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## Seed Dispersal Effectiveness in the Penobscot Experimental Forest

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SEED DISPERSAL EFFECTIVENESS IN THE PENOBSCOT  
EXPERIMENTAL FOREST

by

Gabrielle Link

A Thesis Submitted in Partial Fulfillment  
of the Requirements for a Degree with Honors  
(Wildlife Ecology)

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## ABSTRACT

Previous studies have shown that scatter-hoarding small mammals increase seed germination success through the process of collecting and caching seeds throughout the forest. This study seeks to explore this further by examining how specific cache microsite preferences among these small mammals impacts the germination and growth of northern red oak (*Quercus rubra*). Seeds were planted in six different microsites across three forest treatments. Germination, seedling height, and herbivory were then monitored over time. We found that microsite did not have a significant effect on germination or height, however microsite did impact herbivory probability, and open microsites made seedlings more vulnerable than sapling microsites. Differences in germination and height were significant among different forest treatments, indicating that small mammal abundance within different forest structures may be important to forest success. The results of this study are important to understanding how individual small mammal cache decisions, that can be altered by personality, can be important to predicting forest composition in changing landscapes.

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## INTRODUCTION

Animals, especially scatter-hoarding small mammals, are one of the ways plants disperse their seeds (Lichti *et al.* 2015). Small mammals cache seeds in concealed areas to protect against pilferage and to secure a food source for later consumption (Muñoz & Bonal 2011; Ribeiro & Vieira 2016). Many scatter-hoarder caches end up unrecovered due to the animal's inability to recover seeds and predation on scatter-hoarders after caching (Steele *et al.* 2011). Unrecovered caches leave seeds to germinate, and buried seeds have a much higher germination rate than seeds left undisturbed on the forest floor (Lichti *et al.* 2015; Hass & Heske 2005). Scatter-hoarders are so influential that some plants have even evolved ways to make their seeds more desirable for scatter-hoarders to increase dispersal efforts (White *et al.* 2017). The dispersal of seeds due to unrecovered caches aids plants in many ways, which includes moving the seed away from the parent plant and putting selective pressures on plant traits (Zwolak 2018).

Although all scatter-hoarders cache seeds, their seed dispersal effectiveness varies among species (Schupp *et al.* 1993; Brehm *et al.* 2019). Seed dispersal effectiveness depends on the quantity of seeds dispersed and the quality of their dispersal (Schupp *et al.* 1993). Quantity is dependent on both the number of dispersed seeds and the number of times the scatter-hoarder goes to the parent plant, and quality is dependent on the site at which the seed is deposited (Schupp *et al.* 1993). Quality and quantity of seed dispersal have been shown to differ in both species and individuals within species (Longland & Vander Wall 2019). These differences can be caused by individual behavioral characteristics (Brehm *et al.* 2019) and differences in body morphology (Longland & Vander Wall 2019). Quality and quantity are also heavily influenced by characteristics of

individual seeds such as seed size, condition, and species (Sunyer *et al.* 2014).

Environmental variables like forest treatment (Wang *et al.* 2019) and proximity to anthropogenic features (Chen *et al.* 2019; Cui *et al.* 2018) have also been shown to affect quality and quantity in scatter-hoarders. Sunyer *et al.* (2014) concluded that even changes in season can alter scatter-hoarder seed preference.

Little research has been conducted on the impact that cache site variation has on seed germination and growth. Sipes *et al.* (2013) looked at the germination and overall success of oaks, but they examined sites where seeds had actually been cached rather than placing seeds in possible microsite locations. Woziwoda *et al.* (2018) examined germination success in northern red oak seeds and found that saplings planted in shrub sites were shorter and had a higher germination probability than those in open sites (sites without shrubs), but only shrub and open microsites were analyzed. A recent study has shown how the personality of individual scatter-hoarders has a heavy impact on seed dispersal quantity and quality (Brehm *et al.* 2019). Personality in animals is defined as the individual variation in behavior that stays constant through time (Carter *et al.* 2007). Personality has the ability to impact many aspects of an animal's life history, behavior, and fitness (Boon *et al.* 2007; Boon *et al.* 2008). Scatter-hoarder personality variants affect the microsite locations at which individual animals choose to cache seeds (Brehm *et al.* 2019). Research by Brehm *et al.* (2019) shows that bold and docile individuals choose to cache seeds in different microsites, revealing that personality impacts the most important steps of seed dispersal.

Despite this, studies have yet to reveal how much of an impact cache sites favored by small mammals have on seed germination and seedling growth. Germination is the

initial and most important phase of a plant's life (Donohue *et al.* 2010). Successful germination requires different environmental conditions, such as soil moisture and light, and this can vary depending on the species (Donohue *et al.* 2010). These components can vary in different microsites, which can have great impacts on germination success (Götmark *et al.* 2011). Plant growth occurs after successful germination and can be impacted by microsite features like light (Götmark *et al.* 2011) and protection from herbivory (Uytvanck *et al.* 2008). Scatter-hoarders impact germination site by favoring some microsites over others (Brehm *et al.* 2019). By doing this, scatter-hoarders have the ability to choose microsites that vary in composition, light availability, and protection. This means that scatter-hoarders have the ability to affect both seed germination and seedling growth after caching. By understanding effects of microsites on seeds, links can be made to how scatter-hoarding small mammal caching preferences, like those based on personality, can impact seed success.

