MANAGEMENT PROPOSAL FOR A PRIVATE LANDOWNER TO IMPROVE AN EXISTING SUGAR MAPLE STAND

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ABSTRACT

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Keywords: competition, forest health, release operations, silviculture, sustainability, sugar maple, values.

The presence of sugar maple, *Acer saccharum* Marshall, in Northwestern Ontario is bound by the existence of unique ecological microsites and natural gap dynamic processes. Its' management, though rare and challenging, has been embraced by Jay Stewart and his family with the personal production of maple syrup. A silviculture prescription focused on the improvement of the overall health condition of the stand, the release of sugar maple trees from competition, the nurturing of regeneration and seedbed conditions, as well as the maintenance of additionally important forest values has been developed and proposed in order to meet the landowners objectives.

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INTRODUCTION

With its leaf on the national flag, the sugar maple or hard maple tree, *Acer saccharum* Marshall, offers a wide range of ecological, social, and economic contributions countrywide; however, its most dignified achievement that has left so many Canadians wanting more has been the extraordinary transformation of sap into syrup.

Sugar maple trees have migrated northwards from Southern Quebec as many as 9900 years ago (Pilon et al 2015). Their current distribution reaches as far north as the transition zone between the Great Lakes St. Lawrence and Boreal forest regions of Ontario (Pilon et al 2015). In the Thunder Bay area, the combination of unique ecological features and the effects of natural gap dynamics have created the appropriate growing conditions for sugar maple survival (Pilon et al 2015). As a result, a handful of locals have had the pleasure of enjoying these beautiful trees right in their own backyards. This is the case for Jay Stewart and his family.

Jay is the property owner of an approximate 27 hectares (ha) of forested land, of which a small portion is dedicated to the growth of sugar maple. For him and his family, this forest fosters an intimate relationship with nature and supports countless social, cultural, ethical, and environmental values. Such values are manifested in the form of hunting, recreational activities and trail use, harvesting of non-timber forest products and fuel wood, the production of maple syrup, as well as an aspiration to maintain and enhance the long-term health and sustainability of the forest. Jay has gained a new interest in forestry and forest management concepts, however, continues to face many challenges. Lack of direction and available, clearly understood resources can interfere with a landowners ability to properly, effectively, and efficiently manage their privately owned land.

The purpose of this thesis is to propose a silvicultural prescription that will meet the objective of improving Jay's existing sugar maple stand for the production of maple syrup at a personal-use scale while additionally maintaining other social, cultural, ethical, and environmental values.

LITERATURE REVIEW

IDENTIFYING FEATURES

Sugar maple has the ability to grow up to 35 m tall and live for more than 200 years (MNRF 2014). Its palmate leaves are five-lobed and display an iconic arrangement of yellow, orange, and red in the autumn (Goertz 2016). It fruits single-seeded, paired samaras approximately 2.5-4 cm in length (Goertz 2016). Its bark, gray and smooth, becomes darkened and furrowed with age (Goertz 2016).

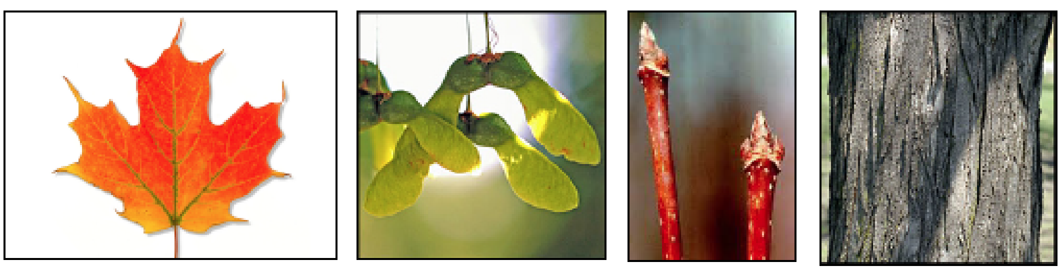

Figure 1. Identification features of sugar maple displaying (left to right) a palmate leaf, paired samaras, buds, and mature bark. Source: Google Images 2017.

DISTRIBUTION

As a species, it is native to eastern North America with a natural range from Nova Scotia towards the border of Manitoba expanding into the northeastern parts of the United States (Goertz 2016). It dominates much of southern and central Ontario and flourishes in the Great-Lakes St. Lawrence and Deciduous forest regions (Goertz 2016; Wang 2016). The combination of appropriate microsites and shifting natural disturbance regimes has allowed populations of sugar maple to establish and survive as far north as the transition zone into the Boreal forest (Pilon et al 2015).

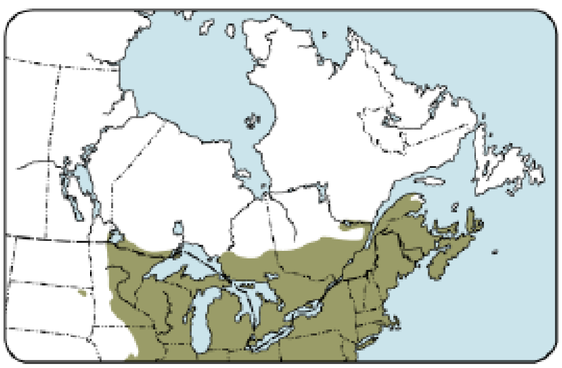

Figure 2. Distribution of sugar maple in North America. Source: Natural Resources Canada 2015.

HABITAT AND REGENERATION

The sugar maples preferred habitat includes deep, rich, well-drained soils generally alluvial or calcareous in composition; however it is known to grow on less optimal sites (MNRF 2014; US Forest Service; Houston et al 1990). It commonly exists in both pure and mixedwood stands alongside dominant or co-dominant beech (*Fagus* *grandifolia* Ehrh.), birch (*Betula spp.*), basswood (*Tilia americana* L.), and select conifer trees (US Forest Service). It supports a diverse understory community often comprising of, but not limited to, beaked hazel (*Corylus cornuta* Marsh.), alternate-leaf dogwood (*Cornus alternifolia* L. f.), bush honeysuckle (*Diervilla lonicera* P. Mill.), Canada yew (*Taxus canadensis* Marsh.), and raspberry (*Rubus idaeus* L.) shrub species (US Forest Service).

Sugar maple naturally reproduces sexually, however is understood to reproduce asexually through sprouting in its northern range (US Forest Service). It typically begins seed production between the ages of 30 and 40, exhibiting highly variable fluctuations in seed years (US Forest Service). It utilizes wind as a primary mechanism for seed dispersal, travelling as far as 100 m in distance (US Forest Service). An undisturbed forest floor creates the optimal environment for regeneration establishment and success (Wang 2016). Seedlings have the ability to persist in an understory, shaded environment for long periods of time and are highly plastic, responding well to a release of available resources (Wang 2016). Sugar maple does not capitalize on a strong seed bank, evidenced by the rare capacity for a seed to survive more than one year in the soil (US Forest Service).

Sugar maple can succeed into either an even or uneven-aged forest, depending on disturbance and forest management practices (US Forest Service; Wang 2016). Even-aged monocultures are highly susceptible to insect and disease infestation as well as demonstrate less resilience to environmental changes (Houston et al 1990).

FACTORS AFFECTING SUGAR MAPLE HEALTH

Recognizing signs and symptoms of sugar maple decline or dieback is crucial in forest management. Common examples include the loss of leaves, buds, twigs, or branches within the upper crown, early leaf discolouration, as well as sprouts from the main stem (Sir Sanford Flemming College and LandOwner Resource Centre 1995). There are a variety of biological, environmental, and human-induced factors that cause decline or dieback; however, trees are often affected by combination of these stresses (SSFC and LORC 1995).

Biological stresses range from damaging insects and diseases to poor stand conditions, for example, overcrowding. Bud miners, defoliators, borers, and sucking or scale insects cause physical harm, compromising in many cases, a trees health and value (US Forest Service (b)). Similarly, heart rot decay fungi, such as, Armillaria, cankers, and wilts are commonly occurring diseases in sugar maple trees that cause decline or dieback (US Forest Service (b)). Browse from deer or other wildlife are also considered a form of damage, particularly to juvenile trees (SSFC and LORC 1995).

Environmental stresses, such as severe wind, drought or flooding, frost and ice damage, sunscald, lightning, as well as a lack of available nutrients create highly susceptible trees to decline or dieback (SSFC and LORC 1995). The establishment of windbreaks is an effective technique in mitigating the effects of extreme weather on syrup production operations (Houston et al 1990). Human-induced stresses also affect tree health, for example, improper tapping, careless logging, and poorly timed management operations (SSFC and LORC 1995).

