Silvicultural Analysis of Northern Hardwood Regeneration at the Paul Smith's College FERDA Plots

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Abstract:

In the northeastern forests most regeneration comes from natural regeneration that occurs after a disturbance. The Forest Ecosystem Research Demonstration Area (FERDA) plots located on the Paul Smith's College VIC in the Adirondack Park are set up as an experiment to test different harvest methods in northern hardwood forests and see the results of each. We analyzed tree and sapling size class inventory data from clearcut, single-tree selection, and control treatments to compare regeneration present 14 years after the first harvests occurred. The clearcut treatments were the only treatments analyzed where American beech (*Fagus grandifolia*) was not the most abundant tree regeneration present. Both single-tree selection and control treatments were dominated by American beech with few other species present. Our results suggest that creating larger canopy openings, may allow species other than American beech, such as red maple (*Acer rubrum*) and yellow birch (*Betula alleghaniensis*) to become the most abundant species present.

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Introduction

In the northeastern forests most regeneration comes from natural regeneration that occurs after a disturbance. The disturbance can be either a natural disturbance or artificial in the form of a harvest. The size and extent of these disturbances affects the amount of light that can reach the forest floor, which in turn affects the species composition of the regeneration (Poznanovic, Webster, & Bump, 2013). There are many different types of harvests that occur in forests, each with the goal of giving varying amounts of increases in light to the forest floor, and in turn, the tree species that are likely to regenerate in a given area (Leak, Yamasaki, & Holleran, 2014). Clearcutting is removing mature or defective stands which are 5 to 10 acres or larger (Leak et al., 2014). Leak et al (2014) states that clearcutting is applied to a stand if defective timber makes up at least 50% to 60% of the stand. Natural regeneration or preexisitng regeneration, also known as advance regeneration, is relyed on in this system (Ilisson & Chen, 2009). Single-tree selection is the harvesting of single trees or small groups which are generally separated from each other, in a way that maintains a range of diameter classes and continuous canopy cover (Leak et al., 2014). This method is used to mimic natural gap dynamics in uneven-aged stands (Webster & Lorimer, 2002). It has been shown that 92% of regeneration is shade-tolerent species when single-tree selection is used (Leak et al., 2014).

After a harvest there are two ways that a forest can regenerate, either naturally or atificially (Smith, Larson, Kelty, & Ashton, 1996). There are advantages and disadvantages to each. One of the main advantages to natural regeneration is the cost. Natural regeneration occurs completely on its own after a harvest while artificial regeneration has a significant cost associated with buying and planting the seeds or seedlings (Minore & Laacke, 1992). Natural regeneration also produces seedlings that are better adapted to the specific site they are growing on compared to artificial regeneration grown in a nursery (Minore & Laacke, 1992). One disadvantage to relying on natural regeneration over artificial regeneration is that the species composition can be controlled completely with planting and seeding while natural regeneration is reliant upon the trees or seed present in or adjacent to the stand being regenerated (Nyland, 2007).

In some areas of the Northeast, American beech (*Fagus grandifolia*) can be a problem because it outcompetes other northern hardwood species and dominates the regeneration present after a harvest (Nelson & Wagner, 2011). Generally, American beech is a less valuable timber species compared to other northern hardwood species (Nolet, Bouffard, Doyon, & Delagrange, 2008). Some studies have shown that larger openings created by harvests can be used to promote species other than American beech to regenerate (Nelson & Wagner, 2011).

The type of harvest done in an area and the tree species present before the harvest was completed play a huge role in what tree species regenerate after the harvest. While the outcomes can generally be predicted, the exact species and amounts of those species are relatively unknown until regeneration has started to occur. The Forest Ecosystem Research Demonstration Area (FERDA) plots located on the Paul Smith's College VIC are set up as an experiment to test different harvest methods and see the results of each. The even-aged techniques of shelterwood and clearcuts are used along with the uneven-age techniques of single-tree selection and group selection. There are also two-aged silvicultural systems. We analyzed inventory data collected on the FERDA plots with the goal of investigating and reporting on the regeneration present under clearcut and single-tree selection treatments. The results of this study can be used to guide management decisions on other Paul Smith's College lands and Adirondack forests with similar site conditions.

Methods

Location

This study was conducted at the FERDA plots in Paul Smiths, New York. Two replicates exist in this study, one is located on Keeses Mill Road (KMR) (44.434792, -74.305457), and the other at the Paul Smith's College Visitor's Interpretative Center (VIC) (44.448404, -74.259510) (map is shown in Appendix I). The FERDA is a collaborative research effort between the Northern Research Station of the USDA Forest Service, the Paul Smith's College VIC, and Paul Smith's College. These sites are at approximately 1640 feet in elevation. The soils are Adams loamy sands. The forest type that encompasses the area is a northern hardwood-conifer forest. Dominant overstory species include sugar maple (*Acer saccharum*), American beech, yellow birch (*Betula alleghaniensis*), with minor components of eastern hemlock (*Tsuga canadensis*), red maple (*Acer rubrum*), balsam fir (*Abies balsamea*), and red spruce (*Picea rubens*).

Experimental Design

The FERDA has fourteen 5 acre units, which were treated with different uneven-aged, even-aged, and two-aged silvicultural methods in the winter of 1999-2000 (Smith, Keeton, Twery, & Tobi, 2008). The units created, consisted of two replicates, of the following silvicultural systems: single-tree selection, group selection, shelterwood, two-aged, and clearcut, with the addition of four control plots.

- Control (no treatment) - The forest was left to develop without direct intervention by forest activities. Control units were used as a comparison to the more active management units. It is also used to show people that forests can change naturally (Twery, Olson, Wade, & Rechlin, 2013).

