THE EFFECT OF SLOPE POSITION AND ORGANIC SOIL DEPTH ON *Pinus banksiana* REGENERATION AFTER A FIRE

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ABSTRACT- *Pinus banksiana* regeneration is dependent on fire for the dispersal of its seeds, which further depends on the topography and organic soil depth. In recently burned sites, jack pine germinates predominately in the deep organic soil found in the wetland. However, as time persists, the mature tree density is highest in the upland, where there is no organic soil. Through the comparison of two burned sites, Sleeper Lake and Trout Lake, separated by date since burned, it was determined that initial establishment is found in the wetland, but as time passes, mortality is high in the wetland, resulting in high mature jack pine density in the upland.

Key Words- *Pinus banksiana*, Jack pine, Mature tree density, Sleeper Lake, Trout Lake, Seedling density, Upland, Midland, Wetland, Depth of organic soil, Regeneration, Establishment

INTRODUCTION

Natural fire disturbance is a major contributor to the regeneration of several forests, allowing for species that need an abundance of sun and open areas to establish. Forest fires help reestablish pre-fire forests by triggering a phase of fast nutrient cycling (Sirois, 1993). The seed bed as well as the open area creates an ideal environment for many plant species to germinate and survive in order to reconstruct the pre-fire forest (Li et al., 2009).

One particular tress species, *Pinus banksiana* (jack pine), heavily relies on the inception of fires introducing an array of abiotic factors into the system that become necessary for regeneration of this species to occur. *P. banksiana* is a pioneer species in succession and occupies areas where there is exposed mineral soil, which is often created after major disturbances (Burns & Honkala, 1990; Greene et al.,1999). This tree produces serotinous cones, sealed with a resinous material, which open upon desiccation – warm summer days or by fire (Adamowicz, 1985; Barnes & Wagner, 2004). Once the cones are opened, at or around 50°C allowing for seedling establishment to be made, other abiotic factors contribute to its continued survival (Gautheir et al., 1996; Beaufait, 1960).

Open areas following a fire allows for many herbaceous and tree species to grow, establishing a landscape suitable for succession, especially jack pine (Lavoie & Sirois, 1998). The composition of the burned forest changes dramatically after a fire, decreasing the amount of foliage coverage, increasing number of herbaceous ground cover, and depth of the organic layer. Most importantly, after fires, the depth of the organic layer increases due to the accumulation of unburned duff limiting the successful regeneration of jack pine seedlings (Lecomte et al., 2006).

Sleeper Lake and Trout Lake, both located in the Upper Peninsula in Michigan, are two sites that regenerated following fire only they are differentiated by the age of the forest after the disturbance event. Sleeper Lake, burned August 2007, is in the early stages of regeneration, with an abundance of seedlings on the ground cover. In comparison, Trout Lake, burned forty years ago, is a mature forest stand, with exceedingly low seedling density, which allows for comparison to where the seedlings persisted to achieve maturity (Adamowicz, 1985).

One might assume that the seedling density will be highest in the wetland site decreasing closer to the upland at the recently burned site, Sleeper Lake. In comparison, there will be an inverse relationship of the mature jack pine regeneration at Trout Lake due to the increased depth of the organic layer causing a reduction of mature *P. banksiana* in the wetland area. We report here on an experiment that will evaluate the impact that topographic relief: upland, midland, and wetland, has on the germination and survival of jack pine seedlings. More specifically, the location of seedling germination in congruence with the depth of the organic layer, density of foliage, groundcover, and mature trees contributes to the future of a jack pine dominated forest.

METHODS AND MATERIALS

Two sites, Sleeper Lake (Newberry, Michigan) and Trout Lake (Trout Lake, Michigan), were sampled to determine the density of *Pinus banksiana* seedling regeneration between a site that was recently burned as well as a site burned forty years prior, respectively. In order to accommodate all variables that could impact the regeneration and later succession of the Jack pine forest, many different sampling methods were practiced.