This study attempts to address this knowledge gap by investigating the germination success and height growth of northern red oak (*Quercus rubra*) seeds in six different microsites within three different forest treatments. Scatter-hoarding mammals are the greatest contributors to *Q. rubra* dispersal compared to other seed dispersers (Plucinski & Hunter 2001). I predicted that germination success of *Q. rubra* would differ across microsites and forest treatments. I made this prediction based on research done by Götmark *et al.* (2011) who showed that higher moisture at microsites has been shown to increase germination rates in *Quercus* spp. seedlings. Moisture is an important factor in *Q. rubra* germination success (Kolb *et al.* 1989; Götmark *et al.* 2011), and microsites have been shown to vary in soil moisture (Götmark *et al.* 2011). This means that soil

moisture differences between microsites should impact the germination rates of seeds. I also predicted that height growth of *Q. rubra* would differ across microsites and forest treatments. I made this prediction based on research done by Götmark *et al.* (2011) who showed that canopy openness has shown to promote growth in *Quercus* spp. seedlings. The three forest treatments in this study vary in terms of their canopy openness, and since light availability has shown to impact *Q. rubra* seedling height growth (Brose & Rebbeck 2017; Kolb *et al.* 1989), these light differences should impact the height growth of *Q. rubra* seedlings.

This research will contribute to the understanding of how small mammal personality impacts the stages of plant growth by examining how microsite and forest treatment variation effects plant germination and growth. Seed dispersal studies are very important in understanding biodiversity and ecosystem structure in human-altered landscapes (McConkey *et al.* 2011, Brehm *et al.* 2019). Brehm *et al.* (2019) found that anthropogenic forest modifications impacted small mammal personality, and also therefore the initial stages of the seed dispersal process. By understanding how plants survive in different microsites and silvicultural treatments, inferences can be made on how human land-use in terms of forest modifications will impact future forest composition based on decisions made by scatter-hoarding mammals.

## METHODS

### Study Site

This study took place in the Penobscot Experimental Forest (PEF) of Eddington and Bradley, Maine, USA. A map of the study site can be found in Appendix A. The PEF is managed by the U.S. Forest Service for the purpose of research, recreation, and education. Composed of hardwoods mixed with northern conifers, the PEF is in the Acadian Forest region (Rogers *et al.* 2018). The trees found in the PEF that were of most importance to my study sites were eastern hemlock (*Tsuga canadensis*), red maple (*Acer rubrum*), eastern white pine (*Pinus strobus*), balsam fir (*Abies balsamea*), spruce (*Picea* spp.), and paper birch (*Betula papyrifera*). The PEF is split up into different grids with varying silvicultural treatments. Six grids with a total of three different forest treatments within the PEF were used in this study: 32, Brock's, 10, 6, 7A, and 7B. Grids 32 and Brock's are reference grids that have not been managed in the last 150-200 years. Grids 10 and 6 have been managed using a 2-stage shelterwood with retention system. Grids 7A and 7B have been managed using an even-aged regeneration system. Within each grid, a smaller grid of 90 meters x 90 meters was measured prior to this experiment and was the only area used for this study.

### Field Methods

Northern red oak seeds (*Quercus rubra*) were purchased online and stored in moist conditions until use. All seeds were tested for viability by placing in water, observing whether they sank or floated, and only sinking seeds were used (Tilki 2010). Seeds were planted in the PEF between 05/27/19 and 05/29/19. 18 seeds were placed

within each of the six grids; 36 acorns per forest treatment. At each grid, six different microsite types were used for seed placement (Figure 1): tree base, by coarse woody debris, on coarse woody debris, open, sapling, and fine woody debris. At each grid, three seeds were used for each microsite type. To reduce variability, the microsite type within each grid was chosen to be the same across grids. For each seed, a hole approximately 3 cm deep was created in the microsite, the seed was placed inside, and the removed layer was placed back on the seed for cover (Kostel-Hughes *et al.* 2005). The weight of the seed (taken using a small, portable scale), date of placement, nearest tree species, and GPS coordinates were recorded directly after placement. A square cage was placed over the seed where the covered seed was in the direct center of the cage. Two large staples were pushed into the ground through the cage openings to keep the cages in place. The grid ID (32, Brock's, 10, etc), and microsite type (tree base, on coarse woody debris, near coarse woody debris, etc) with individual seed ID (tree base 1, tree base 2, tree base 3, etc) was written on green flagging tape and the tape tied to a nearby object (usually an overhanging branch) to make relocation easier.

The seeds were left undisturbed until they started to emerge from the ground. Signs of seed emergence started in early July. Examples of seed experiment with emerged seedlings can be found in Appendix B. Seeds were measured five times in July and August, approximately one week apart: 07/08/19, 07/15/19, 07/22/19, 07/29/19, and 08/05/19. Measurements were taken by relocating each seed and collecting individual data directly in the forest. For each seed, height was taken using a ruler by placing the zero at the point where the plant emerged from the ground and measuring up until the tallest stem. Herbivory from animals was also recorded. When the seedlings reached a

height taller than the protective cage, the cage was removed to make measurements easier and reduce interference with seedling growth.