- Single-tree selection – About 30 percent of the tree volume was removed as single trees of different size classes spread throughout the unit. Canopy openings were the size of individual trees. Gaps are created for regeneration to establish after the treatment and ensures a variety of different age classes and sizes through the life of the forest. Treatments are applied about every 20 years or as needed to reduce overcrowding. Shade tolerant regeneration and understory vegetation will have the competitive advantage in this system (Twery et al., 2013).

- Clearcut – This system creates an area favorable to early successional species, with a focus on trees that are shade intolerant. All stems were removed, resulting in an even-aged forest that will be harvested again when the trees mature, in around 100 years (Twery et al., 2013).

Data Collection

Permanent sample plots were set up in 1999 at the VIC and KMR FERDA plots to sample trees, saplings, and seedlings. There are eight plots in each unit for tree sampling. Within each of those eight tree sampling plots are two sapling sampling plots, for a total of sixteen sapling sampling plots in each unit. There are also four seedling sub plots in each of the eight tree plots, for a total of thirty-two seedling sampling sub plots in each unit. The layout of these plots can be seen in appendix II (Myers, 2001). The most recent inventory was done in 2014.

- Tree Sampling - Trees were sampled using 1/10th acre (37 ft. radius) fixed-area plots. All trees at least 1 inch in DBH were measured and recorded to the nearest tenth of an inch diameter, along with the species, and whether the tree was dead or alive (Myers, 2001).

- Sapling Sampling -Saplings were sampled using 1/300th acre (6.6 ft. radius) fixed-area plots. A count of all stems by tree species that were at least 3 feet tall and less than 1 inch in DBH were recorded. (Myers, 2001).

Regeneration Analysis

Based on how the data were collected, we focused our regeneration study on the tree and sapling size class data. We used the latest (2014) inventory data collected in our analysis. This meant that it had been approximately 14 years since the first harvests occurred in the treatments. In determining trees per acre (TPA) numbers for the tree data, we used trees in the 1-6" DBH size class. This was based on the fact that all units were originally harvested at the same time and the largest trees recorded in the clearcut treatments were in the 6" DBH class. We focused our analysis on the clearcut, single-tree selection, and control treatments. We did not include the group selection treatments because it could not be determined what, if any, of the permanent sample plots fell inside harvested groups to determine the regeneration inside the groups. Using the data collected and compiled by the U.S. Forest Service for the eight tree sampling plots in each selected unit, the average number of trees per acre for each species were determined by treatment type at each location. All of the data were analyzed using Microsoft Excel. To determine average TPA for each species in the single-tree selection and clearcut treatments, a count of the number of species in each plot in each treatment was done. This count by species by plot was multiplied by an expansion factor of 10, based on $1/10^{th}$ acre plots, to convert from individual observations to total trees represented in each plot. This was then summed up and divided by eight, the number of sample plots, to determine the average TPA in the single-tree selection and clearcut treatments. The standard deviation was calculated using the number of trees represented by each plot, the counts by species by plot multiplied by 10 each. Standard error for each species average TPA was then determined by the standard deviation of each species divided by the square root of eight for the eight tree sampling plots in each unit. Control treatment's average TPA by species was determined the same way except the sample from both control units at each location was combined. The observations from the 16 control treatment tree sample plots at the VIC and the 16 control treatment tree sample plots at the KMR site. A count was done by species by plot then multiplied by an expansion factor of 10, summed up by species, and divided by 16 to determine average TPA by species in the control treatments. The standard deviation was calculated from the counts by species by plot for all 16 control treatment tree sampling plots. The standard error was determined by the standard deviation by species divided by the square root of 16 for the 16 total tree sample plots at each site. Double bar graphs with standard error bars were then created to show the average TPA by species at each treatment location together.

In the sapling size class all data collected and compiled by the U.S. Forest Service in each selected treatment was used to determine the average number of saplings per acre (SPA) by species for each treatment at each location. All of the data were analyzed using Microsoft Excel. To determine average SPA for each species in the single-tree selection and clearcut treatments, a count of the number of species in each plot in each treatment was done. This count by species by plot was multiplied by an expansion factor of 300, based on $1/300^{th}$ acre plots, to convert from individual observations to total saplings represented in each plot. This was then summed up and divided by 16, the number of sapling sample plots, to determine the average SPA in the single-tree selection and clearcut treatments. The standard deviation was calculated using the number of saplings represented by each plot, the counts by species by plot multiplied by 300 each. Standard error for each species average SPA was then determined by the standard deviation of each species divided by the square root of 16 for the 16 sapling sample plots in each unit. Control treatment's average SPA by species was determined the same way except the sample from both control units at each location was combined. The observations from the 32 total control treatment sapling sample plots at the VIC and the 32 total control treatment sapling sample plots at the KMR site. A count was done by species by plot then multiplied by an expansion factor of 300, summed up by species, and divided by 32 to determine average SPA by species in the control treatments. The standard deviation was calculated from the counts by species by plot for all 32 control treatment sapling sample plots. The standard error was determined by the standard deviation by species divided by the square root of 32 for the 32 total sapling sample plots at each site. Double bar graphs with standard error bars were then created to show the average SPA by species at each treatment location together.

The average number of stems per acre by species in each size class was used to compare and contrast the treatments at both locations to each other. The differences between treatment types were also analyzed. Our results were also compared to the results of other studies and to the silvics of the most abundant species in each treatment.

