# Relationships between Yellow Birch (*Betula alleghaniensis*) Regeneration and Several Environmental Factors Following Disturbance

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## Abstract

Yellow Birch is an early to mid successional shade intolerant tree that is normally displaced by late successional species, such as Sugar Maple, as a stand matures. However, if significant disturbance occurs and allows more sunlight to filter to the canopy floor, Yellow Birch is often able to re-colonize an area. This study characterizes several Yellow Birch stands on the UNDERC property, and attempts to identify which of several environmental factors may serve as a disturbance, or may promote Yellow Birch re-colonization of an area after a disturbance. In so doing, it fails to find any significant relationship between canopy cover, ground cover, or proximity to water and Yellow Birch density. Significant relationships between Yellow Birch sapling density, seedling density, and tree density and proximity to permanent edge, defined in this study as edge along open water and edge along road, were found, but were not found to be important due to relatively weak correlation values. Other significant relationships were discovered between Yellow Birch sapling density and ground slope and Yellow Birch tree density and ground slope were found, which had relatively large correlation values. Additional studies on the relationships between Yellow Birch density and ground slope should be run in the future in order to verify that the pattern exhibited on the UNDERC property is a common one that is widely applicable to other Yellow Birch stands.

## 1. Introduction

The University of Notre Dame Environmental Research Center (UNDERC) forest, like many forests in Northern Wisconsin and Upper-Peninsula Michigan, was clearcut of White Pines (*Pinus strobus*) around the turn of the $20^{th}$ century (Whitney, 1986). After this disturbance, Red Pines (*Pinus resinosa*) were planted in place of the removed white pines in the 1930's, but these red pines did not regenerate well. This poor regeneration of pines provided an opportunity for many new species of trees to enter into the area, including a number of oak, hickory, ash, berry, elm, birch, and maple. With all of these newly introduced species of trees so relatively recently being thrown together, a rather complex community of early and mid successional stands has developed. This community has not had enough time to develop into old growth forest and thus seems rather ripe to lend itself to the study of early and mid successional tree species regeneration.

One interesting mid successional tree species, Yellow Birch (*Betula alleghanensisis*), is particularly abundant in the Northeast corner of the UNDERC property. Yellow Birch slowly disappears from a stand as larger birch trees die and are displaced from the canopy by more shade tolerant late successional species, such as Hemlock and Sugar Maple (Flaccus, 1959). At this point, most of the yellow birch saplings left below the canopy will weaken and eventually die, unless a disturbance, such as windthrow or fire, causes a large enough break in the forest canopy to allow enough light to filter to the forest floor, thus allowing Yellow Birch to grow in once more (Barrett et. al., 1995).

The following study, first, characterizes 7 of the Yellow Birch stands on the UNDERC property. Second, it focuses on a number of environmental factors, including ground cover, canopy cover, proximity to open water, proximity to permanent edge, and ground slope, and attempts to determine which, if any of these factors, influences Yellow Birch's ability to re-colonize an area after disturbance, or serves as a disturbance which allows Yellow Birch to colonize an area. Lastly, this study seeks to qualify any significant relationships that may be found between the environmental factors and Yellow Birch regeneration, in light of differences between the age of stands studied.

## 2. Materials and Methods

### 2.1 Identification of Yellow Birch

Yellow Birch leaves are alternate, elliptical to ovate, and singly to doubly serrate on their margins. In spring, they have a velvety pubescence, but by summer they become dark green and shiny. Yellow birch bark is a very striking silvery yellow and peels off in small strips that curl up on the bole. On saplings, however, the bark is a shiny reddish brown and looks identical to the bark of white birch saplings. The two species can be distinguished by a wintergreen smell, which is present in the twigs of yellow birch, but not in those of white birch.

### 2.2 Layout of Stands

Seven different Yellow Birch stands were identified in the Northeast corner of the UNDERC property around Peter and Paul Lakes (figure 1). Yellow Birch stands were identified as any stand that contained at least 5 adult birch trees present in the canopy, and were chosen for study if they contained little or no White Birch, so as to avoid as much confusion over the identification of White Birch versus Yellow Birch seedlings and saplings. Plots were set up in these stands such that the first point was placed 7 meters from the road and 2 points were set along a transect at 25 and 50 meters from the original point as close to 7 meters from the road as a straight transect would allow. 3 more 50 meter transects, with origins on the 3 original points, were set out perpendicular to the original transect. Two more points were placed at 25 and 50 meters down each of these transects. The final layout of the points thus resembled a square with 8 points around the perimeter of the square and one point in the middle.