Transects were laid, using a 50 m transect tape, in the upland, mid-level and wetland at each site, separated by 10 meters in the upland and mid-level, and 20 meters in the wetland due to its greater area coverage. In the upland and wetland, four transects were laid, leaving only three in the mid-level due to the limited space. In order to integrate random variation in determining the points to be sampled along the transect, a coin was tossed. Within each transect, the five randomly assigned subplots were marked with flags and imaginary perpendicular lines to the transect were created to generate four quadrants to sample. Once the transects were laid, seedling density and percent groundcover, mature tree density, depth of organic layer, percent, and foliage coverage were recorded.

Seedling Density and Percent Groundcover. The quadrants were organized in a way to allow for further randomization when determining the number of seedlings and percent groundcover. A meter squared plot, constructed by plastic pipes, was randomly tossed in each of the four quadrants, which designated a specific area for percent ground coverage and number of *P. banksiana* seedlings to be measured. The percent groundcover was determined by differentiating the percent of the ground that was covered by *Carex pensylvanica* (Pennsylvania sedge) as well as other herbaceous material. The data helped in determining if there was a correlation between the *P. banksiana* seedling density and other herbaceous groundcover in the overall productivity of *P. banksiana* regeneration.

Mature Tree Density. The density of the seedling may be correlated with the density of the mature *P. banksiana* trees in the forest, therefore, several measurements were taken to aid in determining if a significant correlation existed. At each of the four quadrants along the transect line, the diameter at breast height (dbh) and distance from center point were measured.

Depth of Organic Layer. *P. banksiana's* seeds germinate and establish in areas where the organic layer is less than 1.3 cm thick (Burnes & Honkala 1990). To determine the correlation between seedling density and the depth of the organic layer, a metal pole marked at every 10 cm was pushed into the soil at every marked plot on the transect line. If a correlation was found, it would prove that organic depth and seedling dispersal was significant in determining the regeneration of *P. banksiana* forests.

Statistical Analysis. A *t-test* was used to compare seedling density to the three different elevations within Sleeper Lake; upland to midland, upland to wetland, and midland to wetland. A *Mann-Whitney test* was utilized to compare the depth of bare mineral soil to the three elevations at Sleeper Lake; upland to midland, upland to wetland, and midland to wetland. In order to conclude if there was a significant correlation between seedling density to soil depth, a linear regression test was used and visually shown in a graph.

Mathematical Methods. The total density of mature trees in the forest was calculated by using the equation: total density= $1/(\text{sum of distances}/\text{number of quadrants sampled})^2$. The total density was calculated for each of the elevations at Sleeper Lake and Trout Lake and compared using a bar graph. There were no statistical tests applied due to the incomplete sampling method.

RESULTS

The seedling density showed significance when compared to the slope position at Sleeper Lake using a 97% confidence interval *t-test* (upland vs. midland: t=-5.099, df=138, P<.0001; upland vs. wetland: t=-5.577, df=158, P<0.0001; midland vs. wetland: t=-3.14, df=138, P=0.002). The bare mineral soil showed significance when compared to the slope position (P<0.001). A bar graph was constructed to visually represent the seedling density and depth of the bare mineral soil to slope position (Figure 1). The seedling density was compared to the depth of the bare mineral soil at Sleeper Lake using a linear regression, which showed a general trend but was not significantly correlated (R^2=.586; Figure 2). There were more mature trees in the upland and midland at Trout Lake than Sleeper Lake, but more mature trees in the wetland at Sleeper Lake than at Trout Lake (Figure 3). The density of *Carex pensylvanica* was compared between the upland at Sleeper and Trout Lake using a t-test, which showed that it was not significant in the regeneration of *P. banksiana* (t= 0.982; df= 158; P= 0.328). In order to show a correlation between the productivities at Sleeper Lake and Trout Lake, a site index was used, indicating that at both sites, the upland had higher productivity than the midland and wetland. However, the wetland jack pine were not plotted on the given site index; the points were plotted resulting in new site index lines (Figure 4; Table 1).