Results

Clearcut Treatments

There were a total of thirteen tree species present in the tree size class regeneration between the two clearcut treatments (Figure 1, Table 1). At the VIC, red maple, yellow birch, and American beech trees were the most abundant (Figure 1). Black cherry (*Prunus serotina*), striped maple (*Acer pensylvanicum*), sugar maple, pin cherry (*Prunus pensylvanica*), balsam fir, paper birch (*Betula papyrifera*), red spruce, quaking aspen (*Populus tremuloides*), white spruce (*Pinus glauca*), and scotch pine (*Pinus sylvestris*) were also present in the tree regeneration (Figure 1, Table 1). At KMR, yellow birch, American beech, red maple, and black cherry were the most abundant trees (Figure 1). Sugar maple, red spruce, balsam fir, quaking aspen and striped maple were also present in the tree regeneration (Figure 1, Table 1). The VIC had an average of 223 red maple TPA with a standard error of 145 (Figure 1). Yellow birch was the second most abundant there with 160 TPA and a standard error of 68 (Figure 1). American beech was the third most abundant at the VIC with 148 TPA and a standard error of 111 (Figure 1). The KMR clearcut treatment had very little tree regeneration present compared to the VIC. At KMR the most abundant tree was yellow birch with 36 TPA and a standard error of 21 (Figure 1). The second most abundant tree there was American beech with 30 TPA and a standard error of 17 (Figure 1). The third most abundant tree at the KMR site was a tie between red maple and black cherry at 11 TPA each, with red maple having a standard error of 4 and black cherry a standard error of 7 (Figure 1).

The sapling size class regeneration had six tree species present in both clearcut treatment locations (Figure 2). At the VIC, American beech, red maple, and yellow birch were the most abundant saplings (Figure 2). At the KMR location, yellow birch, American beech, and red maple were the most abundant saplings (Figure 2). Striped maple, red spruce, and sugar maple were also present at both locations in the sapling size class regeneration (Figure 2). The most abundant sapling regeneration at the VIC was American beech with an average of 1575 SPA and a standard error of 407 (Figure 2). The second most abundant sapling regeneration there was red maple with an average of 619 SPA and a standard error of 168 (Figure 2). The third most abundant sapling regeneration at the VIC was yellow birch with an average of 375 SPA and a standard error of 130 (Figure 2). The most abundant sapling regeneration present at the KMR location was yellow birch with an average of 938 SPA and a standard error of 468 (Figure 2). The second most abundant sapling regeneration there was American beech with 900 SPA with a standard error of 321 (Figure 2). Striped maple was the third most abundant sapling regeneration at the KMR location with 263 SPA and a standard error of 86 (Figure 2).

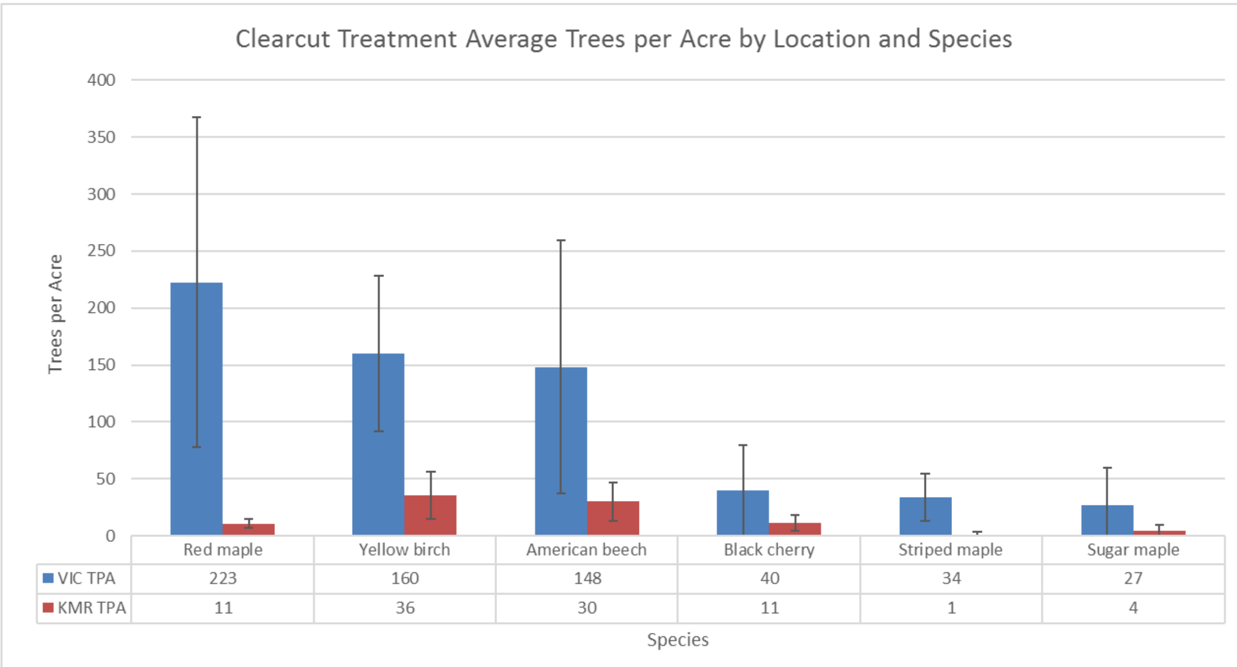

Figure 1. Average number of trees per acre in clearcut treatments by location and species. Error bars represent the standard error of the mean for each species at each location.

Clearcut Treatment Average Trees per Acre Not Included in Graph							
Species	Pin cherry	Balsam fir	Paper birch	Red spruce	Quaking Aspen	White spruce	Scotch pine
VIC TPA	17	5	4	3	2	1	1
KMR TPA	0	3	0	4	1	0	0

Table 1. Average number of trees per acre in clearcut treatments by location and species that are not included in Figure 1.