**2.3 Determining Yellow Birch Abundance**

Each of the points laid out was nested such that each point was located at the center of a series of 3 concentric circles, having radii of 1, 3, and 7 meters. The number of Yellow Birch, Balsam Fir, and Sugar Maple seedlings (DBH $< 0.5$) inside of the 1 meter radius was recorded, the number of saplings (0.5 cm $<$ DBH $<$ 4 cm) of each of these species inside of the 3 meter radius was recorded, and the number of trees (DBH $>$ 4 cm) of each of these species inside of the 7 meter radius was recorded. The total number of seedlings was adjusted for comparison to the 7 meter radius used to count trees by multiplying the number of total number of seedlings by 49. The total number of saplings was adjusted for comparison to the 7 meter radius used to count trees by multiplying the total number of saplings by (49/9). A chi-squared test was then run to determine whether the Yellow Birch's relative abundance in the Yellow Birch stands differed from the Sugar Maple's relative abundance. A second chi-squared test was used to determine whether the Yellow Birch's relative abundance differed from the Balsam Fir's relative abundance.

**2.4 Examination of Environmental Factors**

The percent ground cover for each point in each stand was estimated by visually noting to the nearest 10% how much of the 1 meter radius around each point was covered. The percent canopy cover for each point in each stand was estimated to the nearest 10% by standing on each nested point, looking straight up, and noting how much of the sky was obscured by the overhead foliage. Both ground cover and canopy cover were estimated by one person so as to avoid any possible differences in estimation among different observers.

The closest distance from each point to water was measured, with any distance greater than or equal to 100 meters being recorded as 100 meters. Permanent edge was defined in this study as edge along open water and edge along road, and the closest distance from each point to permanent edge was recorded. Lastly, the slope of the ground was measured at each point within each stand. Possible relationships between each of the above environmental factors and seedling, sapling, or tree density were examined through regression analysis.

**2.5 Determining Age of Stands**

The age of each of the 7 stands was determined by a series of coring. 7 of the most mature Balsam Fir, 7 of the most mature Yellow Birch, and 7 of the most mature Sugar Maple trees from each stand were cored and each core's rings were counted to determine the age of each tree. An ANOVA and a post hoc Tukey's test were run for each tree species, with age of tree as the dependent variable and stand as the factor, so as to determine if the data collected was collected from stands of significantly similar stand age. If a stand was found to be significantly different in age, multiple T-tests were used to compare the significantly different stands' data to that of the remaining stands', in order to verify that all stands varying in age exhibited the same previously characterized relationships between environmental factors and Yellow Birch seedling, sapling, and tree density as the rest of the Yellow Birch stands.

# 3. Results

## 3.1 Yellow Birch Abundance

Sugar Maple proved to be relatively more abundant than Yellow Birch ($\chi^2$=2050.94, P<0.001, dF=2). Closer inspection of Sugar Maple and Yellow Birch seedling, sapling, and tree relative abundance totals (figure 2) revealed that much of the difference between the two species abundance was in seedling abundance and tree abundance. There were over 33,000 more Sugar Maple seedlings than Yellow Birch seedlings, and there were more than twice as many Sugar Maple trees as Yellow Birch trees.

Balsam Fir proved to be equally as relatively abundant as Yellow Birch ($\chi^2$=1.213, P>0.50, dF=2). Closer inspection of Balsam Fir and Yellow Birch seedling, sapling, and tree relative abundance totals (figure 3) illustrated the lack of difference in relative abundance between Balsam Fir and Yellow Birch.

## 3.2 Correlations between Environmental Factors and Yellow Birch Density

Linear regression revealed that there were no significant correlations between ground cover and seedling density (P=0.548), ground cover and sapling density (P=0.833), or ground cover and tree density (P=0.755). Likewise, no significant correlations were found to exist between canopy cover and seedling density (P=0.115) or canopy cover and sapling density (P=0.948).

No significant correlations could be proven to exist between proximity to water and seedling density (P=0.538), proximity to water and sapling density (P=0.376), or proximity to water and tree density (P=0.082). In stark contrast, significant correlations between proximity to permanent edge and seedling density (P=0.013, N=63, $R^2$=0.098) (figure 4), proximity to permanent edge and sapling density (P=0.012, N=63, $R^2$=0.100) (figure 5), and proximity to permanent edge and tree density (P=0.167, N=63, $R^2$=0.167) (figure 6) were found. In each of these cases, density increased slightly the closer a point sampled was to permanent edge. The low $R^2$ values, though, make it unlikely that the relationship between permanent edge and yellow birch regeneration is necessarily an important one.