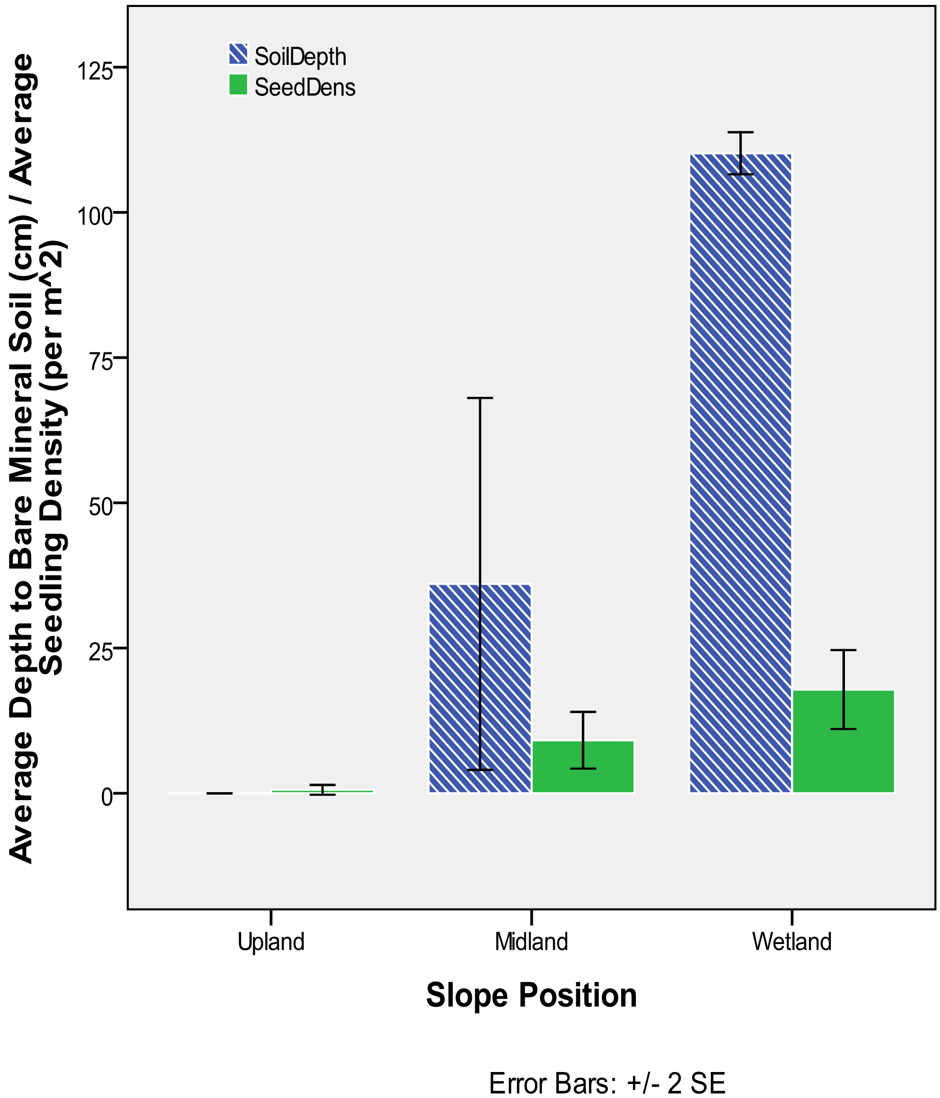

Figure 1. AVERAGE DEPTH TO BARE MINERAL SOIL AND SEEDLING DENSITY COMPARED TO THE SLOPE POSITION AT SLEEPER LAKE The mean depth of the bare mineral soil was compared to the different slope positions at Sleeper Lake. The mean seedling density is compared to the different slope positions at Sleeper Lake.

