950 plants were entered into a spreadsheet and analyzed using R, a statistical computing and graphics software (R-Project.org, 2015). The data were grouped together according to “Buckthorn Present” and “Buckthorn Absent” and then each of the four traits were analyzed: “Height,” “Chlorophyll,” “Area,” and “SLA.” The data values for these groups were plotted as box plots. Box plots show medians, 25-75 percent square, range, and outliers of the data (Zar, 2014). The data were then analyzed using t-tests. T-tests determine if the mean values between two samples are significantly different enough from each other to claim that the two populations are different (Zar, 2014). For this experiment I used $p=0.05$ as the significance value; any test that generated a value greater than this number was determined to be not-significant, and any test that generated a value equal to or less than this value was determined to be significant. In statistical analysis this level of significance is conventional (Zar, 2014). The plots and t-tests were conducted using the R commands

```
plot(Height~Buckthorn,data=d,main="Height"),
t.test(Height~Buckthorn,data=d)
```

with the same commands done for “Area,” “Chlorophyll,” and “SLA.” All of the data were then plotted as frequency distributions and analyzed using the Kolmogorov-Smirnov test. The Kolmogorov-Smirnov test determines if two sample frequency distributions are different enough from each other to claim the two populations are different (Zar, 2014) Again the significance value was set at p=0.05. The graphs and Kolmogorov-Smirnov test were conducted using the R commands

```
plot(density(q$Height),main="Height"), lines(density(r$Height),col="blue")
ks.test(q$Height, r$Height, alternative = c("two.sided"),exact = NULL)
```

with the same commands done for “Area,” “Chlorophyll,” and “SLA.” Analysis was then preformed on the trait distributions for each pairs of sites separately (see Appendix A-D).

In order to control for site variation, additional test were run after preforming the t-test. Mixed model analyses are used when random and fixed effects are present in a study (Bennington and Thayne, 1994). Specifically, site pair was treated as a random effect while buckthorn presence was treated as a fixed effect. This more effectively controlled for the differences between site pairs. The mixed model analyses were conducted using the R commands

```
summary(lme(Height~Buckthorn, random=~1|Site, data=d, na.action=na.omit))
```

with the same commands done for “Area,” “Chlorophyll,” and “SLA.” Values were then compared to the t-test values.

Number of species was calculated to determine species richness and species evenness; species richness is the number of different species present per site and species evenness is the the similarity of the the frequency of each of the species present per site (Molles, 1999). Species per site was calculated using the R commands

```
unique(BackyardPresent$Species)
unique(BackyardAbsent$Species)
```

with the same commands for the other eight sites (with and without buckthorn). From these data species evenness could be calculated. Shannon's measure of species evenness (Magurran and McGill, 2010) was calculated using the R commands

```
diversity(table(BackyardPresen$Species))/
log(length(unique(BackyardPresen$Species)))

diversity(table(BackyardPresen$Species))/
log(length(unique(BackyardPresen$Species)))
```

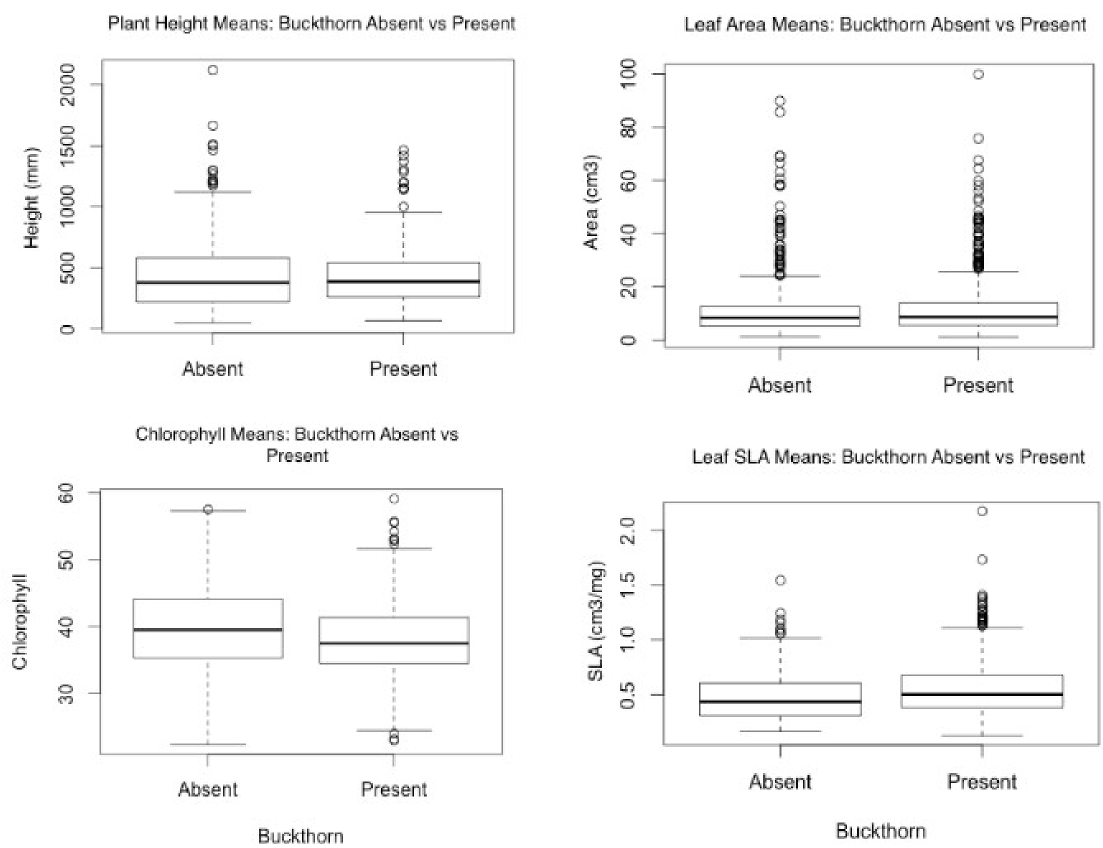
with the same commands for the other eight sites (with and without buckthorn). These data were then graphed with the R command

```
stripchart(Even~Buckthorn,vertical=TRUE)
```