Linear regression showed there to be no correlation between ground slope and seedling density (P=0.058). Rather strong relationships between ground slope and sapling density (P<0.001, N=63, $R^2$=0.581) (figure 7), and ground slope and tree density were found though (P<0.001, N=63, $R^2$=0.312) (figure 8). In these two significant linear regressions increasing sapling and tree density had a relatively strong positive correlation with steeper slope.

**3.3 Age of Stands**

An ANOVA and post hoc Tukey's test which compared Yellow Birch age between stands (figure 9) showed that stands 1, 3, 4, and 5 were significantly different in age from stands 6 and 7. Stand 2 also proved to be significantly different in Yellow Birch age from stand 3. A second ANOVA and post hoc Tukey's test which compared Sugar Maple Age between stands (figure 10) between stands showed that stand 2 was significantly different from every other stand and that stands 5 and 6 were significantly different from stand 7. A third and final ANOVA and post hoc Tukey's test which compared Balsam Fir Age (figure 11) showed that stand 1 was different from every other stand and that stand 4 was different from every other stand.

Since, clearly, there were differences between ages of the 3 major species of trees among stands it was necessary to further analyze the significant linear regression data, obtained from the previous section, by stand, against all other stand data taken cumulatively, to determine whether any of the stands proved to be outliers due to the age difference in tree species. After close inspection of all significantly different stand ages, via multiple t-tests, each of the stands that proved to be significantly different from any of the other stands in species age did not prove to be outliers ($P > 0.10$). All significant correlations observed, such as those between proximity to permanent edge and seedling density, permanent edge and sapling density, permanent edge and tree density, as well as those observed between ground slope and sapling density and ground slope and tree density, must therefore be valid.

## Discussion

### 4.1 Relative Abundance, Environmental Factors, and Stand Age

Before the Yellow Birch stands could be studied, it was first necessary to characterize the Yellow Birch stands on the UNDERC property in order to verify they followed a known pattern of Yellow Birch stand maturation. Results of the relative abundance data indicates that the number of Maple seedlings is much greater than the number of Yellow Birch seedlings, and that there are more than twice as many adult Sugar Maple trees as compared to the number of the Yellow Birch trees in the Yellow Birch stands. This relative abundance is relatively characteristic of Yellow Birch stands maturing from mid successional to climax forests (Zhang et al., 2000).

The relatively equal relative abundance between Yellow Birch and Balsam Fir in Yellow Birch stands is important for two reasons. First, Yellow Birch has been shown to regenerate more strongly in non-dense conifer areas than in non-dense hardwood areas because conifer needles typically do not offer as much shading to yellow birch as the leaves of hardwood trees (Lodding et. al., 2000). Second, conifers are more likely to occur on more moist soils than hardwood trees, soils that aren't as stable and therefore encourage windthrow, which opens more gaps to form in the canopy (Barrett et al., 1995). These gaps encourage fast growing mid successional trees such as Yellow Birch to regenerate and take over the canopy gap (Reiners and Lang, 1979). The Maple and Balsam Fir data taken together seem to suggest that the Yellow Birch stands are indeed exhibiting expected, previously characterized, Yellow Birch stand characteristics and therefore do indeed provide a suitable setting for this study.

Previously, it has been reported that dense canopy cover causes Yellow Birch seedlings and saplings to languish and die in the low light of the forest floor and that broken canopy allows Yellow Birch to mature into adult canopy trees (Bazzaz and Miao, 1993). Results from this study indicate that canopy cover percentage is not influential on Yellow Birch regeneration. It is quite likely that these results were obtained because cases of lower percentages of canopy cover were not often observed in the Yellow Birch tands on the property, and Yellow Birch stands that have lower to mid percentage canopy covered areas often exhibit the greatest amount of seedling and sapling regeneration (Lorimer, 1977). It has been speculated that greater percentages of ground cover may shade Yellow Birch seedlings out by the same mechanism of light deprivation, thereby reducing Yellow Birch seedling density, but it has never been demonstrated, and was not demonstrated in this report, that there is any relationship between ground cover and yellow birch seedling density.

Another study reported that open water areas acts as a disturbance, by allowing more sunlight into an edge of a stand, and encourages disturbance in the form of windthrow, thereby allowing shade-intolerant early and mid successional trees, such as Yellow Birch, to persist in low densities (Canham and Loucks, 1984). This study's results failed to demonstrate any correlation between distance to open water and Yellow Birch regeneration. The results did demonstrate, however, that there were significant relationships between distance to permanent edge and Yellow Birch seedling density, distance to permanent edge and Yellow Birch sapling density, and distance to permanent edge and Yellow Birch tree density, but the relationship had such a weak correlation that that the results were considered not to be important. Previously, it has been demonstrated that larger areas, which have little permanent edge, demonstrate a stronger correlation between permanent edge and Yellow Birch seedling density, sapling density, and tree density (Runkle, 1982). The stands studied on the UNDERC property had a very large amount of permanent edge to stand area, so it is quite possible that the large amount of permanent edge may be having a very significant disturbance effect on Yellow Birch regeneration on the UNDERC property, but can not be properly demonstrated to exist because permanent edge may be so close as to be influencing all of the Yellow Birch regeneration observed.