Additional growth and health defects, as well as their identification features are found in the Ontario Tree Marking Guide (OMNR 2004). Further detail is provided for maple and birch species.

MAPLE SYRUP

Maple syrup production begins when a taphole is drilled into the first tree in early spring when temperatures thaw to above freezing (Davenport and Staats 1998). A spile is gently tapped into the entryway, with caution against creating cracks in the bark (Davenport and Staats 1998). Sap flow fluctuates according to the hour, day, and length of season, often lasting between 12 and 20 days beginning in early March until late April (Pure Canada Maple). Traditionally, sap is collected in buckets and transported to the sugar shack although more modern systems have evolved to include tubing (Davenport and Staats 1998). Once in the sugar shack, sap is processed in an evaporator, which boils down the substance to achieve a certain dark, medium, or light grade (Davenport and Staats 1998). Approximately 40 L of sap will create 1 L of maple syrup (Pure Canada Maple). Syrup should be filtered to remove gritty material before sealing into a final product (Davenport and Staats 1998).

Aspect, slope, and soil type are important factors in maple syrup production influencing the light, heat, and moisture conditions of a stand (Houston et al 1990). As a result, tree growth, sap sugar content, as well as duration and timing of sap flow are impacted (Houston et al 1990). Eastern and southern exposures are recommended for optimal return (Houston et al 1990).

The ideal crop tree supports a healthy stem and a large, vigorous crown with direct access to sunlight (Houston et al 1990). It has been noted that faster growing trees have the ability to produce 30% more sap than their passive counterparts; similarly, trees with a crown that is 50% larger than others are likely to yield twice as much sap (Houston et al 1990). Sap sugar content is an additional influence on harvest amount ranging between 0.5 and 0.8 %, and fluctuates hourly, daily, and seasonally (Houston et al 1990).

A single tree can withstand the pressure from tapping in consecutive years for decades; however, proper techniques must be exercised to mitigate adverse effects on tree health (Houston et al 1990). Tapholes introduce damage to the crop tree that results in discoloured wood and presents an entryway for opportunistic pathogens (Houston et al 1990). Minimizing the number, size, and spacing between these entryways is critical in maintaining healthy crop trees, of which have the ability to heal within 2-3 years (Houston et al 1990). Houston et al (1990) recommend that tapholes are spaced at least 15 cm horizontally and 60 cm vertically from one another; further adjusting this proposition with professional judgment when the health and vigour of a crop tree is compromised. Tapholes should not exceed 6 cm in depth and should be cleanly drilled on an upward angle; this will improve the drainage of sap discouraging the collection of bacteria, yeasts, and fungi (Houston et al 1990).

FOREST MANAGEMENT: SUGAR BUSH DEVELOPMENT

Houston et al (1990) recommend the following steps in developing a sugar maple stand for the production of maple syrup: first, selecting potential crop tree locations at a spacing of 7.5-9.0 m in all directions; second, identifying the tallest tree with the superior crown and eliminating those with noticeable stem or health defects; third, measuring the sap sugar content in order to ensure selected trees achieve optimal production; fourth, releasing the selected trees by progressively removing interfering individuals; fifth, a continuation of release operations as the stand develops; and lastly, perpetually monitoring the health condition of the crop trees, removing those that have the potential to source disease or damage.

MATERIALS AND METHODS

OBJECTIVES

1) Develop and propose a silvicultural prescription that will improve an existing sugar maple stand for the production of maple syrup at a personal-use scale.
2) Maintain other social, cultural, ethical and environmental values.

LOCATION

87 Boundary Drive, Thunder Bay, Ontario

Figure 3. Aerial photograph (left) indicates the location of the house and demonstrates the larger ecological landscape. Aerial photograph (right) from drone flight of the property. Source: Google Earth 2016; Ong 2016.

This location embodies the unique ecological features, such as the Norwestors and Neebing River that provide the appropriate growing conditions for a population of hard maple, occurring at the northern limit of the species range.

INVENTORY

An aerial map, taken from Google Earth, was supplied to the thesis student by the landowner outlining the property boundary. It was modified to exclude the area occupied by the house, garage, and garden; the final area, approximately 27 ha was recorded. A sampling intensity of one plot per hectare was recommended covering 400 m^2 each. The map was imported into ESRI ArcMap and geo-referenced according to Thunder Bay's UTM zone. The fishnet tool was applied, and a plot spacing of 50 m by 50 m was established. Plots were converted into a GPX file and loaded onto a GPS unit.

On the field day, plots were located using a GPS unit. A plot centre was established using a tall stick and flagging tape; each was labeled according to its plot identification number. A radius of 11.28 m was measured and each tree, equal to or greater than 8 cm DBH (diameter at breast height), within the radius was tallied. Their species, DBH, and position in the crown canopy (dominant, co-dominant, intermediate, or suppressed) were recorded. Sugar maple trees were additionally recorded as first, second, or third generation tap trees indicating their future potential to produce maple syrup. "First generation" trees were defined by the ability to be tapped in the current year (approximately 30 cm DBH); "second generation" trees were defined by the potential to establish the succeeding cohort of tap trees (approximately 16 cm DBH); and "third generation" trees demonstrated the potential to establish the succeeding cohort of tap trees but were too small to be considered "second generation" (approximately 10 cm DBH). The objective of this classification system was to instill concepts of sustainable forest management within the syrup production operation. The height of a minimum of three dominant trees per plot was recorded using a laser. In order to assess regeneration, an inner plot of 100 m^2 was measured; the number of saplings was tallied and their species identification was recorded.

Initial inventory was taken in the fall of 2016. Areas of the forest containing the dominant sugar maple trees were inventoried first; six plots were completed, establishing a total sample area of 0.24 ha.

RESULTS AND DISCUSSION

CURRENT STAND CONDITION

Overall Species Composition

As shown in Figure 4, the forest stand examined is predominantly composed of sugar maple (*Acer saccharum* Marsh.) (35%), followed by balsam fir (*Abies balsamea* (L.) Mill.) (34%), black ash (*Fraxinus nigra* Marsh.) (18%), white birch (*Betula papyrifera* Marsh.) (9%), balsam poplar (*Populus balsamifera* L.) (4%), and trembling aspen (*Populus tremuloides* Michx.) (1%). For further analysis, these species were divided into two representative groups: Mh (hard maple) for the population of sugar maple trees and Mwd (mixedwood) for the population of all remaining species.

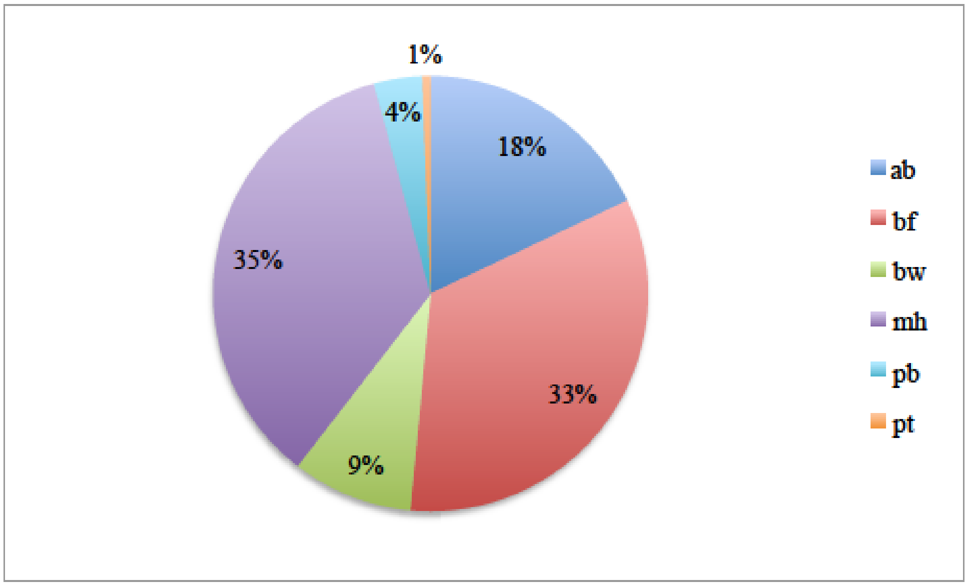

Figure 4. Species percent composition of the forest including black ash (ab), balsam fir (bf), white birch (bw), hard maple or sugar maple (mh), balsam poplar (pb), and trembling aspen (pt). Source: Appendix.