Canopy cover measurements were taken twice: once in May (when seeds were planted) and once in July. Canopy cover was measured using a spherical densiometer and measurements were taken at every seed site (108 total measurements).

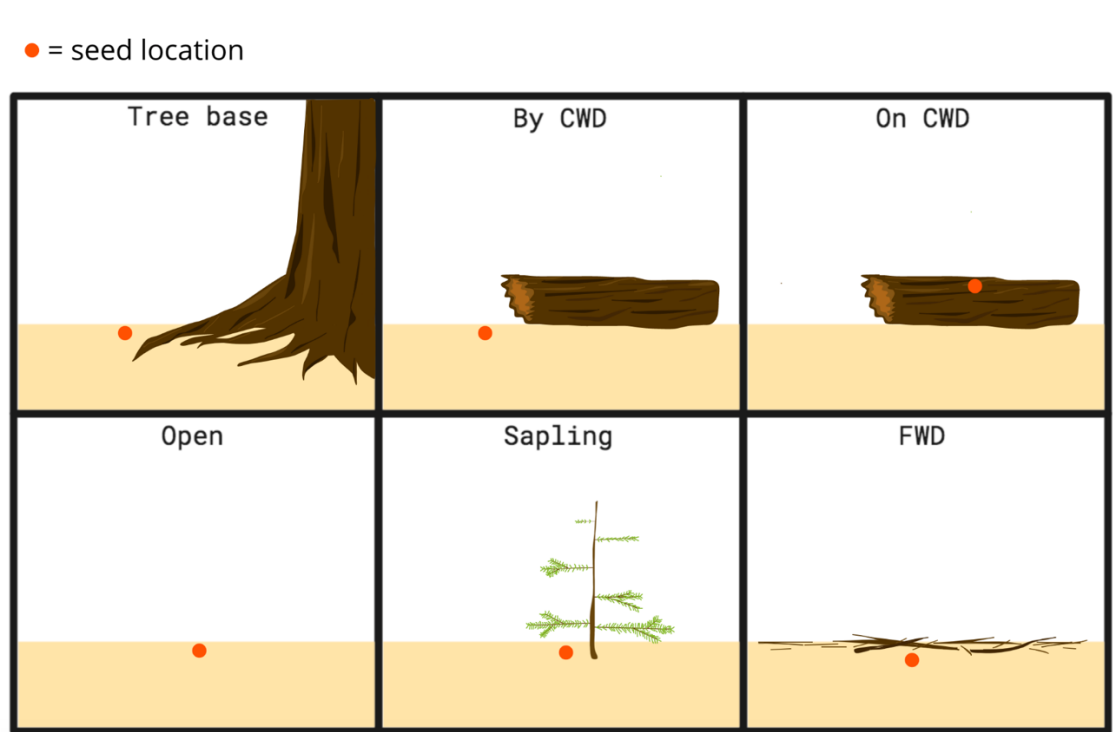


Figure 1. Six different microsites used for seed placement. Each orange dot represents the location of a planted seed relative to the microsite. A cage was placed over each seed to protect from disturbances during the initial stages of germination.

### Data Analysis

A Chi-square goodness of fit test was used to test the relationship between the following pairs of qualitative variables: forest treatment and germination, microsite and germination, forest treatment and herbivory, and microsite and herbivory. Both germination and herbivory were measured and analyzed using either a yes or no system,

making them qualitative variables. This test showed if the observed data differed significantly from the expected data. Data with germination was analyzed by using observed (number of germinated seeds in a treatment), subtracting the expected (% of seeds germinated\*seeds in treatment), squaring the result, and dividing everything by the expected. Data with herbivory was analyzed by using observed (number of eaten seedlings), subtracting the expected (% of seedlings eaten\*seedlings in treatment), squaring the result, and dividing everything by the expected.

A two-way ANOVA test was used to identify if forest treatment or microsite had any significant differences between the mean final heights of the *Q. rubra* seedlings (final height observed in week 5) using combined data from all forest treatments and microsites. The ANOVA is an appropriate test because height is a dependent, quantitative variable, and forest treatment and microsite are independent, qualitative variables. A Tukey HSD test was used on the results from the one-way ANOVA test to examine which microsite or forest treatment had the greatest effect on height. The Tukey HSD is an appropriate test because the variables are independent within groups and among all groups, and this was pre-determined in the ANOVA test.

A three-way ANOVA test was used to identify if forest treatment, microsite, or the interaction between forest treatment and microsite had any significant difference on final seedling height. A Tukey HSD test was used on the results from the three-way ANOVA test to identify which microsite or forest treatment had the greatest effect on height.

Two regression models (final height~May canopy cover, final height~July canopy cover) were run against a null model (height~1) using an ANOVA to determine if the

addition of canopy cover in May or July fit our data better than the null model. This analysis showed if canopy cover significantly impacted final seedling height.