Results indicated that there was no relationship between seedling density and slope, but that there were rather strong correlations between Yellow Birch sapling density and slope and tree density and slope. This may be occurring because areas with steeper slopes are subject to landslides and serve as avenues for water runoff, creating microclimates which can drastically affect regeneration patterns in favor of early and mid successional trees (Lodding et al., 2000). It has also been suggested that steeper slopes allow for windthrow to cause more blow downs, as storms coming up a slope may exert greater force on one side of a hill (Canham and Loucks, 1984).

The results obtained from aging the 3 major tree species in Yellow Birch stands indicate that while the ages of the 3 major species of trees did differ among the 7 stands on multiple occasions, not one stand's permanent edge or slope data proved to be an outlier. Thus, all conclusions based on significant data collected in the UNDERC Yellow Birch stands should exhibit typical trends for Yellow Birch re-colonization subsequent to disturbance.

**4.2 Future Studies**

Further study of the relationship between yellow birch regeneration and permanent edge should be conducted, as there appears to be a slightly significant relationship in this study, one that may be able to be shown to be more significant if an area with less permanent edge per area were sampled. Further studies should also be done on the relationship between yellow birch regeneration and slope, so as to ascertain whether the results found in this study hold true in many other Yellow Birch stands. Lastly, very little data has been gathered on the rates of Yellow Birch regeneration via root sprouting. In root sprouting, the healthy roots nourish shoots that can grow to sapling size much quicker than a seedling can. Studies of root sprouting would help add vital information to how and under what conditions Yellow Birch is able to regenerate and re-colonize an area.

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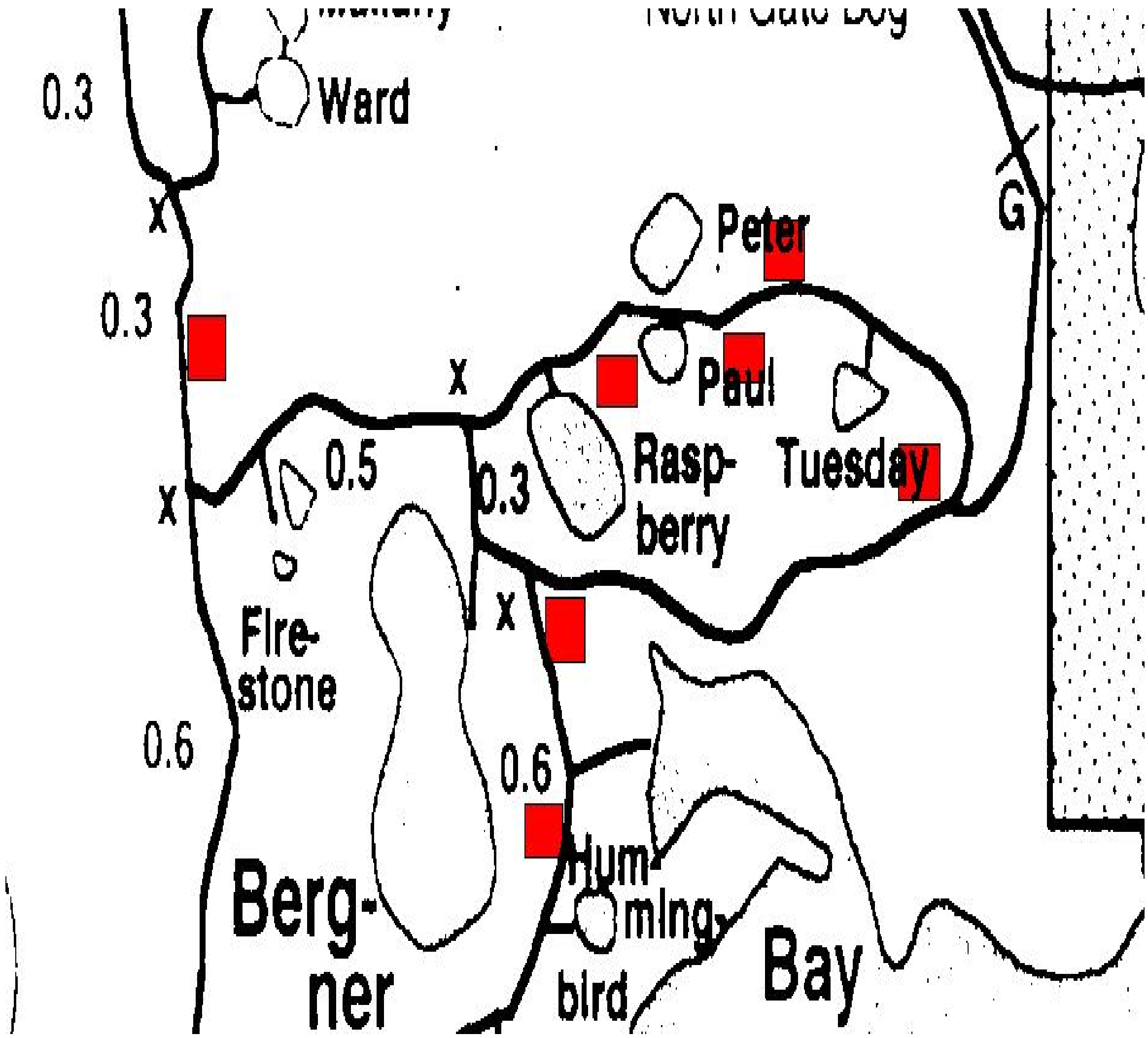