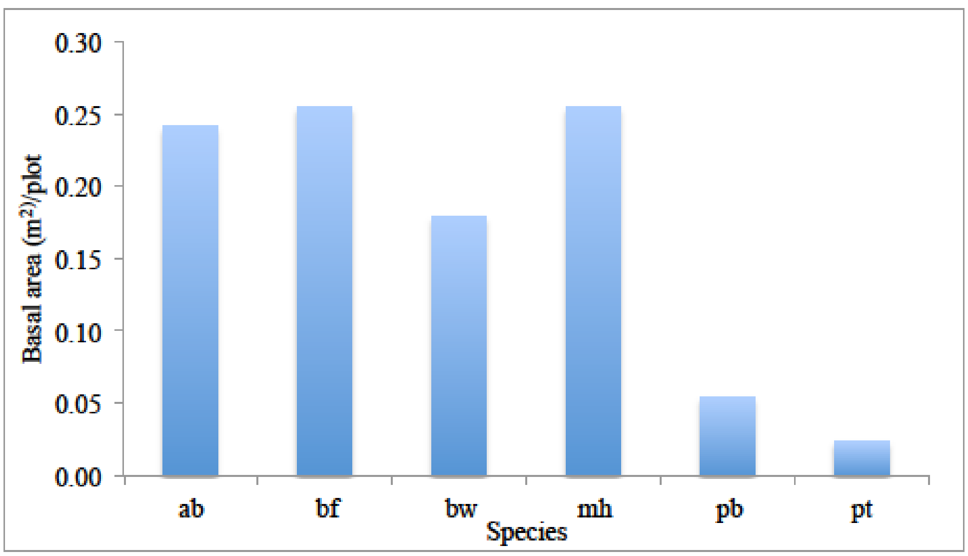

Figure 5. Basal area (m^2) per plot (400 m^2) by species. Source: Appendix.

<u>Overall Stand Structure</u>

The overall stand displays a strong relationship between diameter at breast height (cm) and height (m), as shown in Figure 6. The trend exhibits an increase in height with an increase in diameter. The R^2 value of 0.8 exemplifies the strength of the relationship in the forest stand sampled; this may indicate that, in general, each individual is capable of capturing sufficient resources to allocate to both growth in diameter and height. Further analysis of Figure 6 demonstrates that most of the measured hard maple trees (mh) fall within the shorter and smaller spectrum of the stand.

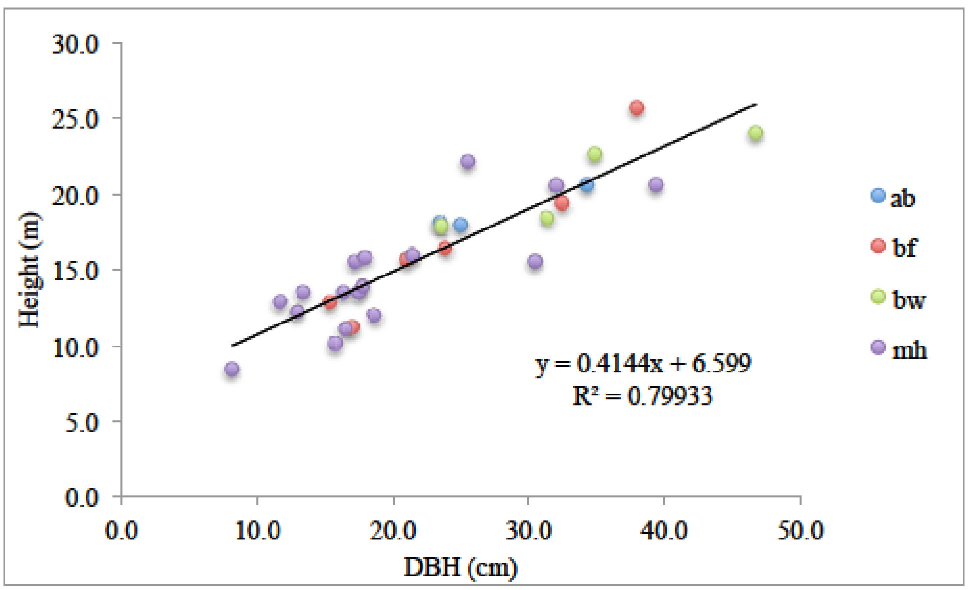

Figure 6. Diameter and breast height (cm) and height (m) relationship of the forest stand. Source: Appendix.

In order to analyze the stand structure, a graph of the number of trees per plot within designated diameter classes (cm) was developed (Figure 7). Where an inverse J curve distribution was expected, an uneven-bimodal distribution emerged. There is a subtle trend representing a decrease in number of trees with an increase in diameter class; however, the consistency of this trend is interrupted on several occasions.

First, and most predominantly, there exists an excess of trees within the 16-18 cm diameter class. Figure 8 demonstrates further analysis of this phenomenon by identifying the species contribution to each diameter class. This includes the sugar maple population (Mh) and the mixedwood population (Mwd) of which is composed largely of balsam fir followed by black ash, white birch, balsam poplar, and trembling aspen. Sugar maple represents 43% of the trees within the 16-18 cm diameter class; the combination of mixedwood species comprises the remaining 57%. The accompanying mixedwood species in this diameter class include balsam fir and black ash. Table 1 further investigates the percent composition, average diameter at breast height (cm), basal area average and total (m^2), as well as height (m) of each species within this diameter class. It is noted that, while each species demonstrates similar values for these quantifiable characteristics, sugar maple contributes the greatest basal area (m^2) and height (m).

The second, more minor interruption describes an excess of trees within the 32-34 cm and 34-36 cm diameter classes. In both cases, the mixedwood species group represents 71% and 83% of the forest stand composition respectively. These diameter classes are composed primarily of white birch accounting for 31% of the population (Table 2) followed by sugar maple, black ash, balsam poplar and balsam fir.

An overall analysis of Figure 8 demonstrates a greater proportion of forest dedicated to the mixedwood species group; with specific regards to the last four diameter classes, or trees that are 40-48 cm in size, of which are composed 100% of white birch, black ash, or trembling aspen. Only the first three diameter classes, or trees that are 8-14 cm in size, are dominantly composed of sugar maple.

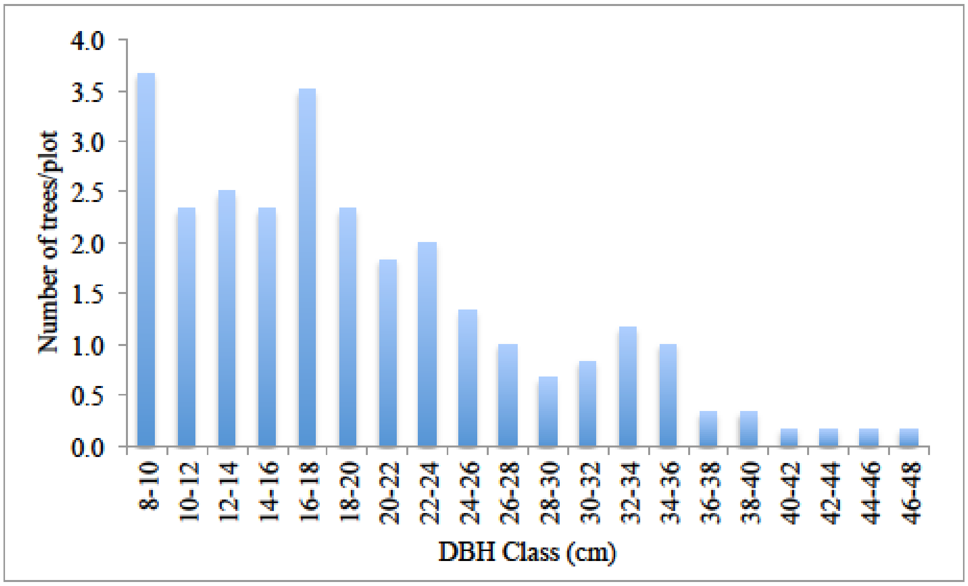

Figure 7. The total number of trees per plot (400 m^2) within each diameter class (cm). Source: Appendix.