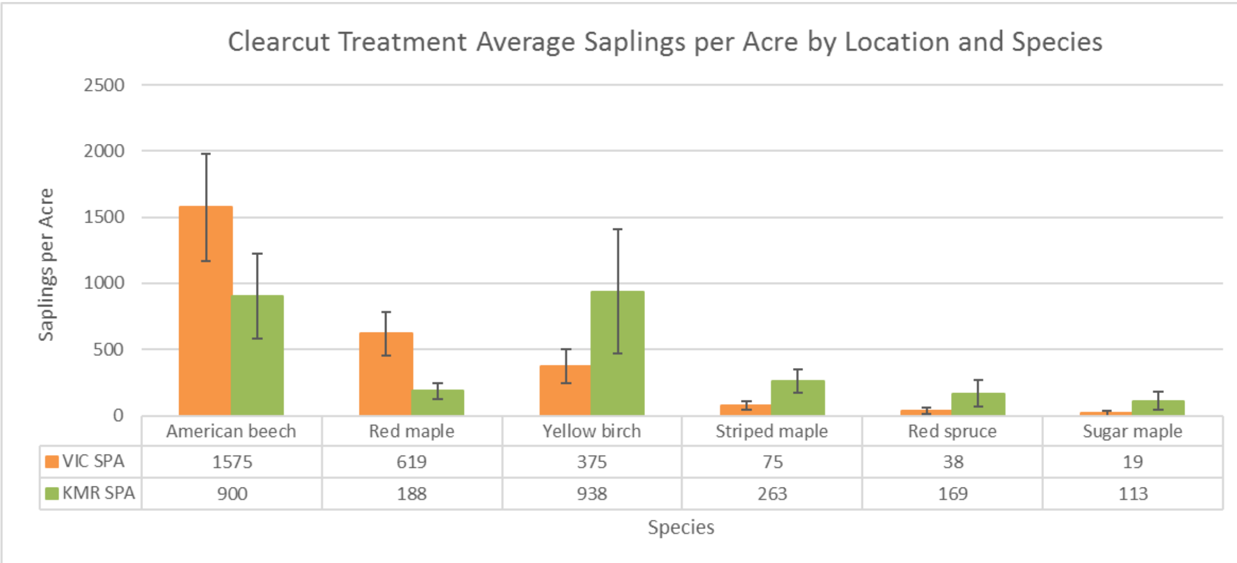

Figure 2. Average number of saplings per acre in clearcut treatments by location and species. Error bars represent one standard error of the mean.

<u>Single-tree Selection Treatments</u>

There were a total of eleven tree species present in the tree regeneration in the single-tree selection treatments, with American beech being the most abundant at both locations (Figure 3, Table 2). At the VIC, there were an average of 276 TPA of American beech with a standard error of 49 (Figure 3). The second most abundant species there was striped maple with 59 TPA and a standard error of 26 (Figure 3). Sugar maple was third in abundance at the VIC with 45 TPA and a standard error of 17 (Figure 3). Other species present at the VIC included red spruce, balsam fir, red maple, and eastern hemlock (Figure 3, Table 2). At KMR, American beech made up an average of 166 TPA with a standard error of 58 (Figure 3). Red spruce was second most abundant there with 94 TPA and a standard error of 57 (Figure 3). Balsam fir was third in abundance at KMR with 26 TPA and a standard error of 17 (Figure 3). Other species present at the KMR single-tree selection treatments included sugar maple, white pine (*Pinus strobus*), hophornbeam (*Ostrya virginiana*), yellow birch, black cherry, and striped maple (Figure 3, Table 2).

There were six tree species present in the sapling size class regeneration in the single-tree selection treatments (Figure 4). American beech was the most abundant at both locations, over three times more abundant than the second most abundant species at each location (Figure 4). At the VIC, there were 619 SPA (standard error = 213) of American beech while there were 188 SPA (standard error = 119) of striped maple, the second most abundant species (Figure 4). At KMR, there were 300 SPA (standard error = 102) of American beech and 56 SPA (standard error = 30) of balsam fir, the second most abundant species there (Figure 4). Other species present at the VIC were sugar maple and red spruce (Figure 4). At KMR, white pine and red spruce were the only other species present (Figure 4).

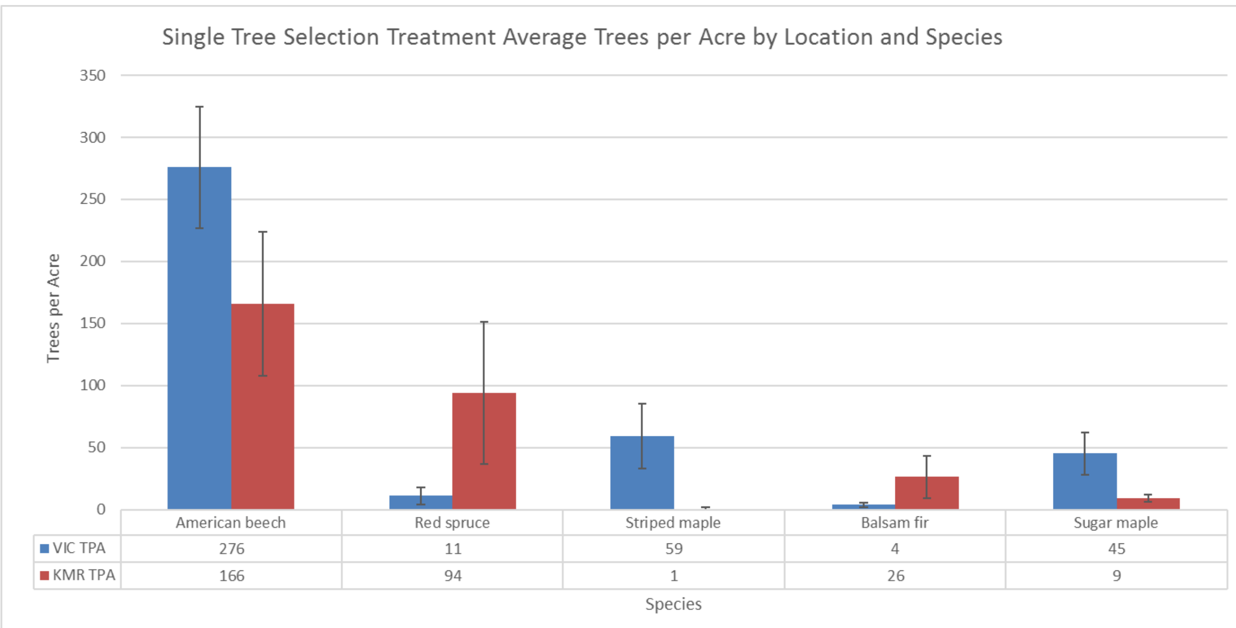

Figure 3. Average number of trees per acre in single-tree selection treatments by location and species. Error bars represent the standard error of the mean for each species at each location.