Figure 1: 7 Yellow Birch sites were identified on the Northeast side of the UNDERC property for study. Pictured above is a map of the area surrounding Peter and Paul Lakes with the & sites clearly marked off as dark black squares.

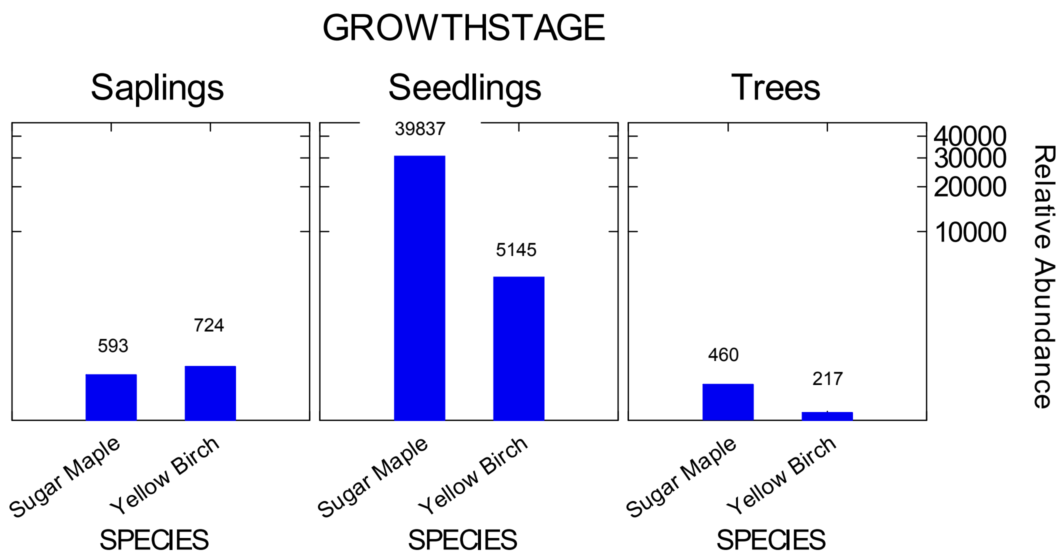


Figure 2: Sugar Maple has a higher relative abundance than Yellow Birch in Yellow Birch stands. In the 7 stands sampled Maple seedlings were present in almost 7 times the number that Yellow Birch seedlings were present. Nearly twice as many Sugar Maple trees were present in the Yellow Birch stand as Yellow Birch.

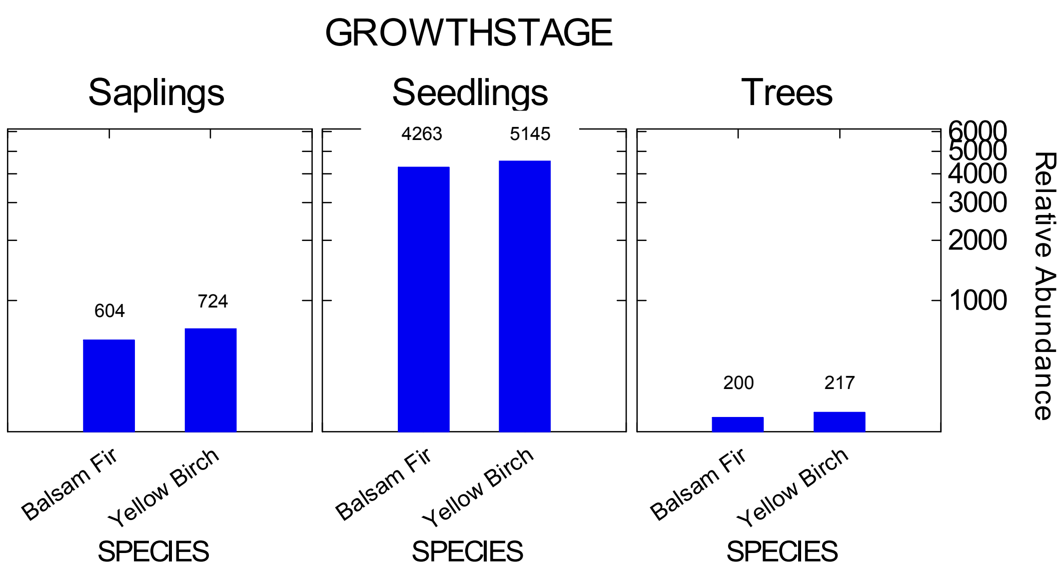


Figure 3: Balsam and Yellow Birch had a relatively equal relative abundance as demonstrated by the almost equal number of seedlings, saplings, and trees shown above.

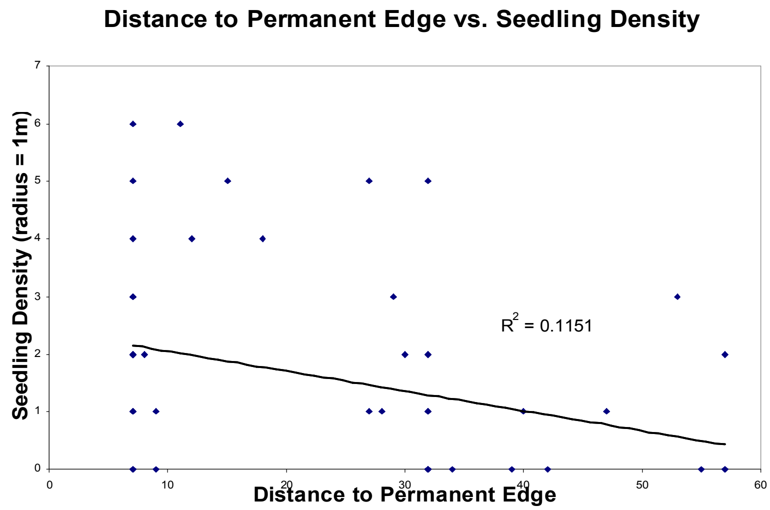


Figure 4: Distance to permanent edge accounted for 11.51% of the observed variation in seedling density. While the correlation was significant, there appears to be a rather large amount of scatter, and therefore the relationship is probably not important.

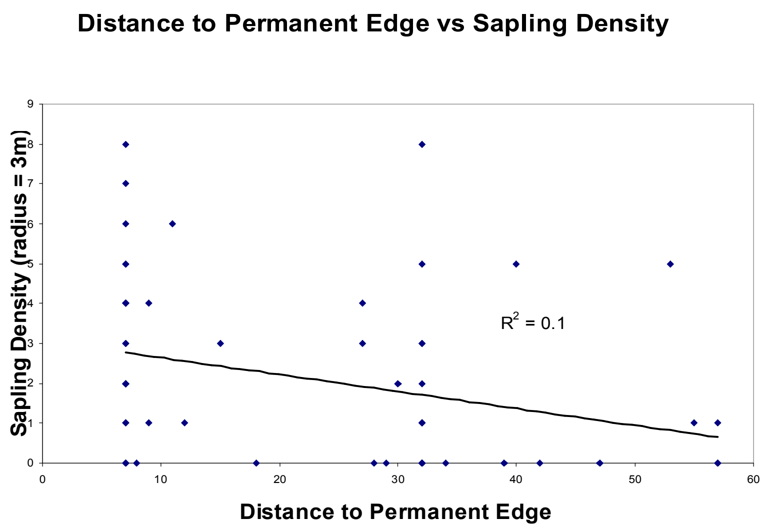


Figure 5: Distance to permanent edge accounted for 10% of the observed variation in sapling density. While the correlation was significant, there appears to be a rather large amount of scatter, and therefore the relationship is probably not important.

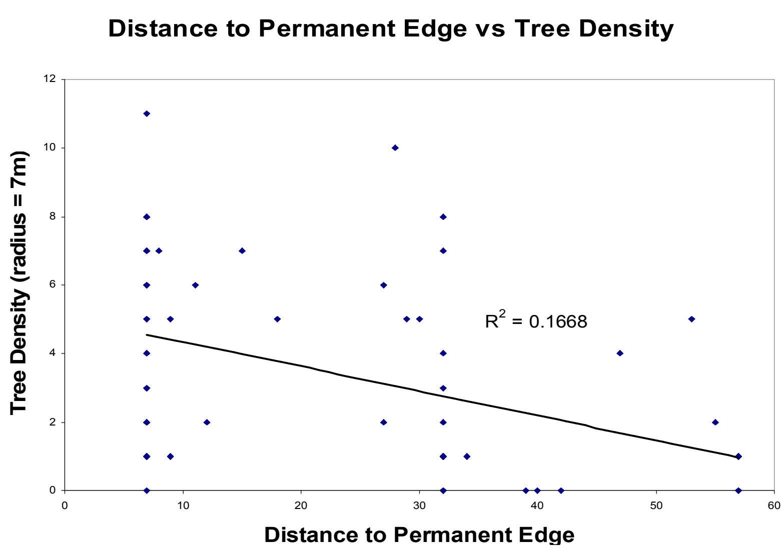


Figure 6 (left): Distance to permanent edge accounted for 16.68% of the observed variation in tree density. While the correlation was significant, there appears to be a rather large amount of scatter, and therefore the relationship is probably not important.

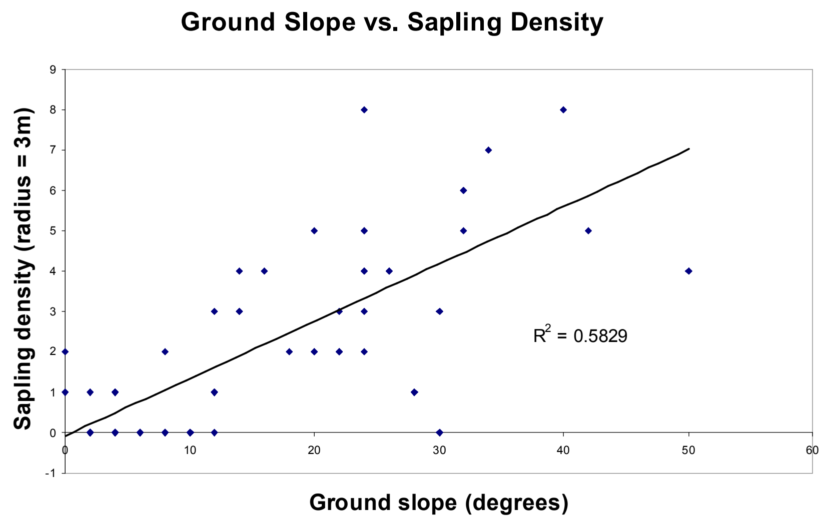


Figure 7: Ground slope accounted for 58.29% of the variation in sapling density. As shown above, sapling density clearly increases as ground slope gets steeper.