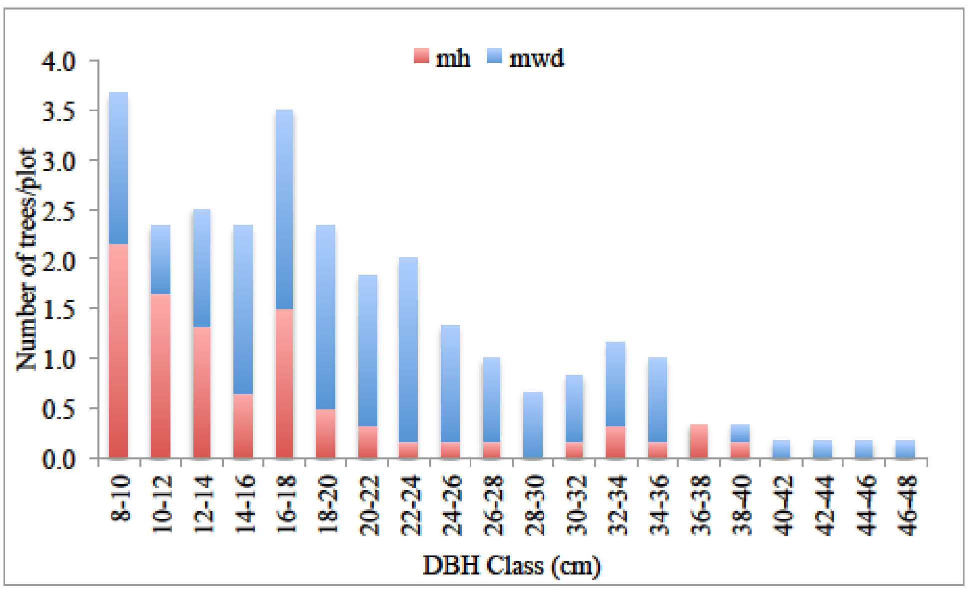

Figure 8. The number of trees per plot (400 m^2) within each diameter class (cm) separated by species group. Mh represents the sugar maple population and Mwd represents all other species within the stand. Source: Appendix.

Table 1. Further investigation of the species and their percent composition, average diameter at breast height (cm), basal area average and total (m^2), as well as height (m) within the 16-18 cm diameter class.

Species	%	DBH Ave (cm)	BA Ave (m^2)	BA Total (m^2)	Height (m)
mh	43	16.9	0.022	0.201	13.5
ab	14	16.8	0.022	0.067	n/a
bf	43	16.8	0.022	0.199	11.2

Source: Appendix

Table 2. Further investigation of the species and their percent composition, average diameter at breast height (cm), basal area average and total (m^2), as well as height (m) within the combined 32-34 cm and 34-36 cm diameter classes.

Species	%	DBH Ave (cm)	BA Ave (m^2)	BA Total (m^2)	Height (m)
mh	23	33.0	0.086	0.257	20.6
ab	23	34.8	0.095	0.285	20.6
bf	8	32.5	0.083	0.083	19.40
bw	31	34.2	0.092	0.368	22.7
pb	15	33.7	0.089	0.178	n/a

Source: Appendix

Sugar Maple

The sugar maple tap tree classification system includes current, first, second, and third generation trees. "Undeclared" trees were not prevalently identified within a specified class during the field visit; however, data analysis may allow for the development of a classification guideline (Table 3). Understanding when a sugar maple tree might be tapped or how many trees fall within each "generation" becomes critical to the long-term sustainability of the maple syrup production operation. It also dictates which trees will be managed and at what intensity.

The diameter distribution of the sugar maple population, as seen in Figure 9, parallels that of the forest stand as a whole (Figure 7). The general negative exponential trend is maintained where a decreasing number of trees is accompanied by an increasing diameter class (cm). An excess number of trees, 16-18 cm in diameter, are present within the stand. In order to analyze what types of sugar maple trees are found within this diameter class, for example, what "generation" classification they have been assigned regarding when they might be tapped for syrup production, their diameter at breast height (cm), average and total basal area (m^2) and height (m) are calculated. A comparison is provided in Table 3, including the sugar maple (mh) values from Table 1 as well as those associated with each generation classification. The second generation tap trees, with an average diameter at breast height of 16.1 cm, average basal area of 0.22 m^2, and average height of 14.6 m most appropriately describe the trees likely found within the 16-18 cm diameter class, of which display values of 16.9 cm, 0.22 m^2, and 13.5 m respectively.

As demonstrated by Figure 10, most of the second generation trees fall within the co-dominant canopy layer. A continued analysis of this figure also displays an excess number of third generation trees within the intermediate canopy layer; this is consistent with the abundance of individuals within the smaller, 8-12 cm diameter class. A surplus of trees within both the 8-12 cm and 16-18 cm diameter classes indicate a high degree of competition for resources and space; therefore, a management opportunity exists to release the most promising individuals from the younger generation in establishment of the future crop of tap trees.

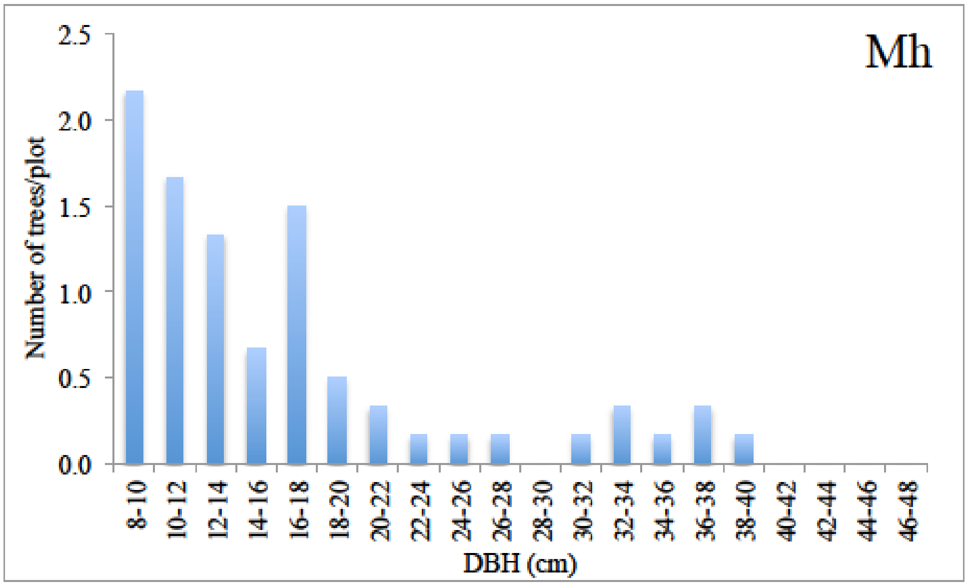

Figure 9. The number of trees per plot (400 m^2) within each diameter class (cm) for the sugar maple (Mh) population. Source: Appendix.

Table 3. Summary of the average diameter at breast height (cm), average and total basal area (m2), and height (m) for the sugar maple tap tree generation classifications. Below, in blue, represents the comparison between the characteristics of trees within the 16-18 cm diameter class and those within the second generation classification.

Tap Tree Generation	DBH Ave (cm)	BA Ave (m^2)	BA Total (m^2)	Height (m)
Current	36.0	0.102	0.512	20.6
1st generation	30.5	0.073	0.073	15.5
2nd generation	16.1	0.022	0.410	14.6
3rd generation	10.9	0.010	0.146	10.8
DBH 16-18 cm	16.9	0.022	0.201	13.5

Source: Appendix

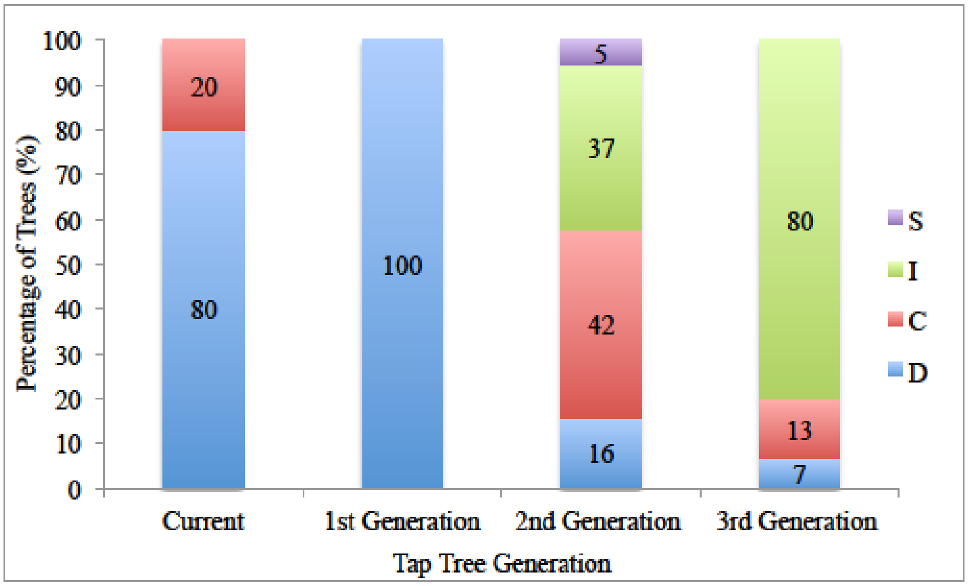

Figure 10. Percentage of sugar maple trees within each canopy layer (D = dominant, C = co-dominant, I = intermediate, S = suppressed) separated by potential generation of tree tapping for syrup production. Source: Appendix.