to show the difference in evenness between buckthorn-absent and buckthorn-present sites. Species richness was plotted in the same manner. The data sets were too small for significance testing, but the graph serves as visual analysis of the species diversity of the two types of sites.

Results:

Once the data were grouped into “Buckthorn Absent” and “Buckthorn Present” and then divided into the four traits they were graphed as box plots (Figures 2-5). The t-tests gave significance values for differences between sample means. The p-value for the difference between plant height means was p=0.8318, which is not significant. The p-value for the difference between leaf area means was p=0.3201, which is not significant. The p-value for the difference between chlorophyll means was p=2.706e-6, which is significant. The p-value for the difference between SLA value means was p=1.063e-7, which is significant.



Figures 2 through 5 Box plots showing values for plant heights, leaf area, chlorophyll, and leaf SLA for buckthorn-absent and buckthorn-present sites. Median values are marked with the bold bar in the 25-75 percent rectangle.

The mixed model analysis gave significance values for differences between sample means while taking into consideration the paired site design. The mixed model results are compiled in Table 1. The p-value for plant height means is not significant, the p-value for leaf area means is not significant, the p-value for chlorophyll means is significant, and the p-value for SLA means were significant. This exactly parallels the results from the t-test.

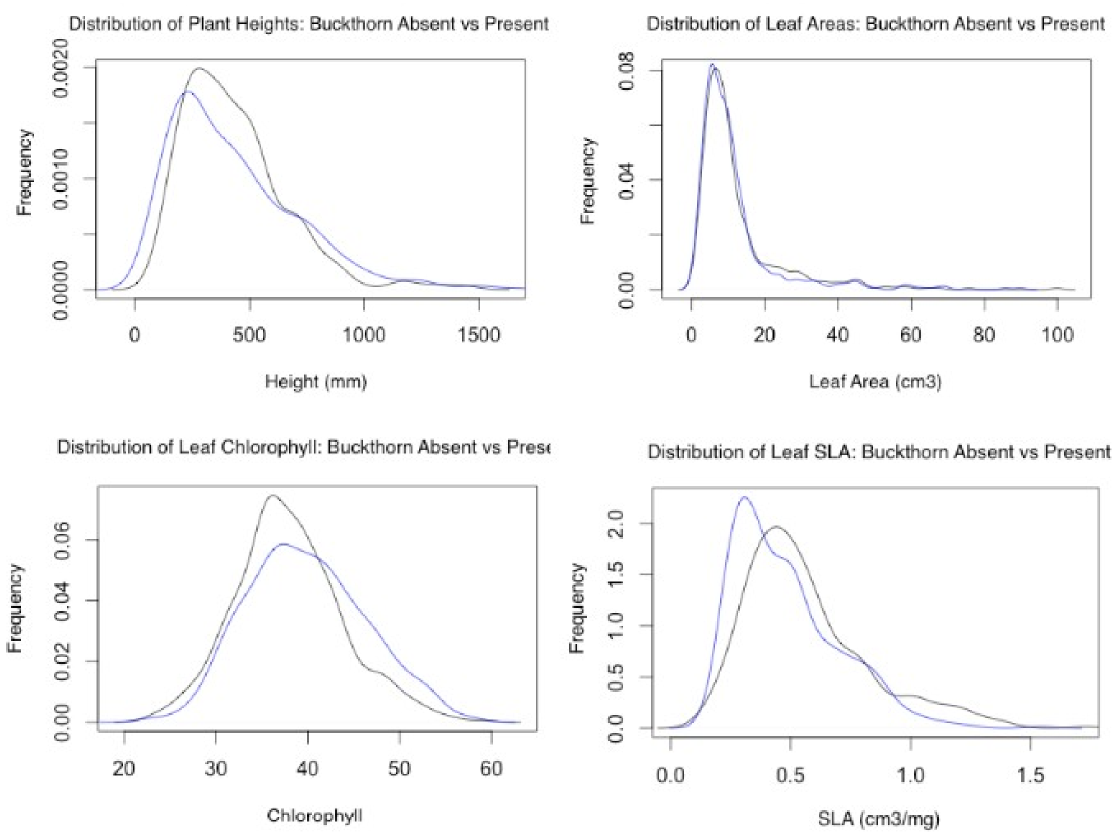
	T Statistic	P-Value
Height	0.35	0.73
Area	1.040723	0.2983
Chlorophyll	4.70496	~0
SLA	6.148086	~0