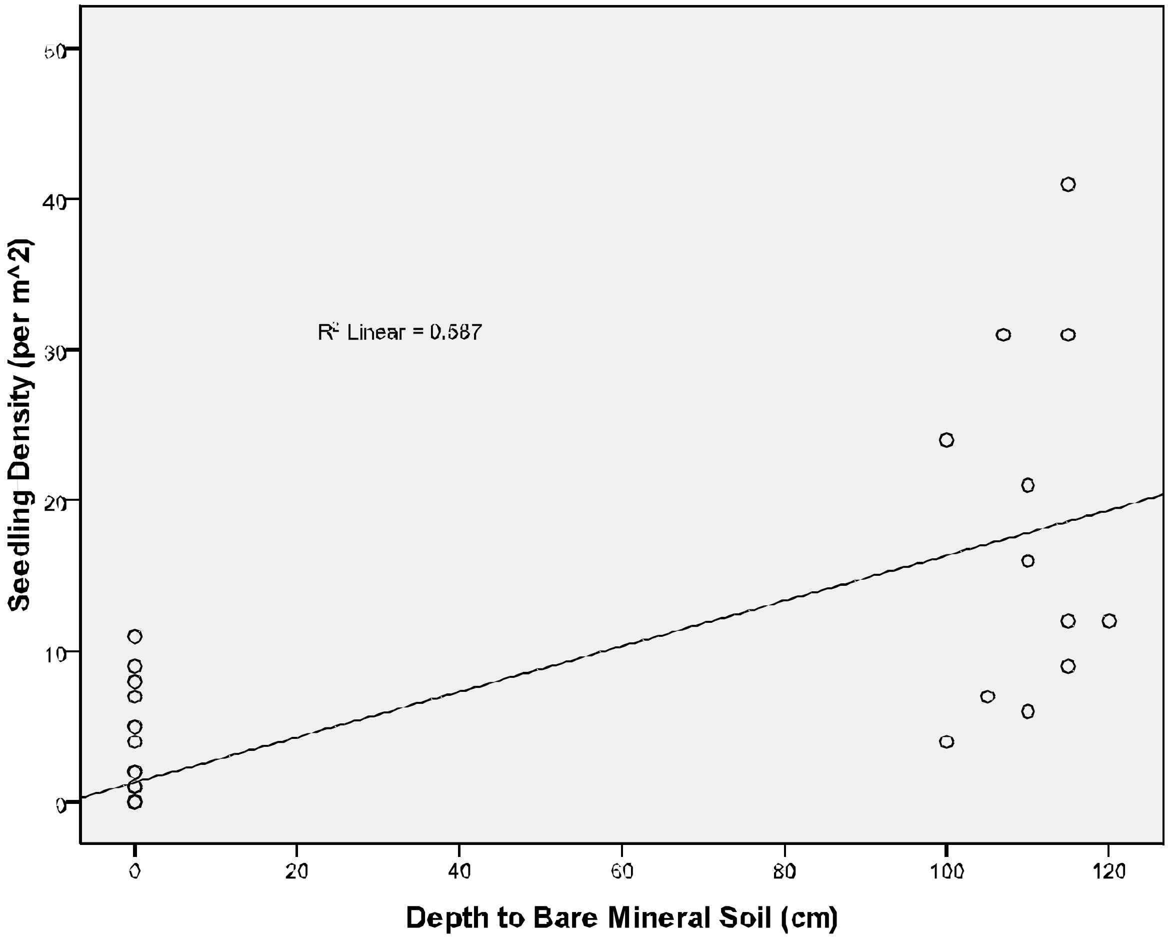

Figure 2. THE SEEDLING DENSITY COMPARED TO THE DEPTH TO BARE MINERAL SOIL AT SLEEPER LAKE Linear regression of seedling density (per m^2) compared to the depth of the bare mineral soil (cm) at Sleeper Lake.