<u>Other Species</u>

The forest is divided relatively evenly into the four canopy layers, with the exception of suppressed trees of which are the smallest represented group (Figure 11). This distribution, however, varies widely amongst species as demonstrated in Figure 12. Relative to other species, black ash (ab) and sugar maple (mh) have the greatest population of dominant trees, balsam fir (bf) has the greatest population of co-dominant and suppressed trees, and sugar maple has the greatest population of intermediate trees. Figure 12 also reiterates the potential for competition of resources between balsam fir and sugar maple trees; this becomes a significant result worth managing.

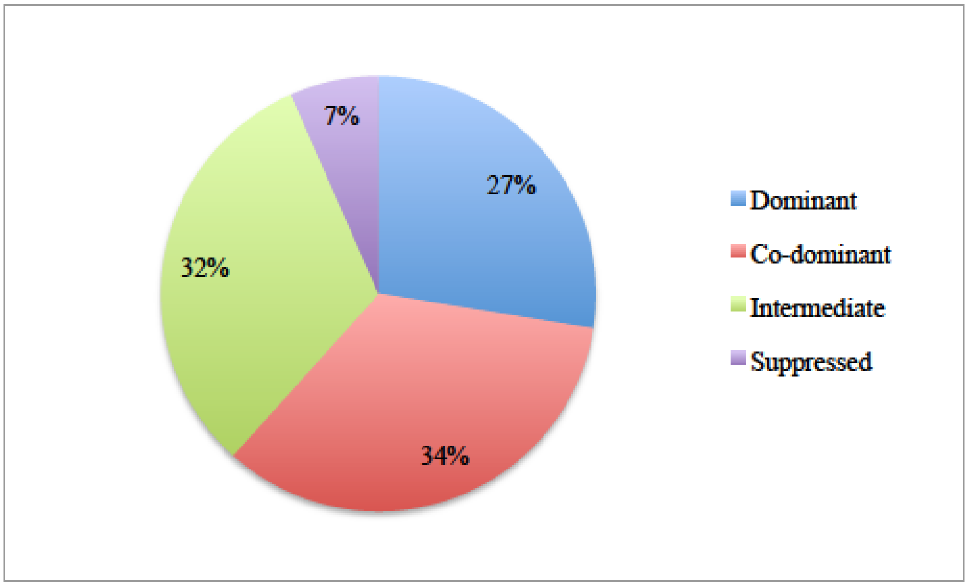

Figure 11. Percentage of trees within each of the four canopy layers: dominant, co-dominant, intermediate, and suppressed. Source: Appendix.

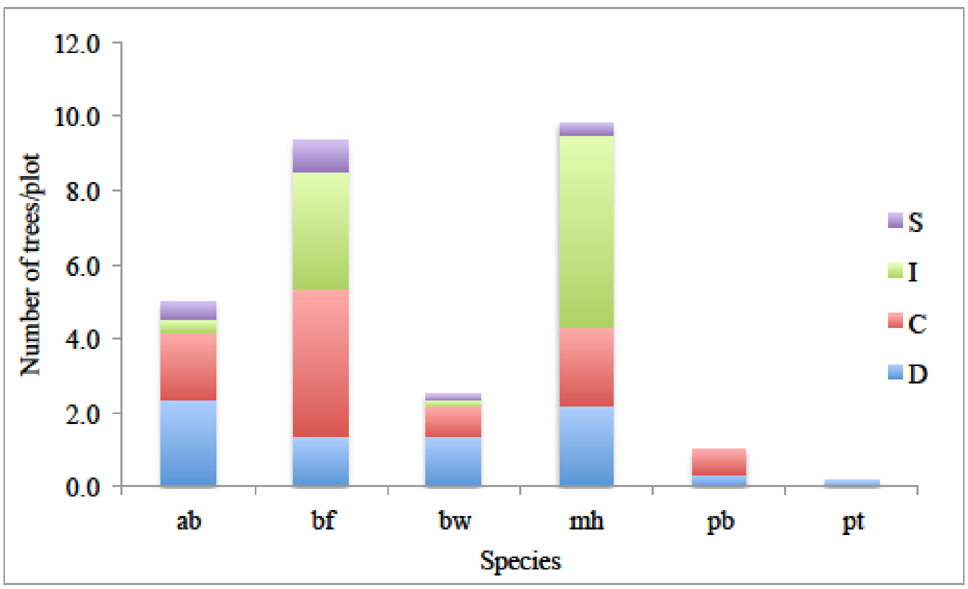

Figure 12. Number of trees per plot (400 m^2) within each canopy layer (D = dominant, C = co-dominant, I = intermediate, S = suppressed) separated by species. Source: Appendix.

MANAGEMENT PROPOSAL

Approaches

There are two approaches that are used in the development of a management strategy for this thesis:

1) The selection silviculture system with direction from the Ontario Tree Marking Guide for assessing potential vigour, risk, and quality in trees.
    a. Section 3.0: Choosing the right tree to leave (pg 31-62).
    b. Section 4.0: Tree marking for wildlife habitat and biodiversity (pg 85-122).
2) Sugar bush management for the improvement of the sugar maple population and the coinciding production of maple syrup.

The Ontario Tree Marking Guide is intended to provide basic guidance in selection silviculture with the objective of maintaining or enhancing the long term health and sustainability of the forest. Particular sections are recommended for referencing in the aid of selecting crop (or tap) sugar maple trees, or in the selection of removal trees. Section 4.0 provides general examples of wildlife habitat and biodiversity management; however, it should be noted that it was developed for the Great Lakes St. Lawrence region of Central Ontario and therefore might not apply in its entirety to the Thunder Bay area. Similarly, principles of sugar bush management are intended to promote high-quality sugar maple tap trees for an improved production of syrup. Additional guidance from Houston et al's (1990) Sugar Bush Management: A Guide to Maintaining Tree Health is provided.

Interpreting the Ontario Tree Marking Guide

Section 3.0: Choosing the Right Tree to Leave

The objective when removing trees is to optimize the growth of residual (remaining) or crop trees. In this case, crop trees are the selected sugar maple tap trees. The following outlines a series of steps when identifying which trees to remove and which to maintain:

Step one: assess trees for potential vigour (the relative capacity of a tree to increase in size, for example, DBH). Factors to consider include crown position (Figure 13), size, architecture, and quality; bark health (Figure 14 and Figure 15); and the degree of competition. Figure 16 provides an overall description of tree vigour classes ranging from good to poor.

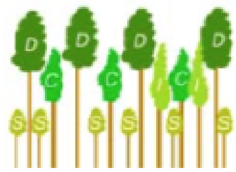 Crown class	Position in canopy	Amount of sunlight received
Dominant (D)	Tree is taller than its immediate neighbours. Crown extends above the general level of the crown canopy.	Receives full light from above and considerable light from the sides.
Codominant (C)	Tree with crown formed at the general level of the crown canopy.	Receives full light from above but comparatively little from the sides.
Intermediate (I)	Tree is shorter than dominants or codominants but with crown extending into the canopy formed by them.	Receives some direct light from above but none from the sides.
Overtopped or Suppressed (S)	Tree with crown entirely below the general level of the crown canopy.	Receives no direct light.

Figure 13. Description of canopy crown classes. Source: OMNR 2004.

Species	Indicators of high vigour	Indicators of low vigour
Rough-barked species (sugar maple and red oak; to a lesser extent white ash and black cherry)	Furrows are: • prominently vertical in pattern • relatively narrow • V-or U-shaped in profile • less than 1.3 cm deep • light in colour at base • less broad than plates or ridges Ridges are: • firm	Furrows are: • often marked with cross-breaks in their vertical pattern • much broader than plates or ridges Ridges are: • soft and corky
Smooth-barked species (yellow birch, beech)	• smooth, thin and, if peeling, then very thin strips (more likely for younger and therefore faster-growing trees for their size)	• rough, with large flaky plates

Figure 14. Description of indicators of high and low vigour in tree bark. Source: OMNR 2004.

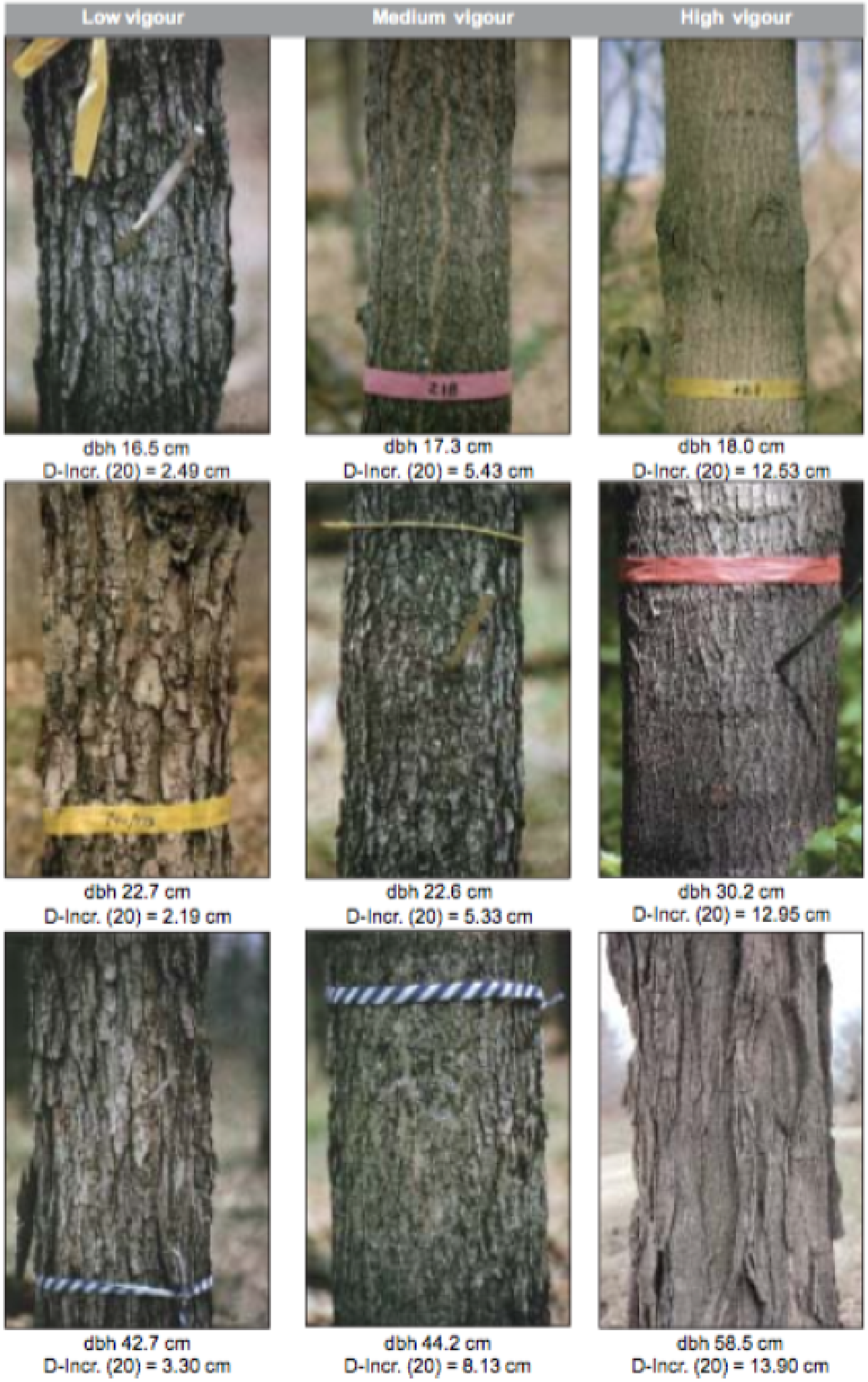

Figure 15. Vigour of bark on sugar maple trees at varying sizes. Source: OMNR 2004 (pg 38).

Vigour class	Identification
I (GOOD)	A tree in this vigour class has a large, healthy, full crown in a dominant or codominant position. Half the crown or more is exposed to direct sunlight. The crown is dense, with no evidence of disease or injury. Crown quality and position are more important than total length. The bark and twigs have good colour and vigorous appearance.
II (MEDIUM)	A tree in this vigour class has a medium-sized crown in a codominant position. Less than half the crown is exposed to direct sunlight. The crown is less dense and not as perfect as that of a Vigour I tree. This class may also include a large-crowned tree that fails to meet the requirements of Vigour I because of mechanical injury or dying limbs.
III (FAIR)	A tree in this vigour class has a medium to small crown, usually in a mid-canopy position. Only the tip is exposed to direct sunlight. The crown may be open, with some dead or broken limbs, or thinly foliated. This class also includes trees with medium to large crowns in a codominant position that cannot meet the requirements for a Vigour II tree.
IV (POOR)	A tree of this class usually has a small, spindly, flattened crown in an overtopped position. This class includes all living trees that fail to meet the requirements of higher-vigour trees.

Figure 16. Description of tree vigour ranging from good to poor. Source: OMNR 2004.

Step two: assess trees for potential risk (the likelihood of death within a specified time frame). Trees that pose higher levels of risk may need to be removed from the stand in order to limit the spread of insect and disease pests. In some cases, they can be maintained to provide wildlife or biodiversity values (see Section 4.0). For the purpose of this thesis, the level of risk should be defined by the landowners' available time and energy as well as level of comfort when dealing with dead or dying trees.

Step three: assess trees for potential quality (presence or absence of health defects). See OMNR (2004) Ontario Tree Marking Guide, pg 46-62 for a list of major health defects, their identification features, images, and their affects on tree quality.

Section 4.0: Tree Marking for Wildlife Habitat and Biodiversity

There are a variety of values that can be managed for the maintenance of wildlife and biodiversity including stick nests, moose and deer seasonal habitat, old growth, riparian zones, wetlands, as well as locations of identified species at risk. Stick nests or large trees with the potential to support a stick nest (typically aspens or poplars greater than 40 cm DBH) should be protected for the management of large birds (Figure 17). Similarly, riparian zones, defined by the interaction of the aquatic and terrestrial environment, should also be protected for their high levels of biodiversity and their sensitivity to disturbance. Cavity trees, used by birds and small mammals for nesting, feeding, roosting, or denning, should be protected for the maintenance of wildlife habitat; they are typically in the form of standing dead trees (snags) or declining living trees (Figure 18).

Figure 17. Example of a stick nest for a bird of prey. Source: Hazlett 2014.

Figure 18. Example of a cavity tree – the pileated woodpecker is considered a keystone species responsible for the establishment of cavities that are used by a diversity of bird and mammal species. Source: Morris 2002.

Silvicultural Prescription

The silvicultural prescription for the sampled area consists of five parts.

1) Improve the overall health condition of the forest by removing dead or dying trees. This includes trees that have the potential to be high risk for insects or diseases, creating a source for future, perhaps severe infestations. This is a particular concern during stress events, such as drought, when trees become increasingly susceptible. This also includes danger trees that present potential harm to people, buildings or trails. It is recommended to assess more mature trees, such as black ash, white birch, balsam poplar, and trembling aspen, which commonly begin to display signs of health decline and decay in the larger diameter classes (DBH greater than 40 cm). Black ash trees should be assessed and continually monitored for the presence of Emerald Ash Borer; immediate action should take place upon detection. Any dead or dying tree that presents

wildlife habitat, such as nests or cavities, or presents the opportunity to support such values should be maintained if their level of risk is acceptable to the landowner.

2) The next generation of sugar maple trees should be managed in order to develop a strong, healthy future crop for sustainable syrup production (see Overall Recommendations for Selecting the Next Generation of Tap Trees). Focus on individuals from the co-dominant and intermediate canopy classes (approximately 16 cm DBH and/or 15 m in height, and approximately 10 cm DBH and/or 11 m in height respectively) in the establishment of second or third generation tap trees. Identify and mark the optimal future tap trees, at a minimum of 7.5-9.0 m apart. These trees should be vigorous in health and growth, displaying no sign or symptom of defect or decline, as well as smooth, gray bark and full, healthy crowns. In a series of harvests, release the identified tap trees from competition on the South, East, West, and North facing sides. This may include any tree whose crown interferes with or overshadows the tap tree. Extra care should be exercised during tree removal operations to prevent damage to next generation trees as well as to minimize site disturbance on seedbed conditions. Identified future tap trees should be continually managed to promote growth and health; encourage access to direct sunlight and other resources by removing competitive individuals, minimize harvesting disturbance, prune as required to manipulate form (should only have one dominant leader or stem) and crown branching structure (should be well-balanced), as well as remove surrounding high-risk individuals that have the potential to source insect or disease infestations.

Ensure the long-term sustainability of the forest by managing abnormally distributed diameter classes or those that do not conform to the negative exponential relationship between the number of trees per plot and diameter class (Figure 7). Reduce the number of individuals within the 16-18 cm diameter class in order to establish a gradual and smooth transition between a high number of small trees and a low number of large trees. Minimize the amount of competition within this diameter class by removing 1-2 trees per 400 m^2 (plot radius of 11.28 m) in areas that are overcrowded and clumped; operations should be limited where the distribution of trees is more sparse. Species, such as balsam fir, black ash, and sugar maple are found in higher percentages within this diameter class and should be managed accordingly. In areas where future sugar maple tap trees are present, competing balsam fir and black ash trees should be a removal priority.

3) Nurture regeneration and suppressed trees for all species, with particular consideration for sugar maple where tree tapping occurs. Young individuals should be protected from harvesting damage and site disturbance should be minimized to maintain seedbed conditions. Competing shrub populations, such as beaked hazel, should be controlled if they begin to severely impede the establishment and growth of targeted tree species.

4) Identify and manage for other values within the forest, such as wildlife habitat, ecological significant areas, riparian zones, non-timber forest products, or harvesting of high quality timber and fuel wood. Cavity or nest trees, often large-diameter and decaying aspens or poplars, provide habitat for a variety of bird and small mammal species. Forested areas with an abundance of young vegetation provide a winter food source for deer. Riparian zones, located along streams or creeks, provide areas of high biodiversity. Mushrooms, berries, or chaga provide an additional source of non-timber forest products. Black ash trees, with a risk for infestation from the Emerald Ash Borer, provide the opportunity to harvest high quality timber for value-added wood products,

such as furniture. Dead or dying trees removed to improve the overall health condition of the forest provide a supply of fuel wood.

5) Forests are highly dynamic ecosystems therefore it is essential to continue monitoring the constantly changing interactions and conditions, particularly in areas where individuals have been removed to encourage the growth of selected crop trees. It is recommended to perform another data collection for the area sampled in five and ten years to assess and compare how the forest has progressed.

Overall Recommendations for Selecting Current Tap Trees

- Selected from the "good" vigour class.
- Selected from the dominant or co-dominant canopy position. Selected trees are a minimum of approximately 24 cm in DBH.
- Have large (wide) vigorous crowns with a well-balanced branching structure that allows most leaves access to direct sunlight. This will improve the production of photosynthate or sugars within the tree yielding a greater amount of sweeter sap in the spring. Tap holes should also be drilled on the south facing side of the tree, where sap flow generally begins earlier.
- Have bark that displays prominent, vertical, and relatively narrow furrows that are less than 1.3 cm deep (V or U shaped).
- Display no signs or symptoms of health defects or stress.

Overall Recommendations for Selecting the Next Generation of Tap Trees

- Selected from the "good" vigour class.
- Selected from the co-dominant (second generation) or intermediate (third generation) canopy position (16 cm DBH and/or 15 m in height and 10 cm DBH and/or 11 m in height respectively).
- Have vigorous crowns with a well-balanced branching structure. Young trees may be pruned to improve form and optimize leaf access to direct sunlight.
- Have smooth, gray bark.
- Display no signs or symptoms of health defects or stress.
- Be spaced approximately 7.5-9.0 m apart from one another.
- Be released on all sides (North, South, East, West) from competition, slowly over time.
- Is located near a trail or can be easily accessed by the landowner.

CONCLUSION

In order to meet the landowners objectives of improving the existing sugar maple stand for the production of maple syrup and maintaining other social, cultural, ethical, and environmental values, two management approaches were exercised. First, guidance from the OMNR (2004) Ontario Tree Marking Guide for selection silviculture was used to meet additionally important objectives, such as maintaining wildlife habitat, recreation and trail use, hunting, fuel wood harvesting, or enhancing the long-term health of the forest. Second, researched practices in sugar bush development and management were used to promote the growth of high quality sugar maple trees for an improved production of maple syrup.

The prescription included five parts, which were developed by identifying key issues during the analysis of the current stand condition. First, improve the overall health of the forest by removing dead and dying trees, particularly with regards to those infested by insect or disease. Second, identify the next generation of tap trees and begin a series of release operations in order to improve the available growing conditions, as well as encourage the development of a smooth inverse-J curve at the stand level by alleviating competition. Third, nurture regeneration and suppressed trees, particularly by protecting them from harvest damage and maintaining seedbed conditions. Fourth, identify and maintain other important values, such as wildlife habitat, non-timber forest products, or riparian areas. Lastly, continually monitor natural and human-induced changes within the forest and assess its progression through time.

The intention of this prescription was to provide feasible forest management practices that will allow the landowner to, with time, meet his objectives. The overall thesis document aimed to provide additional resources as well as directional tools relevant to decision-making. It is encouraged that the landowner continues to foster his relationship with the land, growing as a steward in sustainable forest management on private property.

GLOSSARY

Age and stand structure: the distribution of age classes within a stand. Age structure is usually shaped by stand history (e.g., disturbance) and reflects species traits, such as the ability to reproduce and grow in its own shade (OMNR 2004).

Biodiversity: an expression of the variety and variability of life at numerous level; this includes ecosystem, species, and genetic diversity, for example ranges in forest structure and composition, as well as tree and wildlife species (OMNR 2004).

Decline and dieback: signs or symptoms in trees that may indicate poor health; may be induced by interacting biological, environmental, or human-induced stresses (OMNR 2004).

Diameter at breast height (DBH): standard height of 1.3 m from the ground in which diameter is typically measured.

First generation tap tree: sugar maple trees identified with the potential to be currently tapped (approximately 30 cm DBH); **second generation tap tree:** sugar maple trees identified with the potential to support the succeeding cohort of tap trees (approximately 16 cm DBH); **third generation tap tree:** sugar maple trees identified with the potential to support the succeeding cohort of tap trees, but are too small to be considered "second generation" (approximately 10 cm DBH).

Quality: the presence or absence of health defects (OMNR 2004).

Release operations: silvicultural treatment that removes competing vegetation, releasing resources for young target species. Responses to release vary by species for example, sugar maple is considered plastic, meaning that it responds well to an increase in available resources with and increase in growth (OMNR 2004).

Risk: the likelihood of death within a specified time frame; the level of risk should be defined by the landowner (OMNR 2004).

Selection silviculture system: the harvesting of scattered, single, mature trees to release growing space that facilitates regeneration. Typically applied to the management of uneven-aged, mixedwood forests with shade-tolerant target species (Dang No Date; OMNR 2004).

Shade tolerance: the capacity of a plant to develop and grow in the shade of and in competition with other trees (OMNR 2004).

Silviculture: the practice of controlling the establishment, composition, growth, and quality of forest stands to achieve the objectives of management (Dang No Date).

Species composition: the percentage, based on basal area (m^2), of each tree species comprising the stand (OMNR 2004).

Uneven-aged stands: consisting of at least three or more age classes and are frequently composed of a diversity of tree species (OMNR 2004).

Vigour: the relative capacity of a tree to increase in size for example, DBH (OMNR 2004).

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APPENDIX

Plot Number	Tree Number	Species	DBH (cm)	Basal Area (m2)	Position in the Canopy	Tap tree?	Height	Notes
V1-10	1	bw	20.6	0.033	co-dominant			
	2	bw	31.4	0.077	dominant		18.4	
	3	bw	32.7	0.084	co-dominant			
	4	bw	35.5	0.099	co-dominant			
	5	bf	27.0	0.057	dominant			
	6	mh	15.8	0.020	co-dominant	2nd generation	10.1	
	7	bw	33.8	0.090	dominant			
	8	bw	26.7	0.056	dominant			
	9	bf	17.5	0.024	co-dominant			
	10	bf	22.9	0.041	co-dominant			
	11	bf	20.7	0.034	co-dominant			
	12	bf	16.5	0.021	co-dominant			
	13	bw	30.2	0.072	dominant			
	14	bf	22.5	0.040	co-dominant			
	15	bf	16.4	0.021	co-dominant			
	16	bf	25.5	0.051	co-dominant			
	17	bf	38.0	0.113	dominant		25.7	
	18	bf	11.0	0.010	intermediate			
	19	mh	16.4	0.021	intermediate		13.5	
	20	bf	21.3	0.036	co-dominant			
	21	pb	33.5	0.088	dominant			
V1-11	22	mh	16.5	0.021	dominant	3rd generation	11.1	
	23	bf	32.5	0.083	dominant		19.4	
	24	bw	40.5	0.129	dominant			
	25	mh	8.0	0.005	intermediate			
	26	mh	13.0	0.013	co-dominant	3rd generation		
	27	mh	11.7	0.011	intermediate	3rd generation		
	28	bf	23.5	0.043	dominant			
	29	ab	16.5	0.021	co-dominant			
	30	ab	22.5	0.040	dominant			
	31	ab	17.0	0.023	co-dominant			dead
	32	ab	10.0	0.008	suppressed			
	33	bf	18.3	0.026	co-dominant			
	34	bf	15.5	0.019	suppressed			
	35	mh	36.5	0.105	dominant	current		
	36	mh	32.0	0.080	dominant	current	20.6	
	37	mh	12.5	0.012	intermediate			
	38	mh	25.5	0.051	co-dominant	2nd generation	22.1	
	39	bf	16.5	0.021	intermediate			

	40	bf	14.5	0.017	intermediate			dead
	41	bf	9.0	0.006	suppressed			
	42	bf	16.0	0.020	co-dominant			
	43	bw	46.7	0.171	dominant		24.1	
	44	bw	10.0	0.008	intermediate			
	45	bw	20.5	0.033	suppressed			
	46	mh	12.3	0.012	intermediate	3rd generation		
	47	mh	22.0	0.038				dead
	48	bf	27.0	0.057				dead
	49	bf	26.3	0.054	co-dominant			
	50	mh	10.3	0.008	intermediate			
	51	mh	8.0	0.005	intermediate	3rd generation		
	52	mh	8.2	0.005	intermediate			
	53	mh	18.0	0.025	dominant		15.8	
	54	mh	8.3	0.005	intermediate			
	55	mh	19.5	0.030	dominant	2nd generation		
	56	mh	8.0	0.005	intermediate			
	57	mh	10.3	0.008	intermediate			
	58	mh	16.7	0.022	dominant			
	59	mh	16.0	0.020	dominant	2nd generation		
	60	mh	14.0	0.015	intermediate			
	61	mh	16.0	0.020	dominant			
V1-12	62	bf	23.9	0.045	dominant		16.4	
	63	mh	11.3	0.010	intermediate	3rd generation		
	64	mh	9.9	0.008	intermediate			
	65	bf	19.9	0.031	co-dominant			
	66	bf	21.0	0.035	co-dominant		15.7	
	67	ab	34.7	0.095	dominant			
	68	ab	35.3	0.098	dominant			
	69	mh	9.7	0.007	suppressed			
	70	pt	42.4	0.141	dominant			
	71	bf	19.9	0.031	co-dominant			
	72	bf	19.4	0.030	co-dominant			
	73	mh	15.9	0.020	co-dominant	2nd generation		
	74	bf	15.2	0.018	intermediate			
	75	mh	11.0	0.010	intermediate	2nd generation		
	76	mh	30.5	0.073	dominant	1st generation	15.5	
	77	bf	9.2	0.007	intermediate			
	78	bf	8.1	0.005	intermediate			
	79	mh	17.2	0.023	intermediate	2nd generation	15.5	
	80	bf	17.5	0.024	co-dominant			

	81	bf	21.6	0.037	dominant			
	82	mh	21.8	0.037	co-dominant	2nd generation		
	83	pb	18.5	0.027	co-dominant			
	84	mh	17.7	0.025	dominant	2nd generation		
	85	mh	9.8	0.008	intermediate	3rd generation		
	86	mh	13.4	0.014	intermediate	2nd generation	13.5	
	87	pb	12.5	0.012	co-dominant			
	88	mh	13.7	0.015	co-dominant	2nd generation		
	89	mh	10.3	0.008	intermediate	2nd generation		
	90	mh	13.7	0.015	intermediate	2nd generation		
	91	ab	19.2	0.029	dominant			
	92	ab	19.0	0.028	co-dominant			
	93	ab	30.1	0.071	dominant			
	94	ab	30.9	0.075	dominant			
	95	ab	16.9	0.022	intermediate			
	96	ab	21.2	0.035	intermediate			
	97	ab	9.4	0.007	suppressed			
	98	mh	11.6	0.011	intermediate	3rd generation		
	99	ab	25.3	0.050	dominant			
	100	mh	17.8	0.025	co-dominant	2nd generation	13.9	
	101	ab	29.1	0.067	dominant			
	102	ab	25.3	0.050	dominant	2nd generation		
	103	mh	13.0	0.013	intermediate		12.2	
V1-14	104	ab	19.6	0.030	co-dominant			
	105	mh	9.9	0.008	intermediate	3rd generation		
	106	bw	34.9	0.096	dominant		22.7	
	107	ab	44.1	0.153	dominant			
	108	ab	22.0	0.038	co-dominant			
	109	ab	22.7	0.040	co-dominant			
	110	ab	25.0	0.049	co-dominant		18.0	
	111	ab	28.6	0.064	co-dominant			
	112	ab	21.2	0.035	co-dominant			
	113	ab	22.9	0.041	co-dominant			
	114	mh	11.9	0.011	intermediate	3rd generation		
	115	ab	24.5	0.047	dominant			
	116	ab	21.0	0.035	dominant			
	117	ab	25.4	0.051	co-dominant			
	118	bf	17.0	0.023	intermediate	n/a	11.20	
V1-15	119	ab	23.5	0.043	dominant	n/a	18.10	
	120	ab	9.6	0.007	suppressed	n/a		
	121	mh	10.7	0.009	intermediate	3rd generation		

	122	mh	9.2	0.007	intermediate	3rd generation		
	123	mh	8.3	0.005	co-dominant	3rd generation		next to dead birch
	124	mh	34.7	0.095	dominant	current		
	125	mh	11.7	0.011	intermediate	3rd generation	12.90	
	126	mh	39.4	0.122	co-dominant	current	20.60	
	127	mh	32.3	0.082	co-dominant	n/a		
	128	mh	37.5	0.110	dominant	current		
	129	mh	15.1	0.018	intermediate	2nd generation		
	130	mh	27.2	0.058	dominant	n/a		
	131	mh	8.9	0.006	suppressed	2nd generation		
	132	mh	13.0	0.013	intermediate	n/a		
	133	mh	18.7	0.027		n/a	12.00	Outlier from ht measurements
V1-16	134	Bf	8.0	0.005	intermediate			
	135	Pb	24.9	0.049	co-dominant			
	136	Pb	33.9	0.090	co-dominant			
	137	Bf	13.9	0.015	intermediate			
	138	Bf	29.5	0.068	dominant			
	139	Mh	21.5	0.036	co-dominant	2nd generation	16.0	
	140	Bw	14.7	0.017	co-dominant			
	141	Bf	12.8	0.013	intermediate			
	142	Bf	15.2	0.018	intermediate			
	143	Bw	23.6	0.044	co-dominant		17.9	
	144	Bf	17.2	0.023	intermediate			
	145	Bw	28.5	0.064	dominant			
	146	Bf	9.2	0.007	suppressed			
	147	Bf	16.4	0.021	intermediate			
	148	Mh	8.2	0.005	intermediate	3rd generation	8.4	
	149	Bf	18.8	0.028	co-dominant			
	150	Bf	12.5	0.012	intermediate			
	151	Bf	15.0	0.018	co-dominant			
	152	Bf	14.8	0.017	intermediate			
	153	Bf	15.4	0.019	co-dominant		12.8	
	154	Bf	14.5	0.017	co-dominant			
	155	Pb	27.0	0.057	dominant			
	156	Bf	12.2	0.012	co-dominant			
	157	Bf	12.3	0.012	intermediate			
	158	Mh	17.5	0.024	co-dominant	2nd generation	13.5	
	159	Bf	8.1	0.005	suppressed			

	160	Bf	15.0	0.018	intermediate			
	161	Bf	10.0	0.008	suppressed			
	162	Bf	18.1	0.026	intermediate			
	163	Bf	23.3	0.043	co-dominant			
	164	Bf	18.4	0.027	co-dominant			
	165	Bf	8.5	0.006	intermediate			
	166	Bf	12.5	0.012	co-dominant			
	167	Ab	34.3	0.092			20.6	Outlier from ht measurements