A linear regression analysis was used to understand the relationship between final height and seed weight. Any relationship here would indicate height might be dependent on weight and not the variables we are testing.

## RESULTS

### Germination

#### Forest Treatment

Of the 108 total *Q. rubra* seedlings planted, only nine did not germinate. This means that in all grids combined, the seeds had a germination rate of 91.6%. 100% of the seeds in both reference grids (32 & Brock's Grid) germinated. 94.4% of the seeds in the even-aged grids (7A & 7B) germinated with one seed not germinating in 7A (97.2% germination rate) and one seed not germinating in 7B (97.2% germination rate). 80.5% of the seeds in the shelterwood grids (6 & 10) germinated with two seeds not germinating in grid 6 (94.4% germination rate) and five seeds not germinating in grid 10 (86.1% germination rate). Germination rate was highest in the reference grids and lowest in the shelterwood grids. Using a chi-square goodness of fit test on forest treatment and germination, we found that the differences between the observed and expected germination rates were significant ( $p = 0.0088$ ) (Figure 2). This means that overall, germination rate was significantly different between forest treatments, i.e. forest treatment impacted germination.

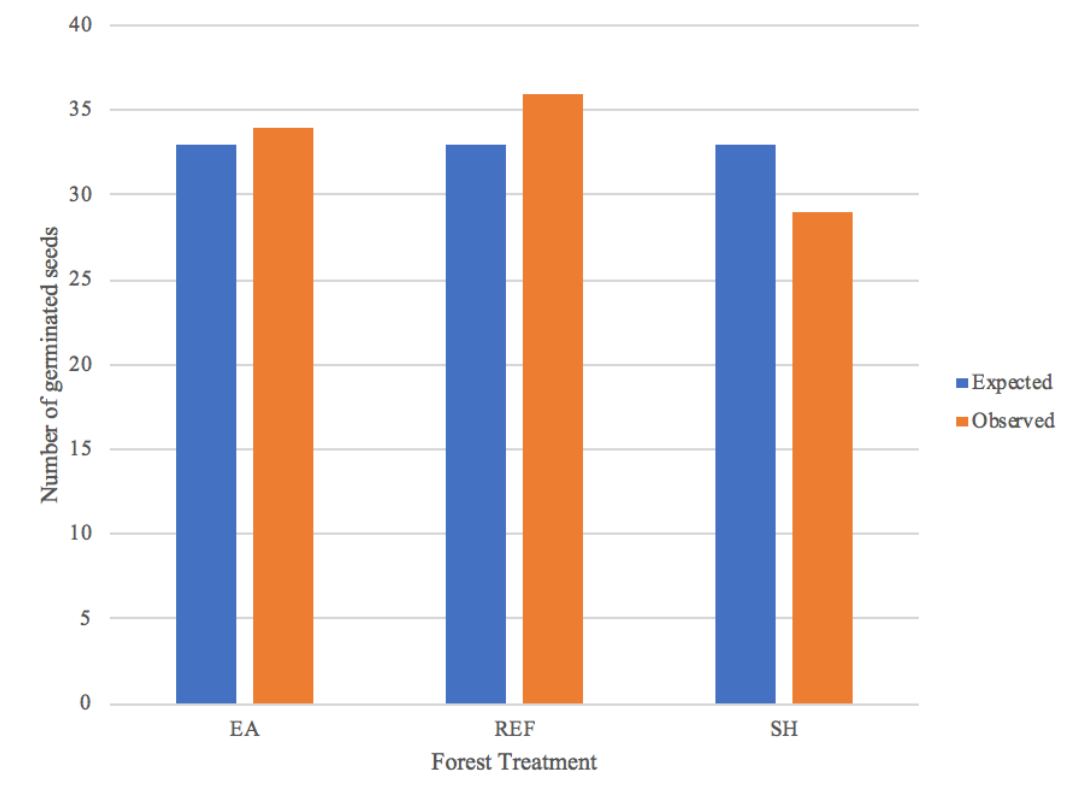


Figure 2. Observed and expected *Q. rubra* germination in the three forest treatments. The observed and expected values were used to run the chi-square test. EA = Even-aged forest, REF = Reference forest, SH = 2-stage shelterwood forest.

### Microsite

When combining all grids, the following germination rates occurred at each microsite: 100% at tree base, 94.4% under saplings, 94.4% in fine woody debris, 88.9% in open areas, 88.9% on coarse woody debris, and 83.3% by coarse woody debris. We used a chi-square goodness of fit test on microsite (combining all grids) and germination and found the differences between the observed and expected germination rates were not significant ( $p = 0.549$ ). This means that overall, germination rates of each microsite were not significantly different from each other, i.e. microsite did not impact germination.

## Height

### Forest Treatment

We used a three-way ANOVA test which showed that the final heights (height at week 5) of the *Q. rubra* seedlings were significantly different between the three forest treatments ( $p=0.0312$ ). We also used a Tukey HSD test used on the ANOVA results, which revealed that the final height was only significantly different between the shelterwood and reference grids ( $p=0.0358$ ).