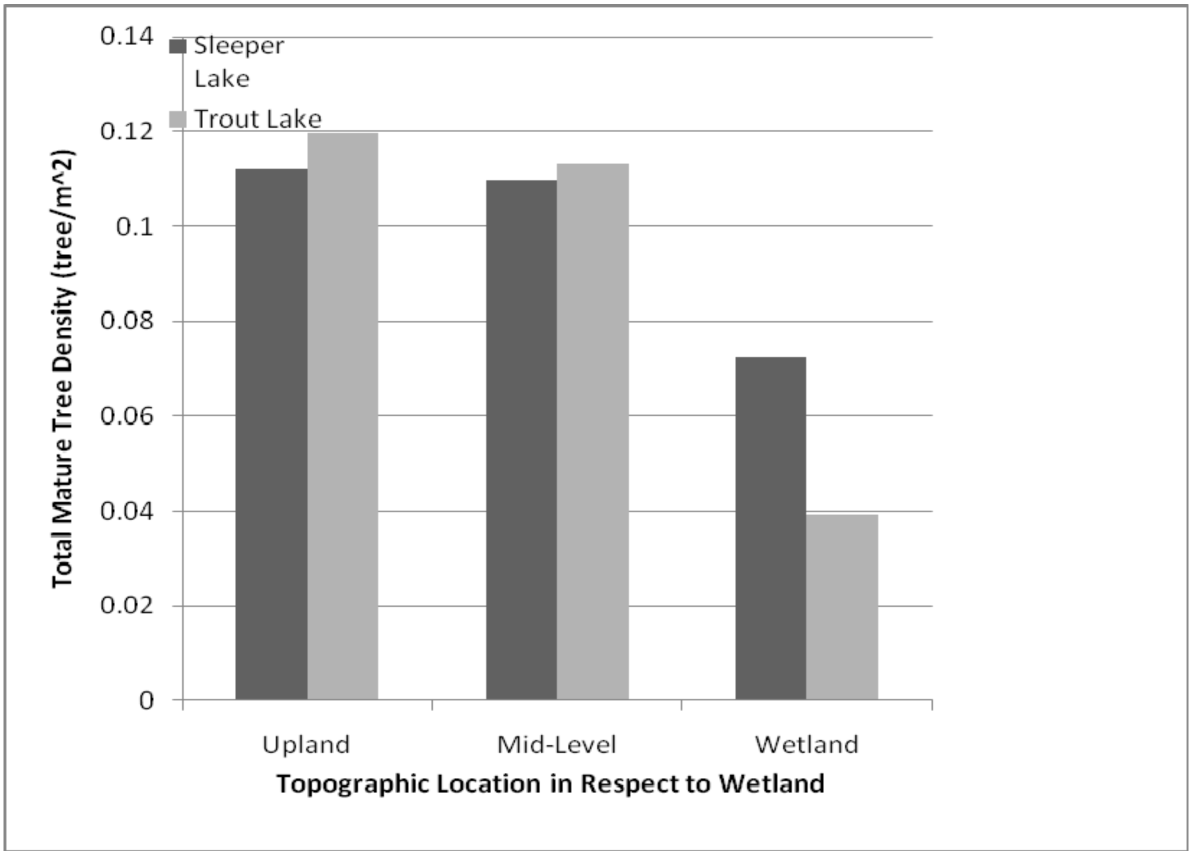

Figure 3. TOTAL MATURE TREE DENSITY VS. TOPOGRAPHIC LOCATION AT SLEEPER LAKE AND TROUT LAKE Total mature tree density (tree/m2) in relation to slope position at Sleeper Lake and Trout Lake.