Table 1 Statistical values given for each of the four traits using mixed model analysis

The data were then graphed as frequency distributions (Figures 6-9). The Kolmogorov-Smirnov tests gave significance values for differences between the distributions. The p-value for the difference between plant height distributions was p=0.009544, which is significant. The p-value for the difference between leaf area distributions was p=0.4267, which is not significant. The p-value for the difference between chlorophyll distributions was p=4.021e-5, which is significant. The p-value for the difference between SLA value distributions was p=1.622e-7, which is significant.

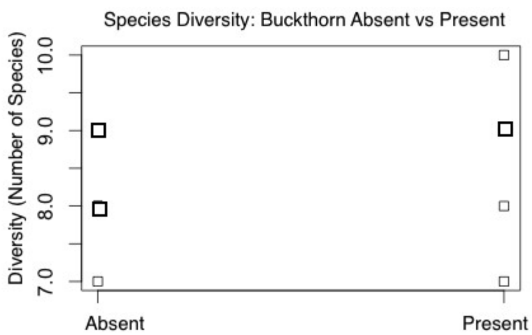
The distributions for plant height (Figure 6) show a decrease in plant frequency in the left and right tails of the distribution and an increase of plant frequency around the peak of the distribution and towards the right tail for areas with buckthorn present when compared to areas with buckthorn absent. This explains how the means were not significantly different while the distributions were. The distributions for leaf area (Figure

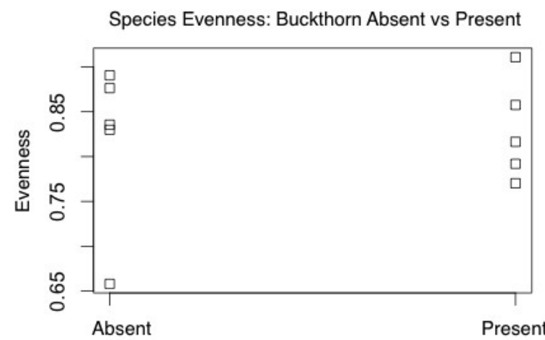
7) do not show a noticeable difference in plant frequency in either tail or center of the distribution for areas with buckthorn present when compared to areas with buckthorn absent. The distribution for chlorophyll (Figure 8) shows a decrease in plant frequency in the right tail of the distribution and an increase in plant frequency around the peak of the distribution and towards the left tail and an increase in plant frequency in the left tail for areas with buckthorn present when compared to areas with buckthorn absent. The distribution for SLA (Figure 9) shows a peak shift towards the right and an increase in plant frequency in the right tail of the distribution for areas with buckthorn present when compared to areas with buckthorn absent.



Figures 6 through 9 Distribution graphs showing the range of trait values on the x axis and frequency of trait appearance within the sample on the y axis. The blue lines indicate buckthorn absent and the black lines indicate buckthorn present.

Species richness and species evenness were plotted to show the richness and evenness of all ten sites divided between "Buckthorn Absent" and "Buckthorn Present" (Figures 10 and 11). No statistical significance values were calculated.





Figures 10 and 11 Strip charts of species diversity and species evenness. Bold squares represent two sites with the same value.

<u>Discussion</u>:

The results from this experiment show the effect of buckthorn on five native communities in Orono, Maine. They show that plant height and leaf area means are not significantly different between the buckthorn-absent and buckthorn-present sites but the chlorophyll mean is significantly lower and the SLA mean is significantly greater for buckthorn-present sites when compared to buckthorn-absent sites. The mixed model analyses confirmed these significance levels (Table 1). The results show that the leaf area distributions are not significantly different between the two types of sites, and they show that the distributions of plant height, chlorophyll, and SLA values are all significantly different between sites. The Kolmogorov-Smirnov test gave similar results to the t-test and mixed model analysis for leaf area, chlorophyll, and SLA, but plant height differences changed from being not significantly different (t-test and mixed model analysis) to significantly different using the Kolmogorov-Smirnov test. This suggests that the plant height values differ between environments even though the means are not significantly different. The results also show what the species richness and species evenness look like between the two types of environments.