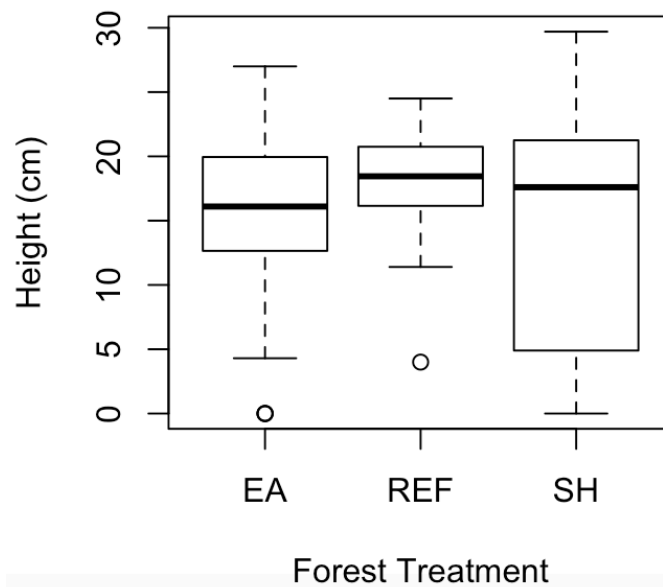


Figure 3. Final seedling height between the three forest treatments. All forest treatments have similar medians, but the variation is much higher in the shelterwood grids and lower in the reference grids. EA = Even-aged forest, REF = Reference forest, SH = 2-stage shelterwood forest.

### Microsite

We used a three-way ANOVA test showed final height was not significantly different between microsite ( $p=0.1924$ ), i.e. microsite did not impact final height of seedlings (Table 1).

Table 1. Results of the three-way ANOVA test results. Only final height between forest treatments ( $p<0.05$ ) was found to be statistically significant

	Df	Pr(>F)
Forest Treatment	2	0.0312
Microsite	5	0.1924
Forest Treatment + Microsite	10	0.3442

### Herbivory

#### Forest Treatment

Of the 99 total *Q. rubra* seeds that germinated, 50 showed signs of herbivory by animals at some point during the study. Only the germinated seedlings were used in this analysis to avoid bias from seeds that did not germinate (and are therefore unable to show signs of herbivory). In all grids combined, 50.5% of seeds were impacted by browsers. 51.7% of the seedlings in the shelterwood grids experienced herbivory with six occurring in grid 6 and nine occurring in grid 10. 50% of the seedlings in the even-age grids experienced herbivory with eight occurring in grid 7A and nine occurring in grid 7B.

50% of the seedlings in the reference grids experienced herbivory with eight occurring in grid 32 and 10 occurring in Brock's Grid. Using a chi-square test on forest treatment and herbivory, we found that the differences between the observed and expected values were not significant ( $p = 0.49$ ). This means that overall, forest treatment did not have an impact on herbivory on seedlings, i.e. forest treatment did not impact herbivory probability.

### Microsite

When combining all grids, the following herbivory rates occurred at each microsite type: 81.25% in open areas, 75% on coarse woody debris, 52.94% in fine woody debris, 50% at tree base, 33.33% by coarse woody debris, and 11.76% under saplings. Herbivory was highest in open areas and lowest under saplings. We used a chi-square test on microsite (combining all grids) and herbivory and found that the differences between the observed and expected values were significant ( $p = 0.0006$ ) (Figure 4). This means that overall, herbivory rates varied depending on the microsite; microsite impacted herbivory probability.