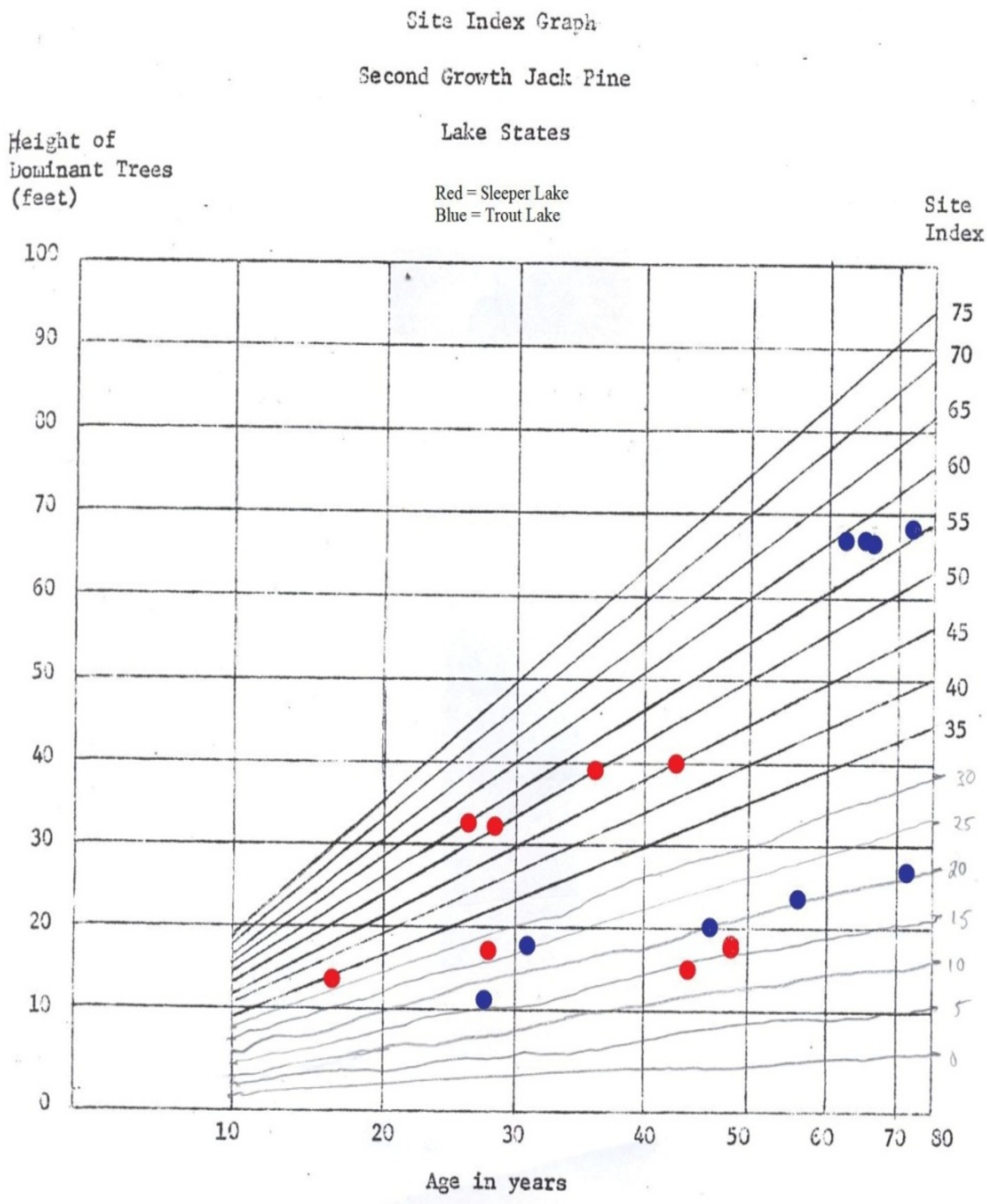

Figure 4. SITE INDEX GRAPH OF SECOND GROWTH JACK PINE LAKE STATES Graph of site index of Jack Pine at Sleeper Lake (circles) and Trout Lake (X)[1].