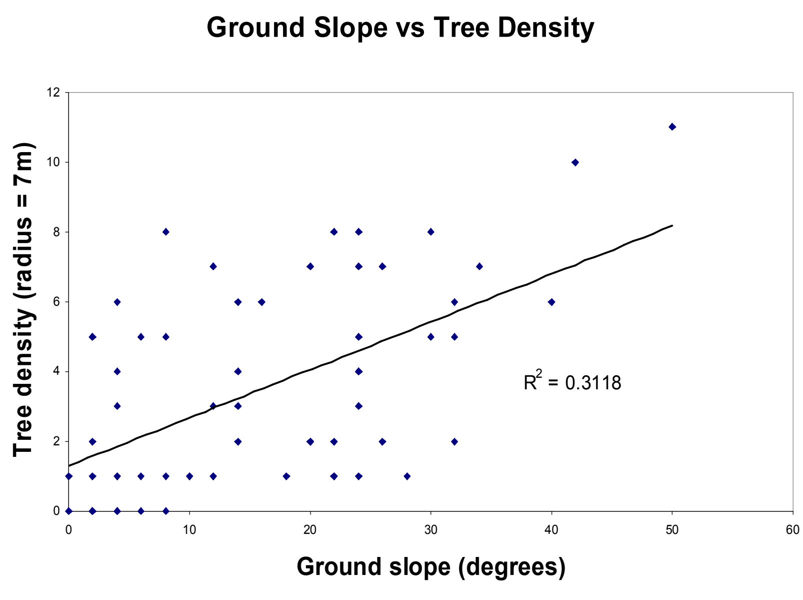


Figure 8: Ground slope accounted for 31.18% of the observed variation in tree density. As shown above, tree density clearly increases as ground slope gets steeper.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1.000 | | | | | | |
| 2 | 0.824 | 1.000 | | | | | |
| 3 | 0.194 | **0.007** | 1.000 | | | | |
| 4 | 1.000 | 0.901 | 0.136 | 1.000 | | | |
| 5 | 1.000 | 0.777 | 0.230 | 1.000 | 1.000 | | |
| 6 | **0.008** | 0.212 | **0.000** | **0.013** | **0.006** | 1.000 | |
| 7 | **0.004** | 0.136 | **0.000** | **0.007** | **0.003** | 1.000 | 1.000 |

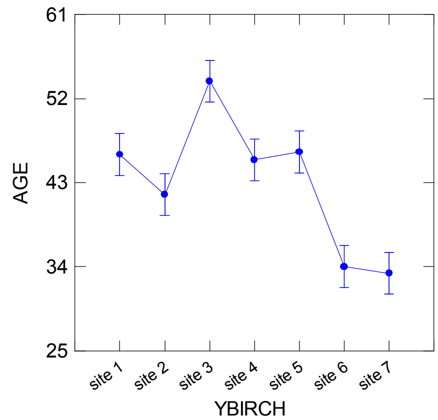


Figure 9: Stands 6 and 7 appear to be different than the other stands in Yellow Birch age (right). Tukey's testing confirms that stands 6 and 7 are different from the rest of the stands and shows that stand 3 and 2 are different (left).

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1.000 | | | | | | |
| 2 | **0.000** | 1.000 | | | | | |
| 3 | 1.000 | **0.000** | 1.000 | | | | |
| 4 | 0.943 | **0.000** | 0.996 | 1.000 | | | |
| 5 | 0.650 | **0.000** | 0.875 | 0.996 | 1.000 | | |
| 6 | 0.432 | **0.000** | 0.693 | 0.959 | 1.000 | 1.000 | |
| 7 | 0.693 | **0.000** | 0.432 | 0.147 | **0.035** | **0.014** | 1.000 |

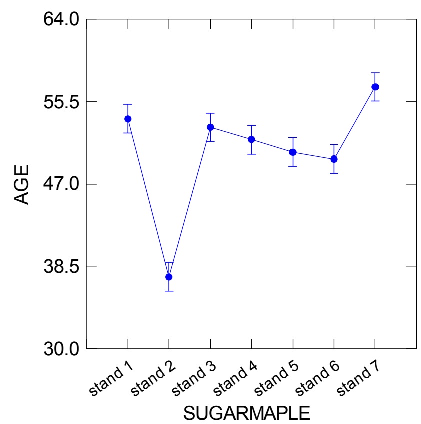


Figure 10: Stand 2 clearly appears to be different than the other stands in Sugar Maple age (right). Tukey's testing confirms that stand 2 is different from the rest of the stands and shows that stand 5 and 6 are different than stand 7 (left).

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1.000 | | | | | | |
| 2 | **0.000** | 1.000 | | | | | |
| 3 | **0.000** | 0.996 | 1.000 | | | | |
| 4 | **0.000** | **0.000** | **0.000** | 1.000 | | | |
| 5 | **0.000** | 1.000 | 1.000 | **0.000** | 1.000 | | |
| 6 | **0.000** | 0.996 | 0.884 | **0.000** | 0.983 | 1.000 | |
| 7 | **0.000** | 0.670 | 0.303 | **0.000** | 0.541 | 0.948 | 1.000 |

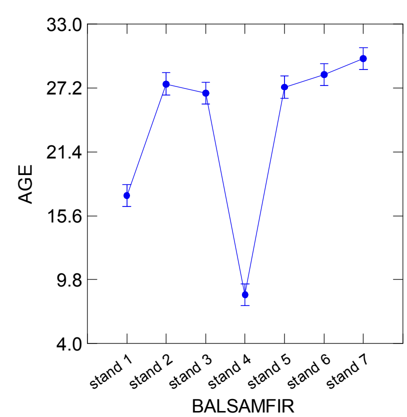


Figure 11: The most mature Balsam Fir in each of the 7 Yellow Birch stands were cored and aged. Anova testing (right) shows that stands 1 and 4 differ greatly from the rest of the stands. Tukey testing (left) confirms that stand 1 is different from every other stand, and that stand 4 is different from every other stand, in mature Balsam Fir age.

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