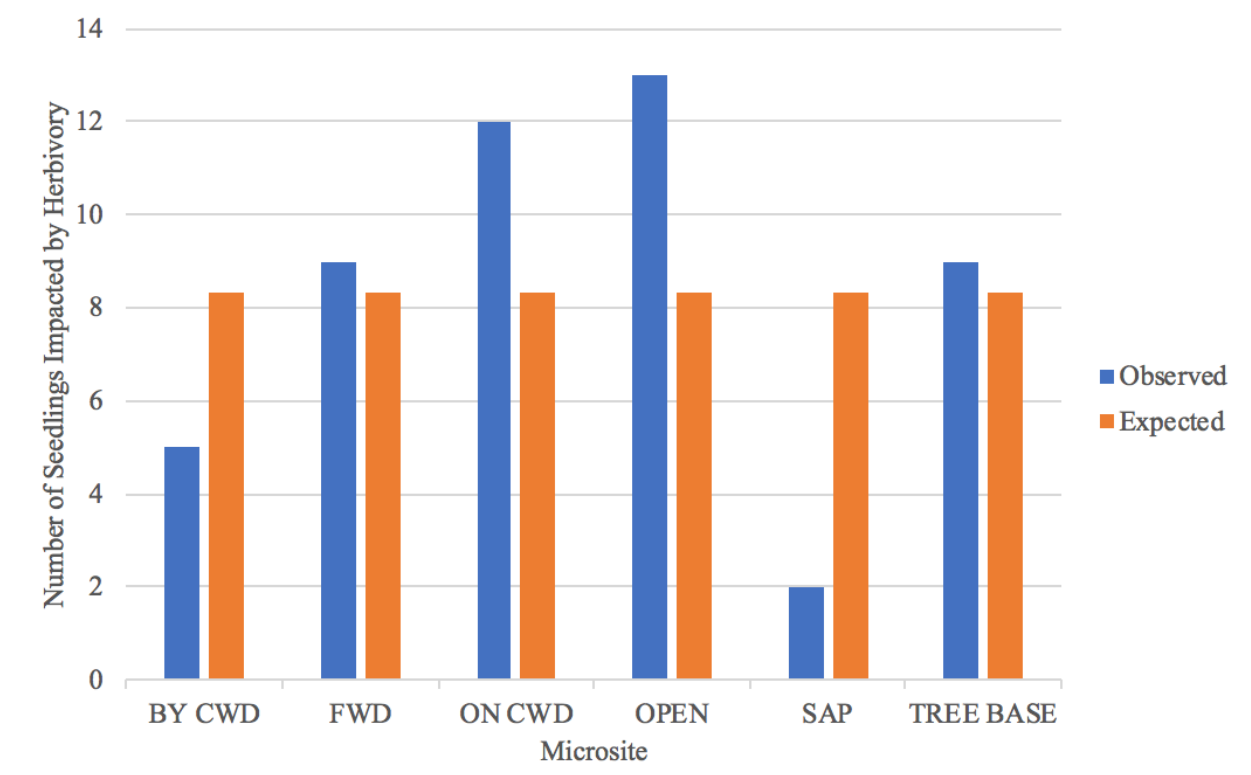


Figure 4. Observed and expected values of *Q. rubra* seedlings impacted by herbivory at the six microsites by the end of the study. The observed and expected values were used to run the chi-square goodness of fit test

### Seed Weight

Using a linear regression analysis, we found that the differences between final height and seed weight showed no statistical significance that seed weight altered seedling height ( $p=0.122$ ). This means that seed weight was not an influencing factor on the final height of seedlings.

### Canopy Cover

Using two different regressions and comparing them with a null model with a ANOVA analysis, we showed that the addition of May canopy cover ( $p=0.0553$ ) or July canopy cover ( $p=0.2236$ ) did not fit our data better than a null model.

Table 2. Results of the regression and ANOVA analyses. May and July canopy models were run against a null model to see if the addition of canopy better fit our data. May canopy ( $p>0.05$ ) and July canopy ( $p>0.2$ ) were not better than the null model.

Model	Pr(>F)
May Canopy	0.0553
July Canopy	0.2236

## DISCUSSION

The results from this study indicate that cache locations typically selected by small mammals in the Penobscot Experimental Forest have no impact on the initial stages of seed germination and growth, but they may impact later stages of plant growth based on herbivory. Microsite location was only influential to plant growth because herbivory was more likely to occur at some microsites compared to others. However, because some forest treatments exhibited higher germination success than others, this means that small mammal abundance within forest treatments may impact overall forest growth. Different forest treatments also showed differences in the final height of seedlings, indicating some forest treatments, like our 2-stage shelterwood forest, affect the height growth of seedlings after germination. This means that scatter-hoarder abundance within forest treatments is more important to the initial stages of plant germination and growth than microsite cache preference.

Germination was relatively high for all of the grids (91.6% across all grids). Bardon (1992) planted *Q. rubra* seeds in a greenhouse setting and found germination was >80%, exhibiting the high germination rate of this species in optimal conditions.

Germination varied between the different forest treatments, indicating the possibility of forest structure differences affecting germination rates. Germination rate was highest in the reference grids and lowest in the shelterwood grids. The reference grids are more open with a lower tree density than the shelterwood grids, which could mean light is an influencing factor in germination probability. However, *Q. rubra* are moderately shade-tolerant (Kuehne *et al.* 2014). Also, the canopy cover measurements at the individual microsites of the non-germinated seeds were higher than many of the seeds

that did germinate. Germination in *Quercus* spp. has been shown to be impacted by amount of soil moisture (Beon and Bartsch 2003). If soil moisture was the greatest factor, then it should be expected that the forest structure that provides the highest soil moisture should experience the highest germination rate. Increased soil moisture has been shown to be positively correlated with increased tree density (Tyagi *et al.* 2013). This means that the shelterwood forest should have more soil moisture than the reference forest, which is not in line with our germination results. However, soil moisture at the individual microsites within the shelterwood grids may have varied due to differences in forest structure. Taking a measure of soil moisture at each microsite may have been useful for linking soil moisture to germination. Overall, it is apparent that forest structure rather than microsite was important for germination. This means that scatter-hoarder abundance in different forest treatments will be important for overall forest growth. Forest structures that have lower germination, like our shelterwood grids, will need a higher number of small mammal inhabitants in order to increase seed germination. Forests structures that exhibit higher germination, like our shelterwood grids, need fewer small mammal inhabitants to maintain ecosystem functions, because more cached seeds left undisturbed will germinate.