The mean plant heights for buckthorn-absent and buckthorn-present sites were not significantly different from each other but the distributions were (Figures 2 and 6), meaning that the presence of buckthorn has an effect on the plant heights of a community. The distribution for buckthorn-present sites has less plants in either tail of distribution when compared to buckthorn-absent sites (Figure 6), meaning the community changed so that it did not allow plant heights to be as small or as large as the extreme values in the sites without buckthorn. The buckthorn-present distribution has a much greater frequency around 250-600mm than the buckthorn-absent distribution, meaning the community changed so that it encouraged more plants to be just above the average height. Overall we can see a shift in community composition; when buckthorn is present the range of plant heights decreases but there is a greater concentration of plants around and just above average height. Plant height is an indication of competition for resources such as sunlight (Cornelissen et al, 2003). Westoby and colleagues claim that plants all need the same resources to survive and they differ in form in order to all acquire these resources; this means plant heights can change as plants compete with each other (Westoby et al, 2002). This decrease in frequency in the tails of the height distribution could be due to the understory plants being shaded out by the buckthorn or competing with buckthorn; the smaller plants are no longer able to compete for light resources and the tallest plants no longer have enough resources to afford building so much biomass or they are too similar in height to buckthorn. The increase in frequency in the center of the distribution could be due to more of the smaller plants using their resources to increase their height to try to capture more light.

The mean leaf areas were not significantly different for the buckthorn-absent and buckthorn-present sites, nor were the distributions of leaf areas (Figures 3 and 7). This means the presence of buckthorn does little to affect the functional trait space of the community leaf sizes; something else (genetic, biotic, or abiotic) must be maintaining leaf size average and range. Variations in leaf size have been know to vary with geology, altitude, latitude, and drought stress (Cornelissen et al, 2003). None of these abiotic conditions would have changed between the paired sites in Orono, ME because they were all at the same elevation, same proximity to water, and same climate.

The mean chlorophyll concentrations per leaf were significantly lower in the buckthorn-present sites and the distributions were significantly different as well (Figures 4 and 8), meaning the presence of buckthorn has an effect on the amount of chlorophyll produced by plants in a community. The distribution for buckthorn-present sites has a lower frequency of plants in the right tail of the distribution and a higher frequency of the left tail of the distribution when compared to the distribution buckthorn-absent sites (Figure 4); fewer plants produced as much chlorophyll as the plants above average (when compared to the sites without buckthorn) and more plants produced chlorophyll at below-average levels. The distribution was also more peaked, meaning more of the plants had chlorophyll values more similar to the average. We again see a shift in community composition; when buckthorn is present the range of chlorophyll values shifts towards the left side of the graph and are more concentrated around the mean which means more plants have less chlorophyll in their leaves. Contradictory to these results, Lambers, Chapin, and Pons write that plants in shade environments tend to increase their chlorophyll levels and that chlorophyll levels increase as SLA increases (Lambers et al, 1998). The reason for this discrepancy could be due to the fact that the atLeaf+ chlorophyll meter shoots light through the cross section leaf in order to detect the amount of light absorbed by the leaf (Zhu et al, 2012); thinner leaves would naturally let more light pass through. Chlorophyll per volume would have to have been calculated using different techniques. While it may seem obvious for chlorophyll levels to increase in order to capture more sunlight, this result could be due to resource allocation; the plants are not able to take as much nutrients from the ground and therefore the growth of the plant must be stunted in some way.

The mean SLA values for buckthorn-present sites were significantly higher than the buckthorn-absent sites, and the distributions of the SLA values differed as well (Figures 5 and 9), meaning the presence of buckthorn has an effect on the thickness of the leaves in the community. When compared to the distribution of SLA values for plants in buckthorn-absent areas, the distribution of SLA values for buckthorn-present areas has a much lower frequency of plants in the left tail of the distribution, a greater frequency of plants in the right tail, and a much higher concentration of plants above average (Figure 9). The distribution was less peaked, but more skewed to the right, meaning more of the plants had SLA values dissimilar to each other. Again there is a shift in community composition: when buckthorn is present there are fewer thick leaves (low SLA), more plants above average thickness (when compared to the sites without buckthorn), and there are more thinner-leaved plants (high SLA). This result is expected according to Lambers, Chapin, and Pons; they write that leaf SLA values increase in plants growing in shade environments (Lambers et al, 1998). According to the leaf economic spectrum theory and leaf life expectancy graph by Westoby and colleagues, leaves begin as investments (negative return) and over time they pay for their construction by accumulating mass for the plant (Westoby et al, 2002). From this information one can conclude that leaves growing in shaded environments should be thinner than light environments; if there is less light available then the leaves will never be able to pay back as much resources to the plant. Constructing thinner leaves allows the plant to conserve resources. Leaf SLA can tell us how much biomass the plants are allocating to their leaves and the relative leaf life expectancy (Mediavilla, 2001, Westoby et al, 2002). Leaf thickness and life expectancy may have to decrease in order to allocate resources to different survival strategies.

These results seem to show that the native plants do better in the presence of buckthorn if they grow above a certain height level while producing thinner leaves. The plants have to adjust their typical growth patterns in order to conserve resources and compete with this new species.

Ten values for species richness and species evenness are not enough to determine levels of significance, however the strip charts can still portray trends. Many sources claim that buckthorn has the ability to outcompete native species and therefore reduce biodiversity (Callaway and Aschehoug, 2000 and Klionsky et al 2009) and Figures 10 and 11 could agree with this idea. Although the site with the highest number of species (10) was a buckthorn-present site, the numbers were not very different among any site (they all varied between 7 and 10 species per site, see Figure 10). Aside from the lowest evenness value being a buckthorn-absent site and the highest evenness value being a buckthorn-present site, overall the evenness values were higher for the buckthorn-absent sites (Figure 11). The data cannot conclude anything about the effects of buckthorn on species diversity or species evenness, but it is possible they could be in agreement with what others have discovered or hypothesized about how buckthorn can outcompete native plants and reduce species diversity.