Single Tree Selection Treatment Trees per Acre Not Included in Graph						
Species	Red maple	Eastern hemlock	White pine	Hophornbeam	Yellow birch	Black cherry
VIC TPA	4	1	0	0	0	0
KMR TPA	0	0	5	4	3	3

Table 2. Average number of trees per acre in single-tree selection treatments by location and species that are not included in Figure 3.

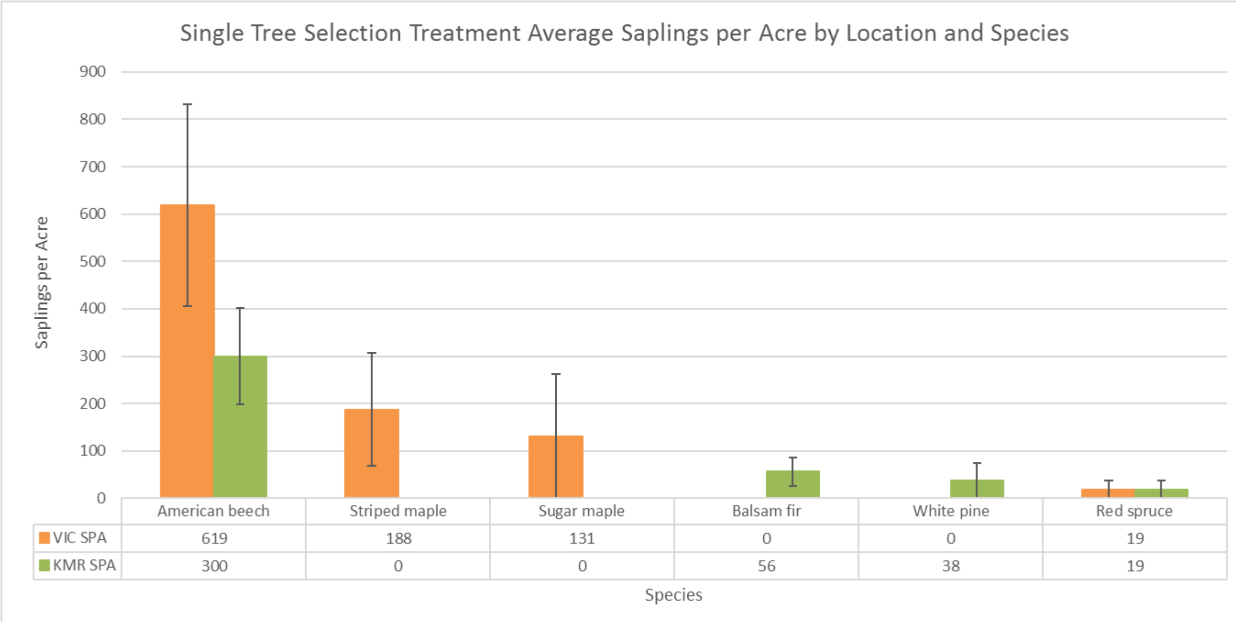

Figure 4. Average number of saplings per acre in single-tree selection treatments by location and species. Error bars represent one standard error of the mean.

<u>Control Treatments</u>

There were seven tree species present in the tree regeneration in the control treatments (Figure 5, Table 3). American beech was the most abundant tree regeneration at both the VIC and KMR locations (Figure 5). There were an average of 277 TPA of American beech at the VIC with a standard error of 33 (Figure 5). At KMR, there were an average of 177 TPA of American beech with a standard error of 25 (Figure 5). Sugar maple, striped maple, yellow birch, red spruce, red maple, and balsam fir were also present at the VIC in much lower amounts (Figure 5, Table 3). At KMR, the other species present were striped maple, red spruce, yellow birch, sugar maple, and red maple (Figure 5, Table 3).

There were three tree species present in the sapling size class regeneration in the control treatments (Figure 6). At the VIC, American beech made up almost all of the saplings sampled with an average of 506 SPA and a standard error of 113 (Figure 6). Striped maple was the only other species sampled at the VIC, with only 9 SPA and a standard error of 9 (Figure 6). At KMR, American beech made up an average of 328 SPA with a standard error of 69 (Figure 6). Red spruce was second most abundant at KMR with 103 SPA and a standard error of 35 (Figure 6).

Striped maple was also a minor component at KMR with 19 SPA and a standard error of 19 (Figure 6).