[1] *site index lines were drawn in for the wetland species*

Table 1. SITE INDEX OF JACK PINE AT SLEEPER LAKE AND TROUT LAKE The site index is shown in relation to the slope position and the site sampled

Site	Elevation	Site Index
Sleeper Lake	Upland	47.5
Sleeper Lake	Midland	41
Sleeper Lake	Wetland	26.33
Trout Lake	Upland	58.67
Trout Lake	Midland	31
Trout Lake	Wetland	22.67

DISCUSSION

There is a general trend between the seedling density and the depth to bare mineral soil; as the organic depth increases, the density of the seedlings also increases; however, there is no significant correlation between the two variables. This could be due to the lack of intermediate soil depths within the sampling site. Also, as shown by Figure 2, the points on the graph vary greatly on deeper organic soils. The increased variance could cause the R^2 value to be an average of the distances from those points to the line of regression causing the R^2 value to be inaccurate. In order to determine if the depth of bare mineral soil and seedling density is significantly correlated, more data could have been collected in the transition slope positions.

The results did not conclude that there is a significant correlation between the density of *P. banksiana* seedlings and depth of bare mineral soil in relation to the slope position. An overall greater abundance of seedlings was found in the wetland, which had the deepest organic soil, however, it is unclear as to why this occurred. jack pine seedlings can establish and germinate following a fire, however, most of the seedlings die unless the depth of the organic layer is less than 1.3 cm thick (Burns & Honkala, 1990). Since the fire occurred only two years ago, the seedlings in the wetland may not have been given enough time to acclimate to their environment due to limiting factors not tested for even though most mortality occurs between the first and second growing season (Burns & Honkala, 1990). If the data were collected and analyzed for several more years, there may be a significant decrease in the number of jack pine seedlings in the wetland.

Other factors could also contribute to the unexplained lack of seedling density in the upland at Sleeper Lake but the increased abundance of mature tree density at Trout Lake. The percent of *Carex pensylvanica* was compared between the uplands at Sleeper Lake and Trout Lake in order to determine if its presence limited the seedling density. The analysis showed that there was no significance in the relation of *C. pensylvanica* to seedling establishment, but it doesn't rule out the idea that other factors could limit the initial germination of jack pine seedlings. In order to further analyze the reasoning behind the lack of seedling density in the upland, one could look at the effect water has on seedling establishment to see if that could be the reasoning for the increased amount of seedling in the wetland than the upland early in succession.

The overall transect sampling method did not truly represent the different slope positions and were not spread apart far enough to gather an adequate sample size. Transects were laid in the true upland and wetland, however, the midland was not a true midland because of a steep ecotone (or transition along the dune/wetland edge). Of the three transects in the midland, one was placed in the transition phase between upland and midland and one was laid in the transition phase between the midland and wetland. Due to the lack of spacing between the transect lines, there was insignificant data to perform statistical tests for the mature tree density vs. slope position at Trout Lake. To ensure that significant and accurate data was collected for future analysis, the midland needs to be eliminated, allowing for the transect lines to be laid with greater area between them. This would eliminate the chance for overlap of mature trees in adjacent sampling points along the two transect lines.

Sleeper Lake and Trout Lake have jack pine forests that were established by natural forest fires resulting in germination of their seedlings. The topography and depth of the organic soils contribute to the density seedlings, causing an abundance of jack pine seedlings in the wetland where the organic layer is the deepest at Sleeper Lake. However, when compared to a forest that has aged forty years since a burn, the abundance of mature trees were recorded in the upland. Although we do not have supporting data as to why this inverse relationship occurs, it can be concluded that jack pine seedlings germinate successfully in deep organic soils in the wetland. However, as time progresses, mortality rates increase in the wetland resulting in *P. banksiana* mature trees successfully regenerating in the upland.

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