The results of this study show us that buckthorn affected all five types of environments in Orono, Maine. It has been established that buckthorn is very successful at planting itself within a community (Gleason and Cronquist, 1963, Campbell et al, 1995, Night et al, 2007, and Qaderi et al, 2009) and by doing so it can introduce more obstacles for the native plants. The understory plants will consequently have to use more resources to capture light while also having to compete more for resources in the soil. The results of this study show that the effects of buckthorn can be found using functional traits due to the fact that the trait space of a community is the summation of all the traits that are able to be successful in a given area while competing with biotic and abiotic factors; when a new factor is introduced a change may occur. The data from this study show us that buckthorn indeed alters the traits that are the most successful within a community.

By looking at the functional traits of the two different types of communities (buckthorn-present and buckthorn-absent) we are able to see so many more trends than just looking at species composition. Many ecologists are now looking towards functional traits for just this reason (Lavorel et al, 2002 and McGill et al, 2006). If I had been able to perform this study using more than ten field sites it is possible I could have figured out that some specific species are never able to grow where buckthorn is, but by using a smaller number of sites I was able to determine the types of plants that are unable to grow where buckthorn is. The functional traits show us how the five communities shifted in the presence of buckthorn, and we can use these models to predict how other communities might change and therefore what other plants might be at the most risk. Using the distributions from the four trait values we could hypothesize that short plants with thick leaves may not be successful if buckthorn were introduced to their community. These plants would have to have enough plasticity to deal with the change or else suffer reduction/elimination from the new community.

In addition to functional traits showing more trends than species composition, entire frequency distributions of trait values show more information than just mean trait values. The amount of change is seen best when looking at the frequency distributions of trait values. While a difference in mean trait values can tell us that a change occurred, it does not show exactly what the change looked like. Looking at the distributions shows us if the range of trait values shifts, expands, or shrinks with the addition of buckthorn. Looking at just the value means can exclude a great amount of community change and is not as helpful at predicting how a new species might fit in in the community.

According to the Maine Department of Agriculture, Conservation, and Forestry

(Maine.gov) there are seventeen other invasive plant species in Maine. The methods from this experiment could be conducted with any one of these plants in order to determine what native plants are at the most risk of being reduced/excluded from invaded habitats, but the conclusion from this experiment with *Rhamnus cathartica* and *Rhamnus franglua* can still be applied: invasive species alter the trait space of a given environment. Different species will alter communities in different ways, but they will add obstacles that change the available trait space for a given area. This information is important because it means that the addition of an invasive species can lead to reduced plasticity or even complete exclusion of certain species.

Conclusion:

When invasive species are added to a community they change the functional trait space that is being used. When buckthorn is added to communities in Orono, Maine it does not drastically increase or decrease the extreme limits of the occupied trait space, but it does distinctly alter where the majority of the plants fall within the community trait space (where they are able to be the most successful). After the addition of buckthorn, the trait space showed shifted height, chlorophyll, and SLA distributions, resulting in higher frequencies of individuals with just-above-average heights, below-average chlorophyll concentrations, and above-average leaf thinness. The models from this experiment could be used in other environments in the Northeast where buckthorn is currently a major problem and the general idea of structure change within a community can be applied to any invasive species.

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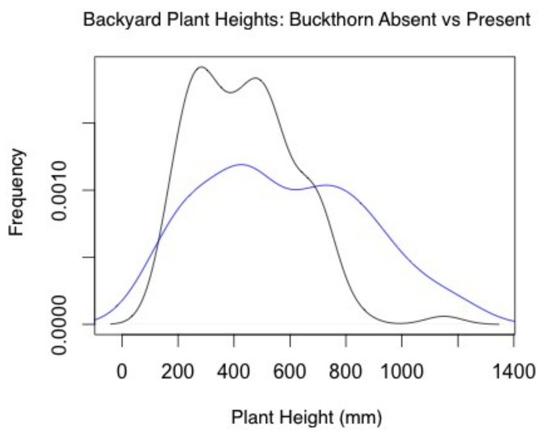
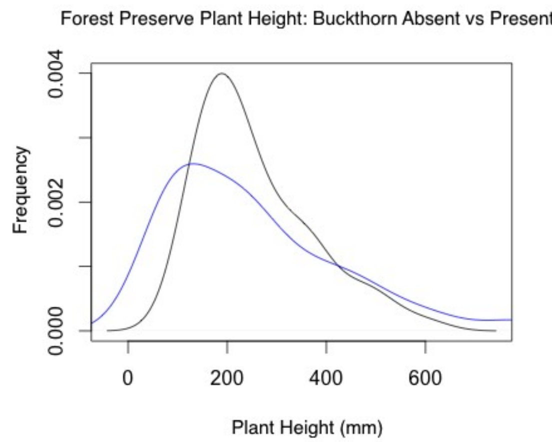
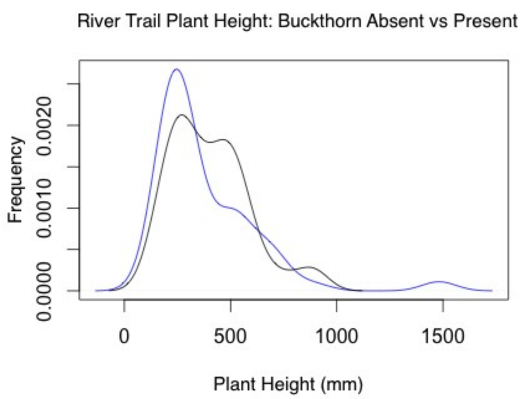
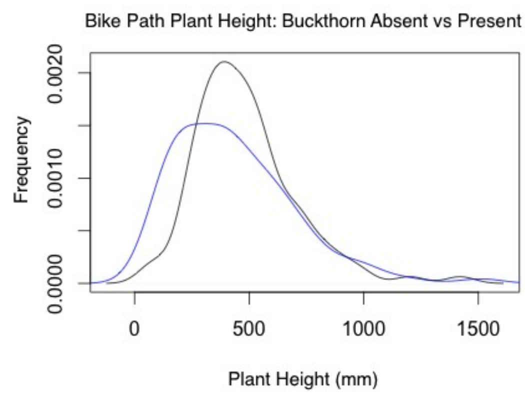
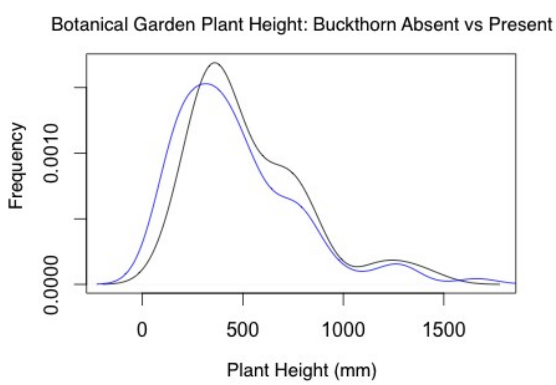
Appendix A: Plant Height Distributions By Site





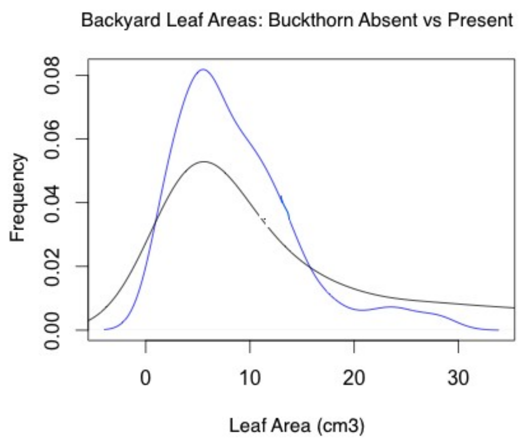


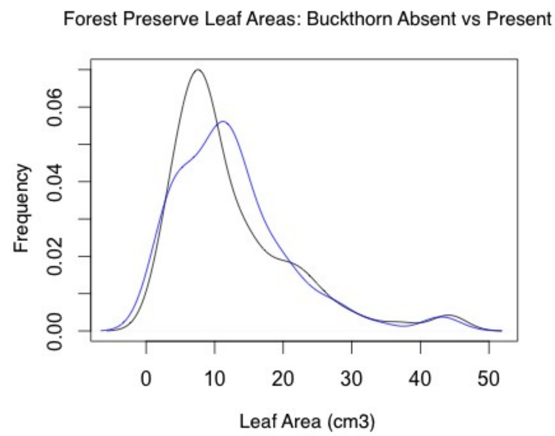


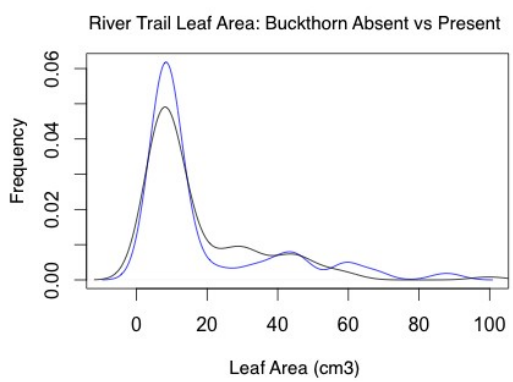


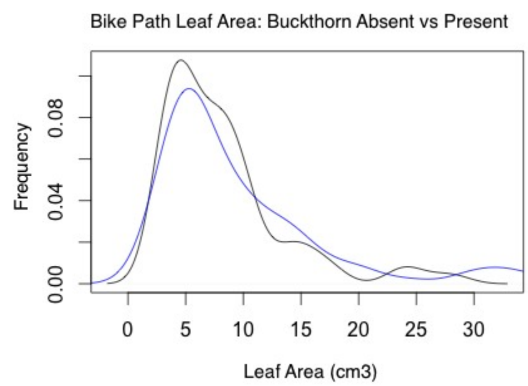
Figures 11 through 15 Distribution graphs showing the range of trait values on the x axis and frequency of trait appearance within the sample on the y axis. The blue lines indicate buckthorn absent and the black lines indicate buckthorn present.

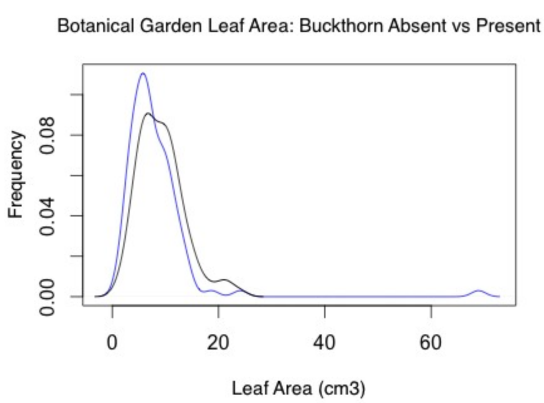
Appendix B: Leaf Area Distributions By Site





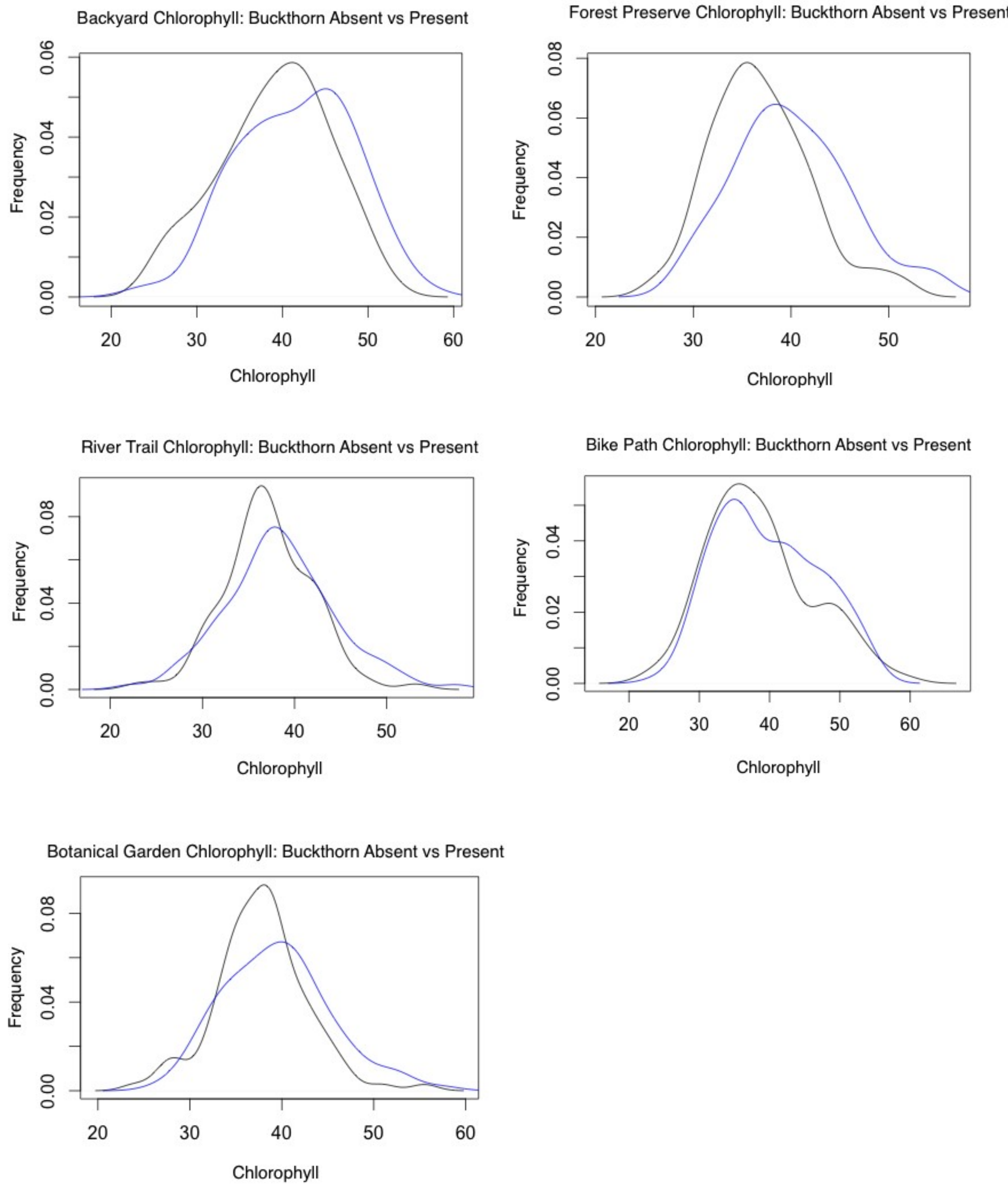






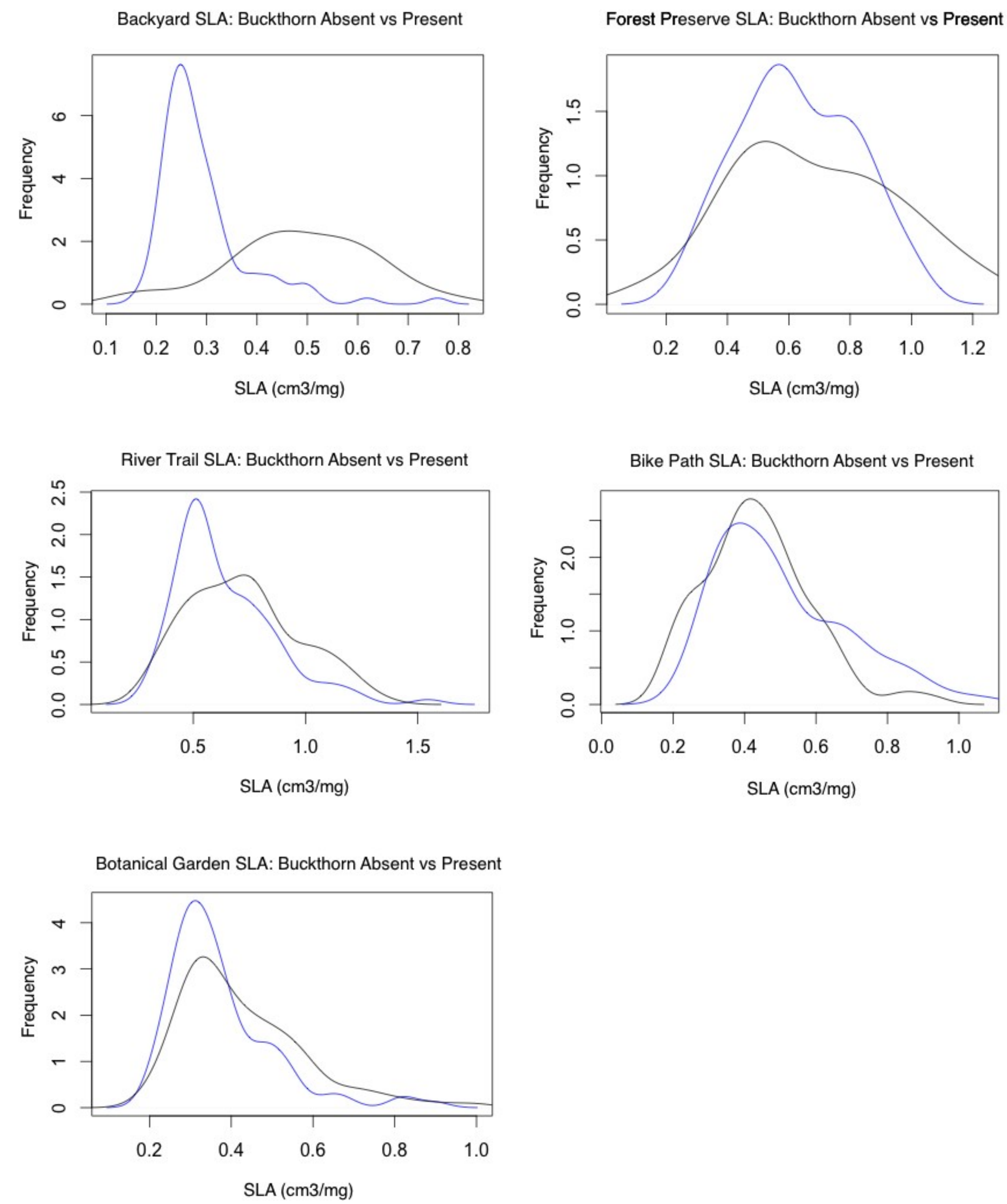
Figures 16 through 20 Distribution graphs showing the range of trait values on the x axis and frequency of trait appearance within the sample on the y axis. The blue lines indicate buckthorn absent and the black lines indicate buckthorn present.

<u>Appendix C</u>: Leaf Chlorophyll Distributions By Site



Figures 21 through 25 Distribution graphs showing the range of trait values on the x axis and frequency of trait appearance within the sample on the y axis. The blue lines indicate buckthorn absent and the black lines indicate buckthorn present.

Appendix D: Leaf SLA Distributions By Site



Figures 26 through 30 Distribution graphs showing the range of trait values on the x axis and frequency of trait appearance within the sample on the y axis. The blue lines indicate buckthorn absent and the black lines indicate buckthorn present.

Author's Biography:

Alexandra Perry was born on April 2^{nd}, 1993 in Portland, ME where she also grew up and attended high school. She graduated Deering High School in 2011 then attended the University of Maine in Orono, ME. Alexandra majors in Biology with a concentration in Ecology and minors in Plant Sciences. She is a member of the National Society of Collegiate Scholars and the Alpha Lambda Delta Honor Society. She has received the Frank H. Lanthrop and Oscar T. Turner scholarships from the School of Biology and Ecology. After graduation Alexandra will be an intern at the Rhode Island National Wildlife Refuge and after that she plans to return to Maine.