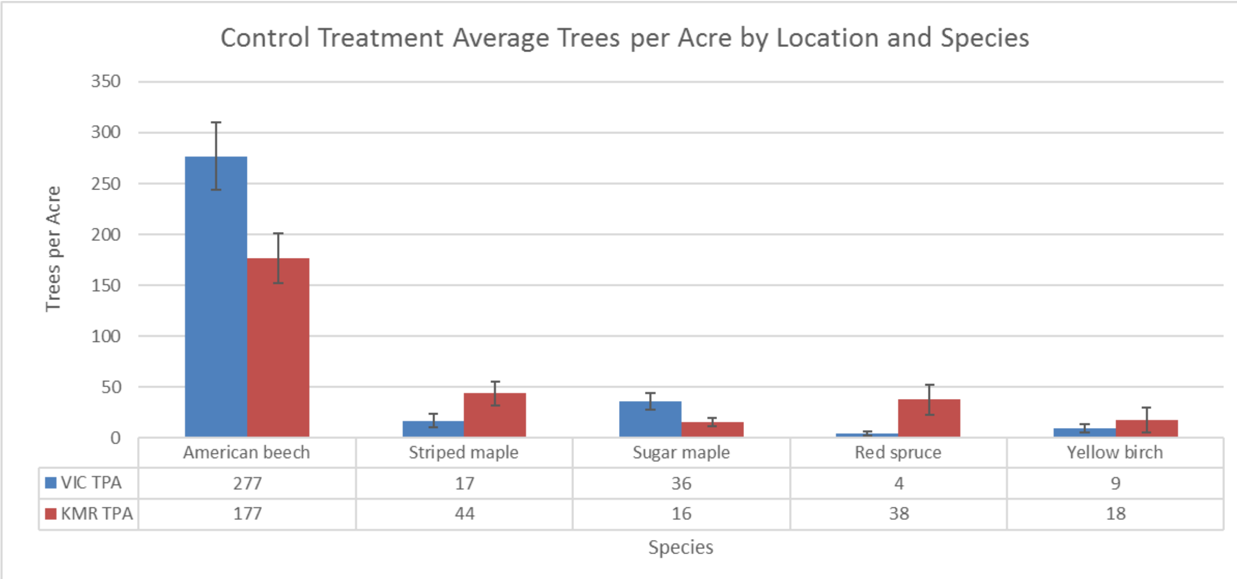

Figure 5. Average number of trees per acre in control treatments by location and species. Error bars represent the standard error of the mean for each species at each location.

Control Treatments Trees per Acre Not Included in Graph		
Species	Red maple	Balsam fir
VIC TPA	3	2
KMR TPA	1	0

Table 3. Average number of trees per acre in single-tree selection treatments by location and species that are not included in Figure 5.

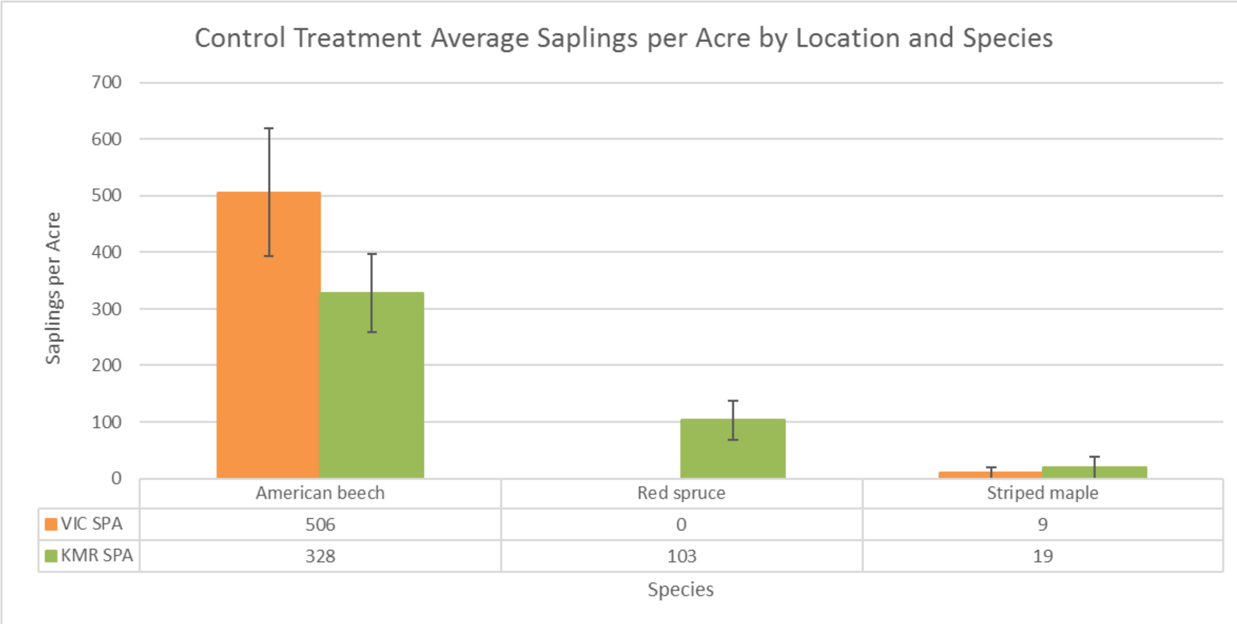

Figure 6. Average number of saplings per acre in control treatments by location and species. Error bars represent one standard error of the mean.