Similar to the germination results, final seedling height was also found to change with forest treatment (Figure 3). Although height increases a plant's ability to reach light and makes them more competitive for light availability (Westoby *et al.* 2002), *Q. rubra* are moderately shade-tolerant (Kuehne *et al.* 2014), and therefore can withstand greater variation in light availability. For this species of oak, variations in height may not be beneficial or detrimental to overall survival, so seed caching in different forest treatments

might not be as important. However, plants that are shade-intolerant may find that decreased height is detrimental to their survival probability. These plants risk being outcompeted by taller or faster-growing plants that will have better access to light. On the other side, shade-intolerant plants with increased height are more competitive. Either way, forest treatment may alter a plant's competitive ability to access light by effecting height growth. This means that small mammals that make cache choices based on forest structure are indirectly affecting the survival probabilities of seeds after germination.

Across grids, microsite did not impact the germination success or height growth (Figure 1) of *Q. rubra* seeds. In a study on soil cover on seeds, it was found that germination of *Q. rubra* seeds increased significantly with burial (García *et al.* 2002). The burial of seeds may have generally increased germination chance, and all microsites provided adequate soil cover for all seeds. *Q. rubra* have been shown to be very tolerant to a variety of conditions (Huebner *et al.* 2018). Microsites across grids must have had about the same soil conditions, and any small differences were not significant enough to impact germination. This suggests that small mammal cache site preference is not a limiting factor to *Q. rubra* germination.

It must be noted that small mammals have small home ranges and will likely only reside in one forest structure. This means that scatter-hoarding small mammals will not be caching seeds in one forest structure versus another, and therefore will not be directly influencing germination success based on location. This, however, does not mean that scatter-hoarders are independent from germination. Seeds have a much higher germination rate when buried (Hass & Heske 2005), and burial is aided in the presence of scatter-hoarders.

Herbivory was observed most in the open microsites and least in the sapling microsites. Uytvanck *et al.* (2008) found that sites with taller vegetation and bramble thickets reduced the probability of herbivory by browsers of *Quercus sp.* This might explain the increased herbivory of seedlings in the sapling sites. The overhanging sapling may have provided a safe site for seedlings because they were not apparent to grazing herbivores (Uytvanck *et al.* 2008). The open sites may have been easy to spot and provided easy access for grazing herbivores as they walked by, resulting in increased herbivory. Studies have shown that browsing by herbivores negatively impacts seedling growth (Owings *et al.* 2017). Woolery and Jacobs (2014) found that browsing by herbivores on *Quercus* spp. reduced seedling height but did not significantly influence seedling survival. However, Woolery and Jacobs (2014) concluded that herbivory may have indirect negative effects on seedling survival, like making them less competitive with other plants. Taller plants are more competitive when it comes to light availability (Westoby *et al.* 2002), so shade-intolerant plants that are cut shorter due to browsing may experience reduced survival based on light availability. Small mammals that choose to cache seeds in more open sites with limited cover from shrubs may be leaving germinated seedlings more vulnerable to herbivores. This could indirectly decrease plant survival based on the competitive advantage observed in taller plants.

Herbivore populations within and across grids is unknown, so number of herbivores might differ between grids. Regardless, the presence of herbivores was apparent in all grids, and about 50% of germinated seeds in each of the forest treatments experienced herbivory. Forest treatment did not impact herbivory probability ( $p=0.49$ ) under the chi square goodness of fit test, so browsing levels were comparable across

treatments. Therefore, the conclusion that different microsites experienced different herbivory probabilities should remain supported.

Actual soil nutrient concentration and soil moisture at each microsite location was not recorded during this study. This may have been a factor in germination rate and height growth, so future studies may want to record these variables to further help interpretation of results.

Although height can give inferences on a plant's competitive ability in terms of light, the metric alone does not give a complete picture of a plant's health. The best way to understand plant height comes from measurements based on mass or stem volume. Mass measurements require removing, drying, and weighing plants. Stem volume measurements require taking height and width measurements of a plant's stem to estimate volume. Mass and stem volume measurements would have allowed for stronger inferences on the health of individual plants based on the variables tested in this experiment. Future studies should use mass and volume as metrics instead of height to make stronger conclusions based on plant health.

It must be noted that *Q. rubra* are a rather tolerant species when it comes to resource needs, making it an invasive species in many countries (Huebner *et al.* 2018). Many plants that require more resources to grow may be more affected when it comes to microsite location. For example, *Q. rubra* germination may not have been affected by soil moisture at different microsites, but other seeds may find microsites with lower soil moisture a limiting factor depending on their germination adaptations (Donohue *et al.* 2010). Further studies looking into other plant species and microsite would be important for which plants small mammal decisions impact the most.

Individual small mammal characteristics, like personality, have the ability to influence an individual's cache site preference (Brehm *et al.* 2019). For plants like *Q. rubra*, microsite choice could have negative effects on life after germination due to herbivore accessibility (Owings *et al.* 2017). Germination and height growth, which are important to initial and overall plant success (Donohue *et al.* 2010; Westoby *et al.* 2002), may be increased in some forest structures compared to others. This means that personality (because it can alter cache microsite) may have effects on seedling growth based on increased herbivory at some microsites, but may not have effects on germination success. Brehm *et al.* (2019) found that scatter-hoarder personality distributions were affected by anthropogenic habitat modifications of forests. Personalities that influence microsite could have varying effects on forest structure if many herbivores are present. For example, if a habitat modification favors personality types that are more likely to cache seeds in open areas, a higher percentage of germinated seeds will be susceptible to herbivory, which could have negative impacts for forest functions. Understanding how individual small mammal characteristics like personality impact cache choice and the results of these choices in varied landscapes will be key to predicting forest health.

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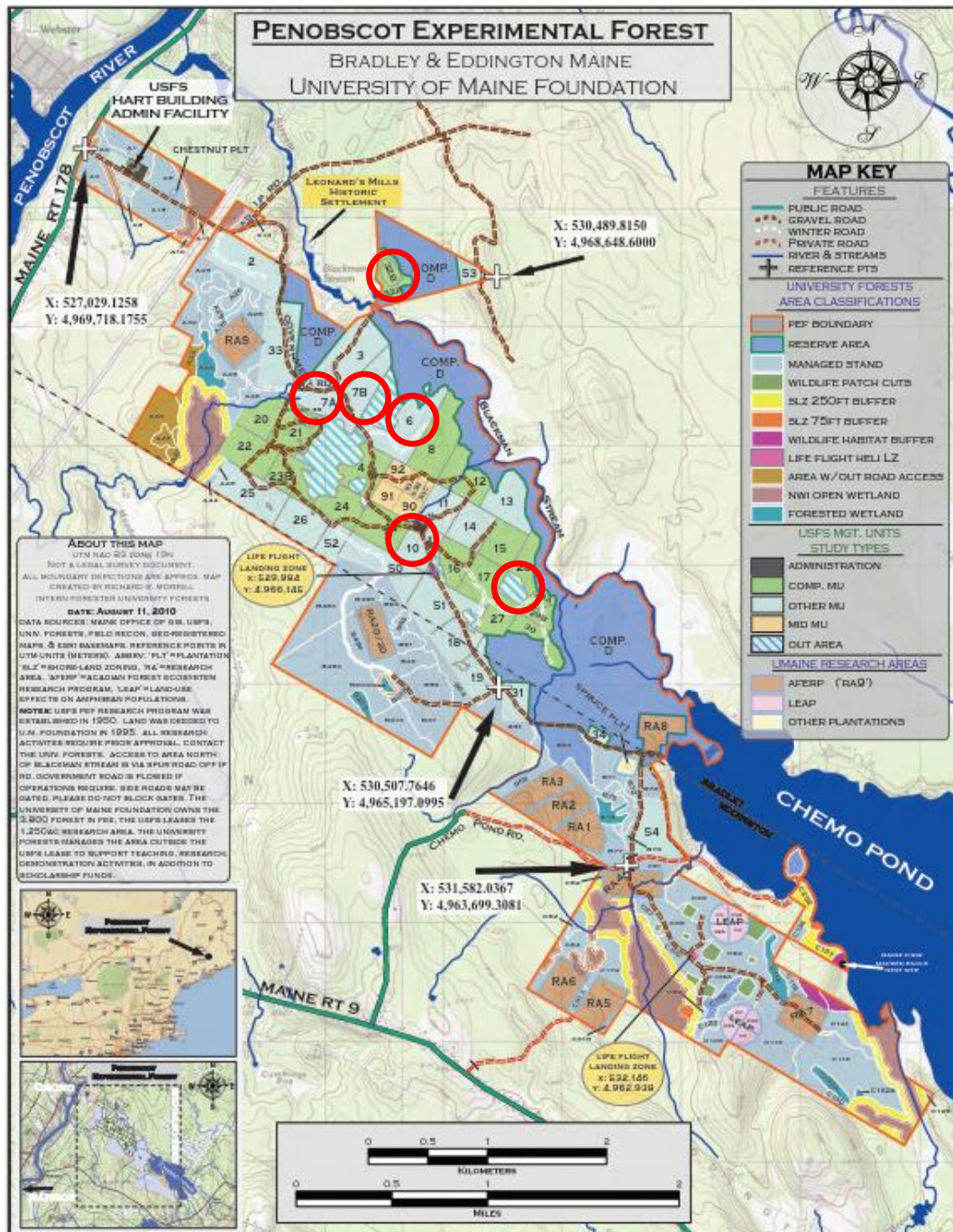
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## APPENDICES

## APPENDIX A: MAP OF STUDY AREA



## APPENDIX B: EXAMPLE OF SEED EXPERIMENT



## AUTHOR'S BIOGRAPHY

Gabrielle Link was born in Chicago, Illinois on August 3, 1998. She was raised in Bar Harbor, Maine and graduated from Mount Desert Island High School in 2016. At the University of Maine, she studied Wildlife Ecology with a concentration in Wildlife Management. Gabrielle was also a member of the Honors College and the Xi Sigma Pi Forestry Honor Society. Junior year she spent a semester abroad continuing her studies in the Galápagos Islands. Gabrielle plans to continue fueling her passion for wildlife by working as a technician after graduation.