Discussion

Clearcut Treatments

Clearcutting removes all of the trees in an area down to a certain size, generally 2” in DBH (Leak et al., 2014). This allows for full sunlight to reach the forest floor and encourages shade intolerant species to regenerate (Leak et al., 2014). One of the biggest differences between the two clearcut treatment locations was the much lower amount of tree regeneration present at KMR compared to the VIC (Figure 1). The species that were highest in abundances were not much different between the locations but average TPA numbers were quite different (Figure 1). At the VIC, red maple was most abundant with yellow birch second, while at KMR, yellow birch was most abundant with American beech second (Figure 1). American beech was third in abundance at the VIC (Figure 1). The clearcut treatment was the only treatment we analyzed that American beech was not the most abundant in the tree size class regeneration (Figure 1, Figure 3, and Figure 5). Red maple and yellow birch were more abundant than American beech in the tree regeneration at the VIC but American beech was more abundant in the sapling size class at both sites (Figure 1, Figure 2). American beech is classed as a shade tolerant tree species and generally establishes better under a closed canopy or small openings (Tubbs & Houston, 1990). In stands that are heavily cut, such as those that are clearcut, American beech regeneration usually grows slower than other hardwood species (Tubbs & Houston, 1990). This may be the reason why American beech was most abundant in the sapling size class and not the tree regeneration. Yellow birch is classed as a mid-tolerant tree species, meaning it prefers moderate amounts of sunlight for optimum regeneration (Erdmann, 1990). Strip clearcutting or small patch cutting are two suggested methods for regeneration (Erdmann, 1990). Since the blocks are only 5 acres in size and rectangular in shape, they are similar to patch or strip clearcuts and yellow birch is one of the most abundant species at each location. Red maple can survive a wide variety of conditions and because of this it is one of the most widely distributed tree species in eastern North America (Walters & Yawney, 1990). Red maple is classed as shade tolerant but is also known as a pioneer species (Walters & Yawney, 1990). Red maple also produces a large number of stump sprouts (Walters & Yawney, 1990) which may account for some of the regeneration present.

The species composition present in our clearcut treatment data did not seem to parallel the results found by Leak et al (2014). That study found that pin cherry was the most abundant in clearcuts, with paper birch the second most abundant, and yellow birch third in abundance (Leak et al., 2014). This differs greatly from our study where pin cherry was seventh in abundance in the tree regeneration at the VIC and was not present at KMR or in the sapling size class at either location (Figure 1, Table 1, and Figure 2). Paper birch was ninth in tree regeneration abundance at the VIC and was not present at KMR or in the sapling size class at either location (Figure 1, Table 1, and Figure 2). Red maple was most abundant at the VIC and third in abundance at KMR (Figure 1). In the sapling size class, American beech was most abundant at both locations (Figure 2). Leak et al (2014) found American beech to be tied for fifth in abundance with striped maple. Our results also differ from those of Allison, Art, Cunningham, and Teed (2003). Twenty years after a strip clearcut harvest in Massachusetts, they found striped maple to be the most abundant followed by red maple (Allison et al., 2003). Yellow birch was sixth in abundance in their study (Allison et al., 2003) while it was first or second in abundance at the FERDA plots (Figure 1). American beech was eighth in abundance in the strip clearcut study (Allison et al., 2003).

The regeneration present in the clearcut treatments differed greatly from that present in the control treatments. The control treatments were dominated by American beech comprising most of the tree regeneration and almost all of the sapling size class (Figure 5, Figure 6). Red maple and yellow birch were most abundant at the VIC and KMR clearcut treatments, respectively (Figure 1). At both the VIC and KMR control treatments, American beech was the most abundant in both size classes (Figure 5, Figure 6). Red maple and yellow birch were either last or almost last in abundance in the tree regeneration in the control treatments at both locations and neither were present in the sapling size class (Figure 5, Table 3, and Figure 6).

We believe one possible explanation for the abundance of shade tolerant species in the clearcut treatments is the location of the sample plots. Four of the eight permanent sample plots are located 66 feet away from the edge of the units. This is close enough to the surrounding unharvested areas that it may have had an influence on the composition of the regeneration present in those sample plots.

Single-tree Selection Treatments

Single-tree selection systems removes single stems from the forest to allow space for shade tolerant trees to regenerate (Twery et al., 2013). At both treatment locations American beech was found to be the most abundant in both sapling and tree size classes (Figure 3, Figure 4). American beech is highly competitive in shaded areas, has the ability to root sprout, and a low susceptibility to deer browsing (Tubbs & Houston, 1990) combine to be the most likely reason why it is the most abundant species present in this harvest system. Red spruce was the second most abundant in the tree regeneration at KMR, while it was fourth in abundance at the VIC (Figure 3). Red spruce was the least abundant sapling present at each location (Figure 4). Red spruce is also able to establish under relatively low light availabilities like American beech, even as low as 10% full sunlight (Blum, 1990). Red spruce requires higher light intensities to continue to grow and not be outcompeted (Blum, 1990) and may be why red spruce is not as abundant as American beech. Striped maple was second in tree regeneration abundance at the VIC and almost non-existent at KMR (Figure 3). At the VIC, striped maple was also second in abundance in the sapling size class, while there were no striped maple found in the sample at KMR (Figure 3, Figure 4). Striped maple is classed as very tolerant of shade and can survive in the understory for many years (Gabriel & Walters, 1990). It responds quickly to increases in light and grows best under a moderate forest canopy or small openings (Gabriel & Walters, 1990). Creating small gaps in the canopy through single-tree selection would have allowed any striped maple in the understory near the openings to respond quickly to the increase in light and produce seed for future regeneration (Gabriel & Walters, 1990). Sugar maple is a valuable species in the Adirondacks and therefore is one of the species usually desired in northern hardwood regeneration (Kelty & Nyland, 1981). Sugar maple was the third most abundant species at the VIC in both size classes (Figure 3, Figure 4). At KMR, sugar maple was fourth in abundance in the tree regeneration while it was not sampled in the sapling size class (Figure 3, Figure 4). Sugar maple is classed as very tolerant of shade, one of the most shade tolerant hardwoods with American beech being the closest competitor that can reach commercial size (Godman, Yawney, & Tubbs, 1990). Browsing by whitetail deer (*Odocoileus virginianus*) can reduce the amount of sugar maple regeneration significantly compared to American beech regeneration, which is very rarely browsed (Kelty & Nyland, 1981). This may explain the low numbers of sugar maple regeneration from personal observations of whitetail deer in the study area.

Leak et al (2014) found areas managed under single-tree selection which had been harvested twice resulted in American beech being the most abundant species present in the regeneration. This compares with our study where we also found American beech to be the most abundant in both the tree and sapling size class regeneration. The abundance of sugar maple in our study was also very similar to that found in the Leak et al (2014) study. Striped maple was found to be third in abundance after American beech and eastern hemlock (Leak et al., 2014). This compares with the results found at the VIC study site where striped maple was second in abundance (Figure 3, Figure 4). In both studies, American beech made up a majority of the regeneration present most likely due to its competitive ability under the stand conditions created by single-tree selection treatments. The composition found in the single-tree selection treatments in our study was similar to that found in the control treatments. In both treatments, at both locations, American beech was the most abundant in both size classes (Figure 3, Figure 4, Figure 5, and Figure 6).

Conclusion

Based on our findings in this study, creating larger openings allows species other than American beech to be the most abundant. American beech is still one of the top species in abundance, but not the most abundant species in the clearcut treatments in our study. The clearcut treatments also had the greatest diversity of tree species in the treatments we analyzed at the FERDA plots. This would allow a land owner or land manager to manage for a wider variety of species at one site if that was one of their goals or objectives. The single-tree selection treatments at the FERDA plots did not change the overall species composition and abundances greatly from that found in the control treatments. American beech was by far the most abundant species found in both size classes in both treatments.

One implication of this study is the small sample size of data from different treatments. We used inventory data given to us for the year 2014. One way to improve the study would be to use data collected over multiple years to compare changes in regeneration over time. Another limitation to this study was the lack of repetition of treatments over a larger area. Both the VIC and KMR sites are located close together and may not accurately represent the forest composition present in other areas of the Adirondacks. Having more time to sample other areas and provide more comparisons between areas could improve the results of this study. Another implication was the location of the sample plots. Inventory data was collected from permanent sample plots that may or may not have fallen in a harvested area depending on the treatment type. An improvement would be locating inventory plots within harvested areas. To investigate other harvest methods, such as group selection for example, you would place sample plots inside groups that have been previously harvested in order to ensure accurate regeneration data. In addition, monitoring those same sample plots over time to record changes.

There are a few different options for future research. The first option would be to investigate the group selection and shelterwood treatments to compare with the other treatments at the FERDA plots. Another option would be to expand the study area to include harvests that have occurred in other areas of the Adirondacks and comparing the regeneration there with that at the FERDA plots.

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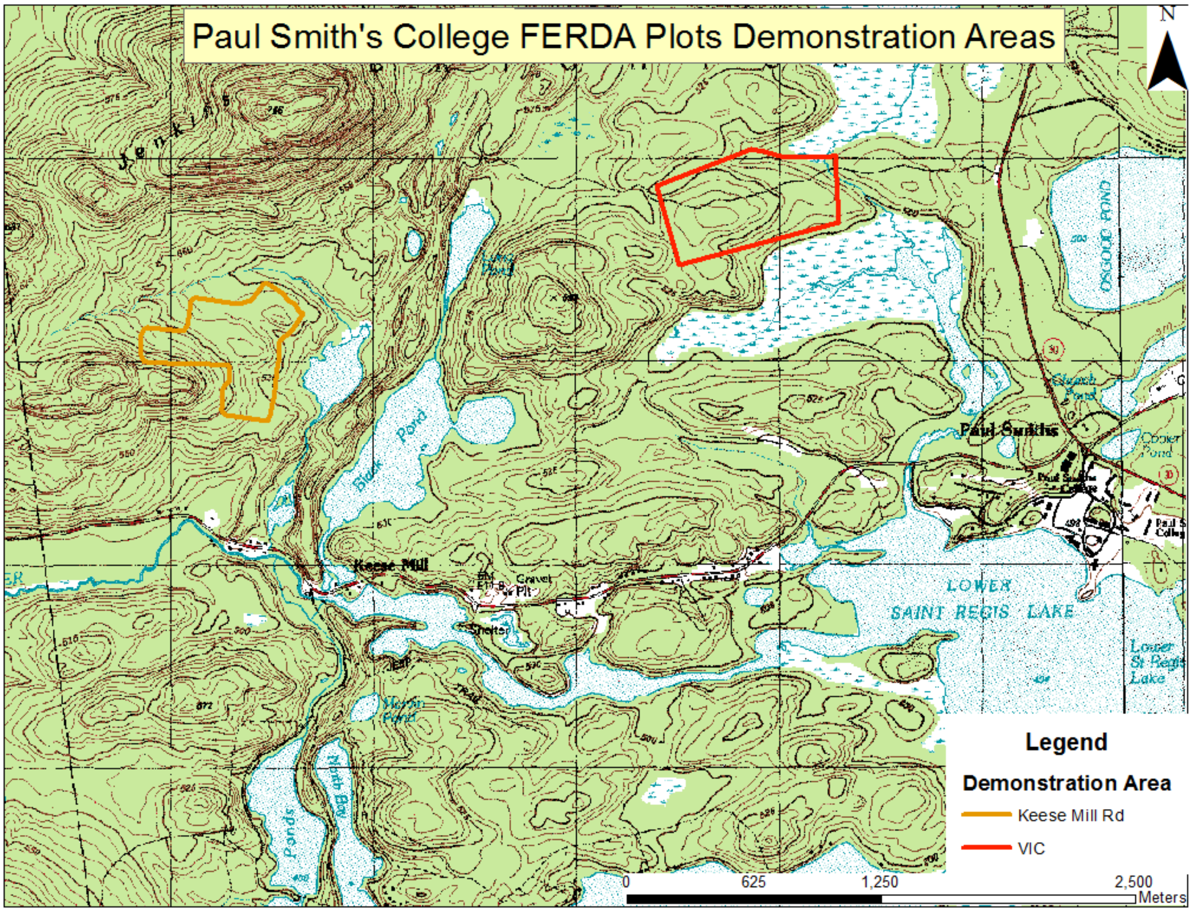
Appendices:

Appendix I:
Map:



Appendix II:

Plot Layout: