THE AGE AND STRUCTURAL CHARACTERISTICS OF TOLERANT HARDWOOD OLD GROWTH FORESTS IN EASTERN MAINLAND NOVA SCOTIA

by

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ABSTRACT

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Old growth forests in Nova Scotia found in the Acadian forest ecosystem are becoming a rare in the landscape, one that provides unique ecological services and biodiversity. Understanding the many components such as disturbance regimes, successional stages and species composition found in old growth forests are essential for better forest management strategies for the few old growth forests we have left. Under the definition and restrictions of the Nova Scotia 2012 old forest policy, red maple does not classify as a climax species. In order to better old growth forest management, this study explored red maple's structural parameters in tolerant hardwoods to compare similarities to other tolerant hardwood climax species, sugar maple and yellow birch. The study concluded that in at least one forest stand; red maple, acts like a climax species and with the absence of sugar maple, the red maple trees are able to recruit into the overstory canopy. It is concluded that more replicates of the study must be completed in order to confidently include red maple as a climax species.

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CHAPTER 1: Literature Review

1.1 Research problem, purpose, objectives

Very few primal old growth forests (OGF) are left in Nova Scotia due to European settlers clearing land for development and the timber trade beginning around 400 years ago (Wallis, 2020). An understanding of the old growth forests we have left in the province is essential for biodiversity conservation. Research done on old growth forests will help understand and maintain diversity that contributes to processes that support biosphere function (Given, 1993). Tolerant hardwoods are one of the types of old growth found in Nova Scotia but have limited studies on them. The Nova Scotia old forest policy was implemented in 2012 as a management tool to help further research, understand and conserve the remaining old growth the province has. William Lahey (2018) reviewed the old forest policy and suggested that further research is needed to determine whether red maple (*Acer rubrum)* trees should be considered a climax species as it shares similar characteristics of other climax species in eastern Nova Scotia forests.

The purpose of this study is to better understand and quantify specific age and structural characteristics of tolerant hardwood forests in eastern mainland Nova Scotia.

The following research objectives will be addressed:

- Quantitatively describe and analyze tree ages (live and snags) and structural parameters such as tree density, basal area, downed woody debris, and horizontal and vertical vegetation structure for selected old forest hardwood stands in eastern mainland Nova Scotia.

- Compare the age and structural parameters of sampled sites to other tolerant hardwood sites in eastern North America.
- Compare the structural parameters of the selected red maple/yellow birch stands to the selected sugar maple/yellow birch stands.

1.2 Old Growth Definition

Over the years, the term old growth forests have been used interchangeably with terms such as climax forests, forest primeval, virgin forests, pristine forests or original forests (Hambly, 1992). A variety of definitions from simple to more complex have also evolved over the years.

Some definitions of old growth are based on the minimum age of the forest (Uhlig et al., 2001), or old and undisturbed (Hambly, 1992), whereas others are based on the precise quantification of structural conditions (Kneeshaw and Burton, 1998). These conditions include the number of trees, logs, or snags (standing deadwood) greater than some arbitrarily defined size (Wirth et al., 2009).

These interchangeable terms listed above all have the common variety of characteristics that are associated with old growth forests such as containing a certain species dominance, structure, and disturbance dynamic (Kneeshaw and Gauthier, 2003). The tree canopy structure is an indicator of whether a forest stand is considered old growth as it must be multilayered, contain gaps and have understory growth (Hambly, 1992).

Hambly (1992) refers to old growth as the later successional stage of a forest ecosystem that is dominated by old trees and the absence of disturbance for a relatively long time. Because of the successional characteristic, it is important to incorporate the dynamic nature of old growth forests in its definition as too often the old growth stage has been identified as the end point of stand development. This definition should be avoided as it suggests that the old growth phase is a static one (Kneeshaw and Gauthier, 2003).

In addition to these generally conceptual definitions, there are operational definitions of old growth forest. The Nova Scotia old forest policy defines old growth as a forest stand where 30% or more of the basal area is in trees 125 years or older, total crown closure is a minimum of 30% and at least half of the basal area is composed of climax species (NSDNR, 2012). Climax species listed are hemlock (*Conium maculatum)*, red spruce *(Picea rubens)*, white pine *(Pinus strobus)*, sugar maple *(Acer saccharum)*, yellow birch *(Betula alleghaniensis)*, and American beech *(Fagus grandifolla)* (NSDNR, 2012).

1.3 Forest Ecosystem Services

Ecosystems are able to provide the basic services needed in order to make life possible, processes that work together to make ecosystems clean, sustainable, functional and resilient to changes (The National Wildlife Federation, 2018). Biodiversity boosts ecosystem productivity, making conservation of old growth forests essential (Shah, 2014). Old growth forests have been identified as a potentially important stage of development for maintaining biodiversity in the landscape (O'Hara, 2014). This is the result of the ecosystem services old growth forests provide from the structural diversity of their forest floor, which provides optimal habitat for a variety in plants and animals (Rusterholtz, 1989). The pit and mound topography characteristically found in old growth forests is a key component in maintaining herb layer diversity and promoting tree regeneration (Rusterholtz, 1989). The decomposition of fallen logs, makes perfect conditions for species only found in old growth forests, as well as supplying nutrients for tree growth. Salamanders, wood ducks, screech owls and flying squirrels thrive in old growth forests because of their undisturbed nature, and downed logs provide the perfect habitat for them, as well as many other invertebrates and vertebrates species (Ho, 2015).

Old growth forests function differently than younger forests because of their nutrient cycle and the diversity of habitats and species that colonize them (Hambly, 1992). Old growth forest's net primary production is lower and relatively stable, which leads to a steady state condition regardless of bioaccumulation. Nutrient cycles are conservative and complex leading to the capture and storage of nutrients, which are slowly released into the ecosystem (Hambly, 1992). This process makes old growth forests excellent carbon stores as they contain much larger stores of carbon than their younger counterparts (Hambly, 1992). Logs, (downed woody debris) play an important part in nutrient cycling when they decompose, capturing nutrients such as nitrogen, which are then slowly released in a form that is readily available for plant growth (Rusterholtz, 1989).

The specific topography and structures that are commonly found in old growth forests provide a unique diversity of habitat and species. Mantyka et al., (2011) states that removing dead and dying material from a forest impoverishes its flora and fauna by at least 20%

1.4 Main Disturbance Regimes

Successional stages are largely due to the frequency and abundance of disturbance types on specific tree species and their tolerances. Disturbances are described as the primary determinant of age-class formation (O'Hara, 2014); they are a discrete event that disrupts ecosystems, communities, or population structures and changes the availability of resources for the physical environment (Helms, 1998). Oliver and Larson (1996) describe disturbance as an event or series of events that changes the availability of growing space or an intangible measure of resource availability, whereas Runkle (1991) simply defines disturbance as a force that kills at least one canopy tree. Although disturbances may seem like a negative event, they are critical in stand development; they recycle nutrients, renew forests and control species composition and stand structure (O'Hara, 2014).

Disturbance regimes are used to characterize disturbances and their effects on forest ecosystems, which can be either natural or human, occurring at different frequencies and severities (O'Hara, 2014). Components of the disturbance regime generally include the type of disturbance and its duration, the severity, frequency, size, timing, and spatial pattern (White and Pickett, 1985). Different types of disturbances favour different tree species depending on their resistance to fire, wind, etc. (O'Hara, 2014).

Windthrow is a common forest disturbance resulting in trees being uprooted or broken by wind. It often results from large-scale frontal systems such as hurricanes (O'Hara, 2014). Hale et al. (2012) state that windthrow increases growing space availability exposing understory trees and stimulating the regeneration of new trees. Regeneration leads to the formation of new age classes forming multi-aged stands; more severe winds lead to more forest gaps that can be colonized by the understory (O'Hara, 2014).

Differing fire severities and frequencies also affect stand structure and species composition. Low fire intensities and frequencies may stimulate the development of a new age class of trees. This would result in the regeneration of all species after a fire. Fires at high frequencies may only be successful in establishing new age classes only occasionally; high frequency fires form multi-aged stands because fire resistant species dominate (O'Hara, 2014).

Insects are another disturbance regime that can cause damage and initiate new age classes of trees, especially in single species stands where insects such as the bark beetle can do damage (Fleming, 2000). Many other forms of insect disturbance are minor usually focused on a single or small group of species, affecting tree vigor or seed production. This can result in multi-aged stands because of the rarity of smaller trees being attacked (Oliver, 1980).

Pathogens such as laminated root rot (*Phellinus weirii)* and shoestring root disease (*Armillaria spp.*) affect only certain species and create patches of tree mortality that may contribute to the formation of canopy gaps, creating multi-aged stands (O'Hara, 2014). Nonnative pathogens such as beech flea beetle (*Orchestes fagi),* beech canker (*Neonectria ditissima)*, and balsam wooly adelgid *(Adelges piceae)* can also create multi-aged stands as they are considered to be an extreme disturbance event; they have the potential to eliminate susceptible species (NSDNR, 2017) (Oliver, 1980).

Ice storms are prevalent in Acadian forest regions and they can cause breakage of tree branches or even whole trees (Irland, 2000a). Species vary in their ability to shed ice, sustain bending, or recover from ice loading events (O'Hara, 2014). This disturbance regime can also create multi-age stands as small trees can often recover from bending and are protected from the bulk of the damage by overstory trees (Bragg, 2003).

1.5 Forest Succession

The successional stages in forest development are 1) herb and shrub stage. 2) young forest. 3) mature forest. 4) subclimax old-growth forest. 5) climax old growth forest (Kneeshaw and Gauthier, 2003). These different successional stages are characterized by distinct groups of tree species: pioneer species, gap-phased species and climax species. Kneeshaw and Gauthier (2003) describe succession as the progressive change in species composition and forest structure. Hayward (1991) describes succession as the process a stand goes through and includes of young, mature and old growth phases. Hambly (1992) states that the rate of successional development in a forest varies from instant (catastrophic events: fires, floods, tornados) to very slow (gap-phase replacement) and that succession is controlled by both endogenous factors (species' tolerance, competitive abilities) and exogenous factors (fires, insects, climate). Dynamics that separate multi aged from even aged stands include the sequence of disturbance, and understory dynamics that form suitable conditions for regeneration (O'Hara, 2014).

Oliver and Larson (1996) say that after a fire has occurred in forests, the successional stages that follow are stem establishment, stem exclusion, and understory re-initiation. Kneeshaw and Gauthier (1993) have concluded that under natural conditions, a new forest is usually initiated as the result of catastrophic disturbances, and then progresses through a series of successional stages, until at some point the forest is destroyed by a natural catastrophe.

The old growth stage is defined in a successional sense when the original cohort begins to die and understory stems are recruited to the canopy (Hunter and Parker, 1993). This highlights the importance of gap dynamics when defining old growth and takes into account that the old growth forest stage isn't static and will continue to change (Hunter and Parker, 1993). Runkle (1991) agrees with this as he states that the point at which understory trees begin to replace overstory trees, can only occur through a process of gap dynamics.

These old growth forest successional characteristics listed above are accepted for all forest community groups in general, but when talking about a specific forest community group such as the tolerant hardwood group, characteristics differ slightly. Disturbances at stand level are rare, and the tree species present in the tolerant hardwood forest group such as sugar maple, beech, yellow birch, and red maple are able to maintain themselves though gap replacement because of their tolerance to shade (Neily et al., 2005). The gap dynamics in tolerant hardwood forests allows for shade tolerant trees to recruit into the overstory and gives opportunity for shade mid-tolerant and shade intolerant trees to recruit into the overstory when larger openings become available from older trees falling (Poznanovic et al., 2013).

1.6 Ecological Characteristics

Helms (1998) defines stand structure as the horizontal and vertical distribution of components in a stand including the heights, diameters, crown layers, shrubs, herbaceous plants, standing (snags) and downed (coarse woody debris) wood. The structure dynamics apparent in old growth forests involve individual trees of pioneer species dying and producing canopy gaps. These gaps provide appropriate conditions for gap phased tree seedlings and understory species that require high light availability (Rusterholtz, 1989).

The best indicators of an old growth forest are the presence of old, usually larger trees, snags and coarse woody debris (Irland, 2000b). However old growth forests are more complex. They are seldom composed of only large, old trees. The reality is, many old growth forests contain many small and medium sized individuals of climax and gap-phased tree species such as sugar maple and yellow birch, which may enter the canopy as tree fall gaps appear (Irland, 2000b).

When standing trees die, they are referred to as a snag, and the presence of large snags is an indicator of an old growth forest. It must be noted though that not all old growth forests contain an abundance of snags. For example, some tree species such as red pine generally experience little tree mortality until they are over 150 years old, leaving the forest with few snags present (Duvall and Grigal, 1999).

The presence of many downed logs, also known as coarse woody debris (CWD), is a common indicator that a forest is old growth. However, they are not always abundant in the earlier stages of old growth forests. CWD is more common in younger forests because it is the result of a catastrophic disturbance. This initiates the growth of new forests and the CWD is usually well decayed by the time the forest reaches maturity (Rusterholtz, 1989).

The topography of the forest floor is an indicator of an old growth forest. The floor of old growth forests is topographically complex because of the diversity caused by fallen tree boles, their uprooted butts, and an abundance of pits and mounds produced when trees are uprooted and left to decay (Rusterholtz, 1989).

1.7 Climax Species/ Pioneer Species/ Gap Phase Species

Climax species, pioneer species and gap phase species all play an important role in successional stages and species composition of old growth forests because of their variety in tolerances and resistances. Kneeshaw and Gaunthier (2003) describes longevity for a given species varies from one region to another and depends on genetics, soil moisture, soil fertility, temperature and other biotic and abiotic factors.

The relative shade tolerance of trees is often a limiting factor for multi-aged stands because it determines the structural arrangement of trees in mixed species stands. It is the ability of a tree to survive or endure the shade of another (O'Hara, 2014). Shade tolerance is the result of relative light compensation points (light level where respiration and photosynthesis are equal) for different species. Below this level, the plant is unable to produce enough carbon to sustain itself, but above this level, the plant produces a surplus (Malcolm et al., 2001). Climax species such as sugar maple and yellow birch reproduce and persist under low light conditions beneath the forest canopy and therefore dominate old growth forests. They enter the tree canopy when small canopy gaps occur. In comparison, gap phase species such as balsam fir and eastern hemlock, are more shade tolerant than pioneer species but only enter the canopy when a gap appears, usually as the result of the death of an individual canopy tree. They may dominate subclimax old growth forests and persist in climax old-growth forests. Pioneer species are usually the first to become established following a catastrophic disturbance and dominate the early stages of succession (Rusterholtz, 1989).

Resistance in tree species comes from several mechanisms such as fire-resistant bark, deep root systems and reduced branch retention in the lower bole. Some tree species such as white pine are able to regenerate quickly after a disturbance, such as fire, because of dormant fire resistant seed stored in the surface layers of the bark, or in their crowns.

1.8 Acadian Forests

The Acadian forest region covers three Maritime Provinces (Nova Scotia, New Brunswick and Prince Edward Island), parts of Quebec and New York, New Hampshire, Vermont, and Maine (McNab and Avers, 1994). The Acadian forest is one of eight forest regions, which are regarded as geographic units, characterized by some community of species distribution and association (Rowe, 1972). What makes the Acadian forest type unique is that it is a mixed forest type of deciduous and conifer tree species, with a total of 32 species, making Acadian forests one of the most diverse temperate forests in the world (Simpson, 2008). This is a result of the northern hardwood region and the boreal forest type blending together to make a combination of softwood and hardwood trees, with a concentration on tolerant hardwoods (Simpson, 2008). The defining features of Acadian forest types is the presence of deciduous late-successional species such as sugar maple, yellow birch and American beech and late-successional conifer species; eastern hemlock, white pine, and red spruce (Mosseler et al., 2003). The Acadian forest region is situated where the warm Gulf Stream from the coast collides with the cold Labrador Current, creating a habitat that is suitable for this mixed forest type (Loo and Ives, 2003).

The natural interval for windthrow is 1000 years and the natural internal for stand replacing fires is 1200 years (Lorimer and White, 2003). This means the average rotation of natural disturbances far exceeds the average amount of time the canopy lives, resulting in the dominant disturbance regime being small-scale gap formation (Loo and Ives, 2003; Runkle, 1991). It is estimated that upwards of 72% of the forested landscape would be at least 300 years old without significant anthropocentric interference during a period of major disturbance absence (Lorimer and White, 2003). Instead, old growth in the Acadian forest types only exists in small, isolated pockets that are associated with areas difficult to harvest with an estimate of only 1-5% of the forested area being old growth (Mosseler et al., 2003).

1.9 Forest Community Types

The Forest Ecosystem Classification (FEC) project was developed by the Nova Scotia Department of Natural Resources to create a guide to identify and describe the vegetation, soil, and ecosites at stand-level in the province. Classifying ecosystems at the stand level allows for better landscape analysis, planning, and management (Neily et al., 2010). There are 14 different forest ecosystem communities including the tolerant hardwood forest group (TH) throughout Nova Scotia's nine climate-based ecoregions that vary in species composition, soil moisture, nutrient regimes and slopes (Neily et al., 2010). The 14 forest community types are further classified into two ecological land classifications groups, Acadian Boreal and Maritime Boreal. The Acadian Boreal group contains zonal ecosites, which supports climatic forests containing mainly shade tolerant and shade intermediate species as well as several successional tree species (Neily et al., 2010).

Over past centuries, explorers, surveyors, and settlers have negatively affected the successional stage status and age distribution of Acadian forests. The result of human impacts in these regions increased the frequency of young, even-aged, trees in an early successional stage (Loo and Ives, 2003). These tree species include balsam fir (*Abies balsamea),* white spruce *(Picea glauca),* red maple (*Acer rubrum*), and white birch (*Betula papyrifera*). This increase in these earlier successional trees have caused a decline in late successional trees found in Acadian forest types such as sugar maple *(Acer saccharum),* red spruce *(Picea rubens),* eastern hemlock *(Tsuga canadensis),* yellow birch *(Betula alleghaniensis),* and beech *(Fagus)* (Mosseler et al., 2003).

1.10 Tolerant Hardwood Forests of Nova Scotia

Tolerant hardwoods account for 28% of hardwood volume (39 million m^2) in Nova Scotia (McGrath, 2017). Tolerant hardwood forests in Nova Scotia have been broken up into eight forest groups based on species composition, vegetation, environmental setting, successional dynamics and ecological features (Neily et al., 2010). The tolerant hardwood forest groups as a whole are found on zonal sites within the Acadian ecocite group, consisting of mid to late successional vegetation types (Neily et al., 2010). The vegetation types are closed canopy forests dominated by beech, ironwood, red maple, red oak, sugar maple, white ash and yellow birch, with balsam fir a common significant understory species (Neily et al., 2010). Regenerating trees is the main component of the shrub layer, but it also consists of striped maple, mountain maple and hobblebush (Neily et al., 2010). An array of fern species are found in the herb layer, but hay-scented fern, New York fern, and northern beech fern are the most typical species found (Neily et al., 2010). Most sites that tolerant hardwood forests are found in are non-rocky; soils are mainly derived from glacial till and moisture level ranges from fresh to moist (Neily et al., 2010). As mentioned before, because stand-level disturbances are rare, these tolerant hardwood species can maintain themselves through gap replacement, creating uneven-aged climax forests.

The Nova Scotia Uplands compared to the lowlands, experience more severe winters, more precipitation and shorter growing seasons creating conditions for tolerant hardwoods to dominate (Neily et al., 2017). Sites that experience exposure to more moisture contain a mixed wood forest of yellow birch, hemlock, and red spruce. The Nova Scotia Uplands contain a number of vegetation types including sugar maple – yellow birch variant (TH1b), and red maple – yellow birch (TH8) tolerant hardwood forest groups that will be the focus of this study.

1.11 N.S Old Forest Policy

The purpose behind the Nova Scotia old growth forest policy is to conserve the remaining old growth forests on public land, including national and provincial parks, wilderness areas, and nature reserves, through guidelines and procedures (Nova Scotia Department of Natural Resources (NSDNR), 2012)). The policy will ensure more broad, sustainable forest management initiatives that are able to address maturity and community across ecological landscapes (NSDNR, 2012).

The policy objectives also include establishing and sustaining an ecologically representative network of old forest, providing direction and procedures for integrated resource management, involving old forest values, as well as establishing a spatial database for storing and tracking old forest identified under the policy (NSDNR, 2012).

The policy defines old growth as a forest stand where 30% or more of the basal area is in trees 125 years or older. Of these trees, half the basal area needs to be composed of climax species, with a minimum total crown closure of 30% (NSDNR, 2012).

Under the definitions of forest maturity in the policy, climax species are defined as the species that typically dominate stand composition during the late stages of natural selection that live the longest and are the most shade tolerant (NSDNR, 2012). According to the definition in the policy, climax species on Zonal Acadian Forest ecotypes include hemlock, red spruce, white pine, sugar maple, yellow birch, and American beech (NSDNR, 2012).

An Old Forest Scoresheet is used to quantitatively evaluate old forest conditions (NSDNR, 2012). Part one of the scoresheet will be able to identify if the stage of forest development is old growth or younger. Part two scores the forest stand on structural attributes that are associated with old forests such as age, primal forest value, tree diameter, quantity of dead woody material, canopy structure, and understory development. Part three of the scoresheet ranks the collective patch size of adjacent old forest stands, which are within 100m of each other (NSDNR, 2012).

The OGF policy also involves an Integrated Resource Management (IRM) review that assesses the ecological representation of old growth forest by ecosection within the ecodistrict using the Ecological Land Classification. The report based on the IRM review will also include a summary of the forest vegetation types from the Forest Ecosystem Classification. The IRM review will use data from part one to three of the old forest scoresheets to determine the stage of development, the stand quality and the patch size class (NSDNR, 2012). Within the OGF policy, the province commits to preserving eight percent of the land within each of Nova Scotia's 38 ecodistricts (Berry et al., 2018).

However, because the policy is designed to be quantitative and measurable within a conservation program, it lacks a specific regulatory framework to address OGF. Berry et al., (2018) addresses the concern that the protection of OGF in Nova Scotia is not mandatory and the regulatory framework does not ensure conservation. This is the result of having the OLF policy primarily based on regulations of the Crown Lands Act (1989), Forests Act (1989), and the Forest Enhancement Act (1989) (Berry et al., 2018). Although Nova Scotia has still not reached the goal of conserving eight percent in all of Nova Scotia's ecodistricts, it has met its goal in 32 of them (Berry et al., 2018).

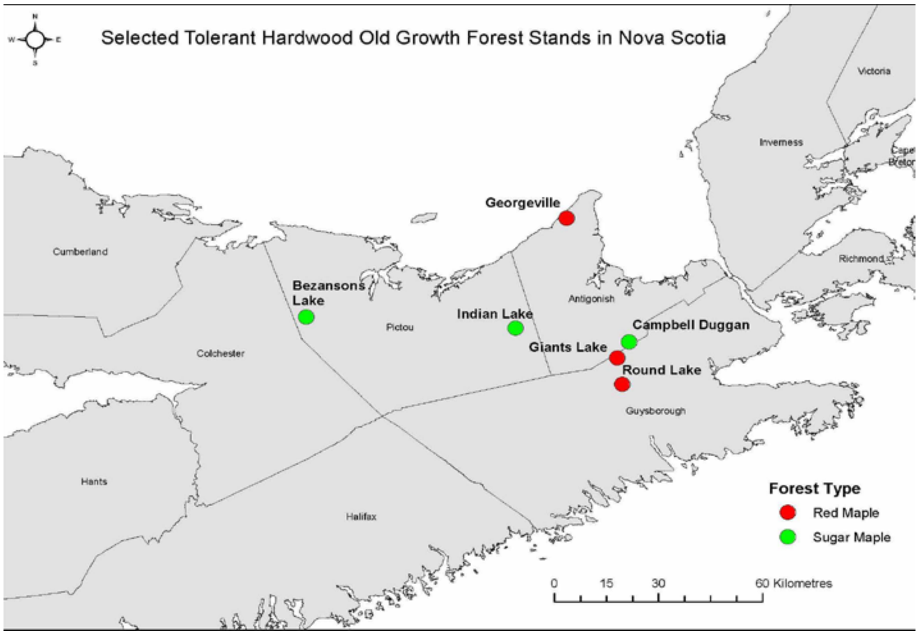
In August of 2018, William Lahey published an independent review of Nova Scotia forestry practices and made a total of 45 recommendations, including reviews and recommendations on the Old Growth Policy (NSDNR, 2012). In Lahey's report, he establishes that defining what old growth is not clear, but what is clear is that there is currently little of old growth left in Nova Scotia. Lahey suggests that the Department of Natural Resources (now the Dept. of Lands and Forestry) targets for the protection and restoration of old growth is not ambitious enough. One of his recommendations to improve the abundance and conservation of old growth in Nova Scotia is to potentially include other tree species in the climax group such as red oak and red maple (Lahey, 2018).

CHAPTER 2: Methods

2.1 Study Area

A total of six stands were sampled during the summer of 2019 in the Nova Scotia Uplands Ecoregion (Neily et al., 2017). The conditions in this area such as severe winters, abundance of precipitation, and short growing seasons, give rise to the Acadian hardwood forest that is dominated by sugar maple and yellow birch (Neily et al., 2017). To identify true old growth forests in the region, I attained a list of forest stands that had been previously scored following the NSDNR forest scoring protocol (Nova Scotia Department of Natural Resources, 2012). From the list, I opportunistically selected six tolerant hardwood forest stands, three stands that were red maple/ yellow birch dominate and three stands that were sugar maple/yellow birch dominate. These sites correlate with research my supervisor is conducting as a landscape ecologist for the Nova Scotia Department of Lands and Forestry.

Figure 1. Locations of sampled sites



2.2 Field sampling

2.2.1 Live trees

Starting at the plot center, a basal area factor 2 (BAF2) metric prism was used to determine the basal area of the plot and therefore determined which trees would be sampled as the research plot. All trees counted within the plot were numbered and were recorded for diameter at breast height by diameter tape, height of canopy using a laser height, and species. An increment borer was used on each tree within the research plot to extract a wood tissue core at breast height for the age of the tree to be determined.

2.2.2 Deadwood

Dead wood greater than 10cm in diameter and leaning ≤ 45˚ from vertical stance were measured in each plot as snags (Chrisensen et al., 2008). Snags were tallied by species where possible and assigned a decay class based on 5-class system (Maser et al., 1988). Diameters of each snag were measured at breast height and the tops. Heights were measured for each snag by either a clinometer or measuring tape as well as heights were recorded when applicable, for diameters at 20, 30, 40, and 50cm.

Dead wood greater than 10cm in diameter and leaning > 45̊ from vertical stance were measured as downed course woody debris (CWD) in each plot along an equilateral triangle transect of 20 x 20 x 20 meters. Transects started and finished at the plot center running at bearings of 90, 270, and 330̊. Along these bearings, the line-intersect method was applied and all pieces of downed CWD greater than 10cm in diameter were tallied by species when applicable measured for diameter at point of intersection and applied by the same 5-class decay rankings as snags (Wagner, 1968).

2.3 Tree cores and estimating site age

Tree cores were stored and then later mounted, sanded and aged in the geography physical lab. Tree cores had to be mounted by being glued onto grooved boards with vertical vessels oriented properly. The tree cores were sanded with coarse grit sandpaper starting at 100 and worked down by increments of 100, until 600 grit sandpaper was used. Under a microscope starting from the bark side of the core, each summerwood (latewood) ring is counted as a year until the pith of the core is reached which determined the age of the tree the core was sampled from.

2.4 Statistical methods

This study explored comparing similarities and differences between the red maple/yellow birch and sugar maple/yellow birch stands statistically through ANOVA. Power tests were ran through G*Power by using the mean and standard deviations of diameter and height to determine the effect size. Unfortunately, as a result of low sample size (i.e. 6), the outcome was a low power (1-β err prob) of 0.0839 for diameter and 0.0563 for height. This inhibited statistical analysis to be done as there was a high risk that it would make conclusions that there is a difference between the two groups when there is in fact no (Type 2 error). Instead, a descriptive analysis was used to find trends between the red maple/yellow birch and the sugar maple/yellow birch dominated stands.

CHAPTER 3: Results/Discussion

3.1 Individual Stands

Each of the six sampled stands have been descriptively analyzed to show the relationship between age and diameter by species as well as show the stand age distribution between red maple, sugar maple, and yellow birch. None of the sites visited had any visible evidence of recent forest management activity, however more investigation using historical air photos may be required to verify this.

3.1.1 Red Maple Stands

3.1.1.1 Georgeville

The Georgeville (GV) stand is dominated by yellow birch (30%) and red maple (50%) species with the presence of balsam fir (10%), white ash/white birch (10%) tree species. The stand's age averaged 106±44 years (range 29-225 years), with an old growth reference age of 126 years (NSDNR, 2012). The stand averaged 23.8±7.54 cm dbh (range 10-39.9 cm). Yellow birch's age averaged older than the stand at 135±45 years (range 47-225 years) and averaged 27.1±8.58 cm dbh (range 10-39.9 cm). The results indicate that the stand is composed of yellow birch of uneven age distribution and size, producing a younger (<125 years) and older (>125 years) cohort. The younger cohort consists of 40% yellow birch, and the older cohort consists of 60% of yellow birch. This indicates that the younger cohort of yellow birch have optimal recruitment opportunity to continue to dominate the stand while the older cohort maintaining dominance in the over story canopy (Hunter and Parker, 1993). Red maple's age averaged younger than the stand at 102±38 years (range 29-188 years) and averaged 23.78±6.25 cm dbh (range 12.4-35.5

cm). The results indicate that the stand is composed of red maple of uneven age distribution and size. These results support that red maple is behaving like a late successional species in this stand. Within the stand, red maple and yellow birch both have their largest diameter trees present in the 30 cm dbh class. The red maple in the stand also contains a large cluster of trees making up a younger cohort (77%) and a smaller cluster of trees making up an older cohort (23%). These dynamics still gives opportunity for red maple to co-dominate the over story canopy with yellow birch in the stand as well as recruitment opportunity into the overstory canopy. The older cohort cluster consists of 44% red maple trees and 56% yellow birch trees, which indicate that red maple and yellow birch trees can both co-exist as an older, dominant species.

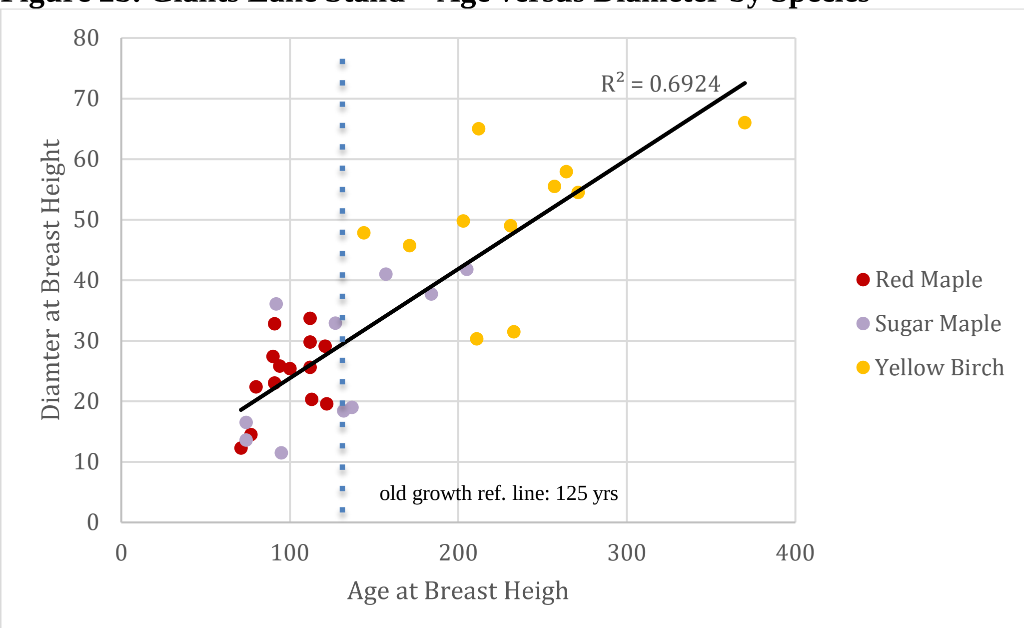
Figure 2a. Georgeville Stand - Age versus Diameter by Species

3.1.1.2 Giants Lake

The Giants Lake (GL) stand is composed of red maple (40%), sugar maple (20%), and yellow birch (40%) tree species. The stand's age averaged at 147±71 years (range 71-370 years), an old growth reference age of 205 years (NSDNR, 2012), and averaged 32.38±15.3 cm dbh (range 10.1-66 cm). Red maple averaged younger than the stand at 99±17 years (range 71-122 years) and averaged 24.4±6.28 cm dbh (range 12.3-33.7 cm). The red maple trees are clustered 100% in the younger cohort, and 0% present in the older cohort. The red maple in the stand lacks opportunity to establish itself in the overstory canopy due to the absence of gap disturbance in the canopy that the yellow birch and sugar maple species present are occupying. Red maple does have the opportunity to be recruited into the overstory canopy as the species' age distribution is clustered just before the older cohort starts, but further studies will be needed to know if red maple trees are capable of thriving in the older cohort as none exist now. This stand does not support the statement that red maple is behaving as a late successional species. Yellow birch's age averaged older than the stand at 219±65 years (range 132-370 years) and averaged 45.9±15.2 cm dbh (range 18.4-66 cm). In the younger cohort, no yellow birch is present, only existing spread out in the older cohort. Yellow birch dominates the overstory canopy but lacks recruitment aged trees, posing a risk to future dominance of the stand. The lack of yellow birch in the understory may be due to competition, resource availability, or windthrow disturbances that inhibit suitable growing conditions for the species to establish itself (O'Hara, 2014). Sugar maple's age averaged younger than the stand at 123±47 years (range 81-205 years) and averaged 26.0±13.0 cm dbh (range 10.1-41.8 cm). The sugar maple in the stand is located 60% in the younger cohort with a clustered age distribution, while 40% of the sugar maple is spread out in the older cohort.

It is indicated that because sugar maple trees are present in the older cohort, it contributes to the overstory canopy, co-existing with yellow birch, while having recruitment opportunity in the younger cohort. The younger cohort of the stand contains 74% red maple and 26% sugar maple trees, while the older cohort contains 28% sugar maple and 73% yellow birch trees. Red maple trees in the stand are prevented to act like a climax species when sugar maple is present, and that sugar maple's uneven aged distribution shows characteristics of multiple layers and understory growth as defined by old growth forests (Hambly, 1992).

Figure 2b. Giants Lake Stand – Age versus Diameter by Species



3.1.1.3 Round Lake

The Round Lake (RL) stand is dominated by red maple (30%) and yellow birch (60%) trees with the presence of sugar maple/balsam fir (10%) trees. The stand's aged averaged

138±70 years (range 19-328 years), an old growth reference age of 172 years (NSDNR, 2012), and averaged 39.1±17.8 cm dbh (range 10.3-79.8 cm). Red maple's age averaged younger than the stand at 70±32 years (range 19-134 years) and averaged 24.2±13.6 cm dbh (range 10.3-46.4 cm). Red maple is 91% in the younger cohort and 9% in the older cohort. Red maple is clustered within the younger cohort, with an average age far from old growth, and having a weak presence in the older cohort with only one tree present. It is clear that red maple is able to achieve an older age and be present in the overstory canopy but may not be resilient enough to flourish and continue to recruit into the older cohort. This stand supports that red maple is behaving as a late successional species to a lesser degree as it is in the Georgeville stand. There is only one sugar maple tree sampled in the entire stand so it would be hard to come to any conclusions to discuss. The presence of sugar maple, although small, may be what is preventing the red maple in the stand to be able to substantially recruit into the overstory canopy. Yellow birch's average age is older than the average of the stand at 172±60 years (range 74-328 years) and averaged 45.8±15.9 cm dbh (range 21.2-79.8 cm). Yellow birch is 18% in the younger cohort and 82% in the older cohort. Yellow birch clusters in the older cohort, while achieving a presence in both the younger cohort for recruitment opportunity and older cohort for overstory canopy dominance. It is expected that yellow birch is predominately in the older cohort as this species is resilient to disturbances and is a late successional species (Mosseler et al., 2003). The younger cohort is made up of 7% balsam fir, 67% red maple, and 26% yellow birch. Mosseler et al. (2003) states that balsam fir and red maple are considered earlier successional species, which correlates with why balsam fir only exists in the younger cohort but not why there is a higher presence of red maple than in the older cohort. The small percentage of sugar maple present in both the younger and older cohort could be the result of only two sugar maple trees sampled in the stand. The older cohort is made up of 5% red maple, 5% sugar maple and 90% yellow birch. The red maple has reached the older canopy, establishing itself with the other late successional species as it has in other yellow birch stands. As there is such small presence of red maple in the older cohort, we may be able to infer even a small presence of sugar maple may be hindering red maple's resilience and preventing it to thrive in the overstory canopy.

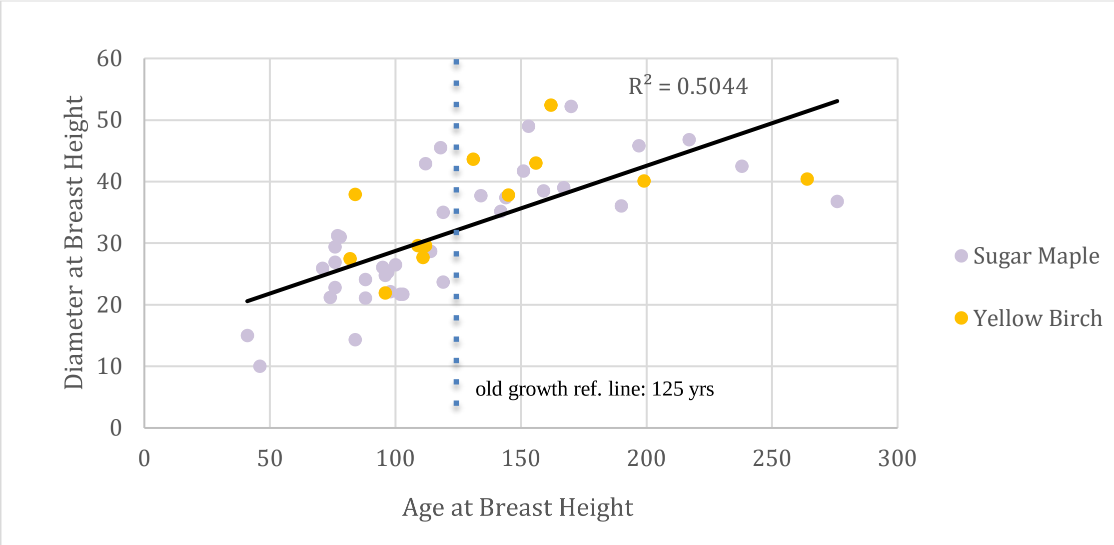
Figure 2c. Round Lake Stand – Age versus Diameter by Species

3.1.2 Sugar Maple Stands

3.1.2.1 Bezansons Lake

The Bezanson Lake (BL) stand consists of two climax species, yellow birch (20%) and sugar maple (80%). The stand's age averaged at 124±53 years (range 46-276 years), an an old growth reference age of 144 years (NSDNR, 2012) and averaged 32.1±10.3 cm dbh (range 10.0-52.4 cm). Yellow birch's age averaged older than the stand at 132±55 years (range 61-262 years) and averaged 34.4±10.1 cm dbh (range 15.7-52.4 cm). The yellow birch trees have a broad age distribution among the younger and older cohort with 54% present in the younger cohort and 46% in the older cohort. Sugar maple's age averaged younger than the stand at 121±53 years (range 41-276 years) and averaged 31.2±10.4 cm dbh (range 10.0-52.2 cm). The sugar maple age distribution in the stand is generally spread out with a cluster of trees of relevant age in the younger cohort. The sugar maple exists 68% in the younger cohort and 32% in the older cohort. The younger cohort is dominated by 79% sugar maple and 21% yellow birch, as well as the older cohort is dominated by 68% sugar maple and 32% yellow birch. The age distribution of both the sugar maple and yellow birch in the stand is characteristic of an old growth forest as it provides multiple layers, understory growth for future recruitment, and an overstory canopy (O'Hara, 2014). The stand consists of more sugar maple trees than yellow birch trees, explaining why there is a stronger presence of sugar maple in both the younger and older cohort of the stand.

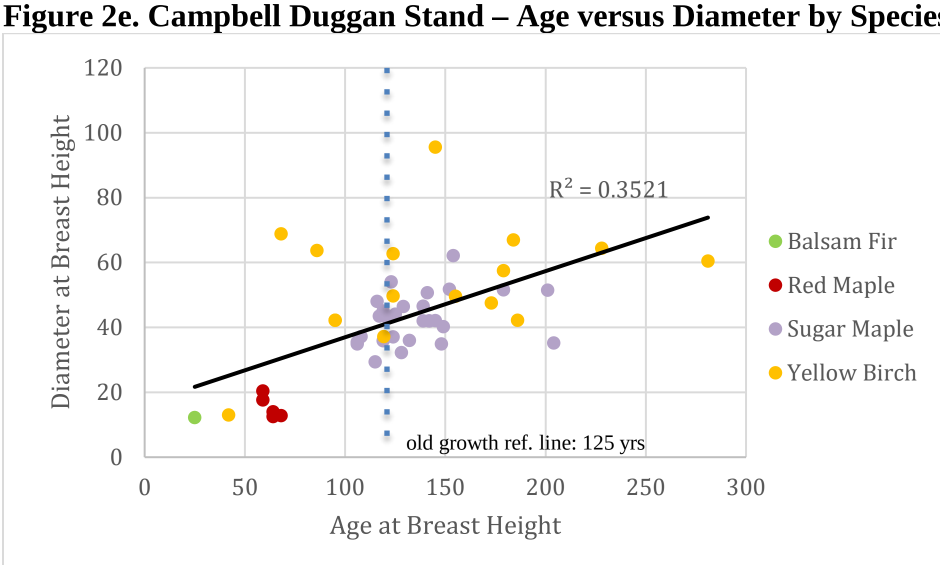
Figure 2d. Bezansons Lake Stand – Age versus Diameter by Species



3.1.2.2 Campbell Duggan

The Campbell Duggan (CB) stand is dominated by sugar maple (40%) and yellow birch (40%) with a presence of red maple (10%) and balsam fir (10%). The stand's age averaged 119±42 years (range 25-281 years), an old growth reference age of 142 years (NSDNR, 2012) with an average of 37.2±13.0 cm dbh (range 11.7-95.5 cm). Red maple's age averaged much younger than the stand at 57±10 years (range 41-64 years), averaged 15.2±6.67 cm dbh (range 11.7-20.4 cm), and only exists in the younger cohort. There is a cluster of small, young red maple trees in the younger cohort without supporting evidence that are able to recruit into the older cohort through gap dynamics as there is no red maple older than 64 years present in the stand. Sugar maple's age averaged close to the stand's average at 133±31 years (range 57-204 years) and averaged 41.1±10.6 cm dbh (range 12.8-62.1 cm). The sugar maple trees are clustered around the 125-year mark that typically divides the younger cohort from the older, while still maintaining 36% presence in the younger cohort and 64% in the older cohort. Yellow birch's age averaged older than the stand's average at 142±57 years (range 68-281 years) and averaged 54.3±15.5 cm dbh (range 34.9-95.5 cm) and is present 53% in the younger cohort and 47% in the older cohort. Yellow birch's age distribution is spread out across the younger and older cohorts with opportunity for the younger trees to recruit into the overstory canopy where yellow birch has established many older trees. The younger cohort is made up of 6% balsam fir, 29% red maple, 36% sugar maple, and 29% yellow birch. The presence of balsam fir and red maple in the beginning of the younger cohort correlates with them being early successional species in the Campbell Duggan stand, not supportive of the statement that red maple is behaving as a late successional species. (Loo and Ives, 2003). However, because there is low recruitment opportunity for yellow birch, the stand may transition into 100% sugar maple or a sugar maple/red maple mix. The older cohort is made up of 68% sugar maple and 32% yellow birch, characteristically dominating the overstory canopy. It is my interpretation that red maple lacks the evidence to be able to co-exist in the older cohort/overstory canopy alongside sugar maple.

Figure 2e. Campbell Duggan Stand – Age versus Diameter by Species



3.1.2.3 Indian River Road

The Indian River Road (IR) stand consists of sugar maple (80%) and yellow birch (20%). The stand's age averaged 108±52 years (range 32-199 years), an old growth reference age of 155 years (NSDNR, 2012) with an average of 33.9±16.2 cm dbh (range 11.5-70.5 cm). Sugar maple's age averaged slightly younger than the stand's average at 93±48 years (range 32-192 years), averaged 28.9±13.8 cm dbh (range 11.5-61.2 cm), and existed 77% in the younger cohort and 23% in the older cohort. There is a large cluster of sugar maple within the younger cohort, while more are spread out in the older cohort achieving old ages. The sugar maple in this stand is comparable, although younger, to the sugar maple in the only sugar maple/yellow birch stand – BL (Figure 2d). The sugar maple's age distribution in both stands is spread out in the younger and older cohorts with opportunity for recruitment as well as dominating the overstory canopy. Yellow birch's age averaged older than the stand average at 158±31 years (range 102-199 years), averaged 50.0±12.5 cm dbh (range 30.1-70.5 cm) and exists 23% in the younger cohort and 77% in the older cohort. It is unclear why there is a lack of yellow birch present in the understory but could pertain to pathogens or insects that focus on a small group of the species, affecting seed production (Oliver, 1980). The yellow birch in the stand doesn't have clustering of age groups and is instead more spread out, which is also comparable to the yellow birch. The younger cohort is made up of 92% sugar maple, and 8% yellow birch, also comparable in the capacity that both younger cohorts are largely made up of sugar maple with a much smaller presence of yellow birch. The older cohort is made up of 50% sugar maple and 50% yellow birch; both climax species thriving in the overstory canopy.

Figure 2f. Indian River Road Stand – Age versus Diameter by Species

3.2 Comparison between red maple and sugar maple stands

3.2.1 Live trees

The red maple stands show a basal area (cross-sectional area of an individual tree at breast height) range of 23-35 m^2/ha and the sugar maple stands show a basal area range of 25-34 m^2/ha (Table 1). Both stands show that there is a similar trend in how fully stocked the stand is based on basal areas. The density range in red maple stands is 457-1600 stems/ha and the density range for the sugar maple stands is 536-585 stems/ha (Table 1). The red maple stand's range far exceeded that of the sugar maple stands, which is the outcome of the GV stand having a much higher density than any other stand. The high density of GV can be attributed to the abundance of smaller diameter trees and the absence of trees in the larger diameter class of 40, 50, 60 cm and correlate with younger age of the stand (Table 2). The quadratic mean dbh range for the red maple stands is 25.33-42.84 cm and the range for the sugar maple stands is 27.49-46.72 cm (Table 1), meaning both stands have a similar trend in average tree sizes overall. However, the range for trees in the 40 cm diameter class for red maple is 0-71 stems/ha and the range for the sugar maple trees in the 40 cm diameter class is 52-118 stems/ha (Table 2). This trend shows that the sugar maple stands have almost double the amount larger diameter trees in this diameter class than the red maple stands. The range in density for the red maple stands in the 50 cm diameter class is 0-19 stems/ha and the range for the sugar maple stands is 10-41 stems/ha (Table 2). The trend shows that again sugar maple stands contain a higher density of the next largest diameter class, approximately double the density of the red maple stands. The range in density for the red maple stands in the 60 cm diameter class is 0-12 stems/ha and for the sugar maple stands, the range is 0-16 stems/ha (Table 2). Both stands have a similar trend in relation to densities in the 60 cm diameter class, as both stands contain no large trees in some areas, while still having similar densities in other areas. The mean height range for the red maple stands is 13.22-15.05 m and the range for sugar maple is 17.49-19.75 m (Table 1). When comparing height between the two stands, the red maple stands are much shorter than the sugar maple stands. Height differences may be a function of local stand conditions such as exposure and/or soil type (Cole, 2014).

Table 1. Stand summary for live trees ≥ 10 cm in diameter at breast height

Stand	Forest Type	Species Composition[1]	Basal Area (m^2/ha)	Density (stems/ha)	Quadratic Mean DBH[2]	Mean Height (m)	Old Growth Reference Age[3]
Georgeville (GV)	Red Maple	1BF 5RM 3YB 1 Other	35	1600	25.33	13.22	126
Round Lake (RL)	Red Maple	6YB 3RM 1Other	23	457	42.84	15.05	172
Giants Lake (GL)	Red Maple	4RM 2SM 4YB	29	617	35.73	14.21	205
Campbell Duggan (CD)	Sugar Maple	2RM 4SM 4YB	34	555	46.72	19.66	142
Bezansons Lake (BL)	Sugar Maple	8SM 2YB	33	585	33.64	19.75	144
Indian River Road (IR)	Sugar Maple	8SM 2YB	25	536	27.49	17.49	155

Table 2. Density (stems/ha) and basal area (m^2/ha) of live trees at 40, 50, 60 cm diameter limits

Stand	OGF Age	All Trees Density (#/ha)	All Trees Basal Area (m^2/ha)	>40cm Density (#/ha)	>40cm Basal Area (m^2/ha)	>50cm Density (#/ha)	>50cm Basal Area (m^2/ha)	>60cm Density (#/ha)	>60cm Basal Area (m^2/ha)
Georgeville (GV)	126	1600	35	0	0	0	0	0	0
Round Lake (RL)	172	457	23	71	13	14	5	12	4
Giants Lake (GL)	205	617	29	36	7	19	5	4	1
Campbell Duggan (CD)	142	555	34	118	22	41	11	16	5
Bezansons Lake (BL)	144	585	33	61	9	10	2	0	2
Indian River Road (IR)	155	536	25	52	10	28	7	6	2

Stand	Snag Basal Area (m^2/ha)	Snag Quadratic Mean DBH (cm)	Snag Density (stems/ha)	Downed Volume (m^3/ha)
Georgeville (GV)	5	16.08	171.7	51.08
Round Lake (RL)	5	31.99	32	55.23
Giants Lake (GL)	11	31.34	502	50.90
Campbell Duggan (CD)	3	25.15	28	54.35
Bezansons Lake (BL)	2	34.51	9.33	36.23
Indian River Road (IR)	2	31.33	10.67	117.4

Table 3: Stand summary for (hardwood) deadwood ≥ 10cm in diameter breast height

3.2.2 Deadwood

Deadwood such as snags (leaning ≤ 45° from vertical) and coarse woody debris (leaning > 45° from vertical) are one of the main structural characteristics that old growth forests contain. Deadwood occurs when there is a large-scale disturbance in the stand or when individual trees die and/or fall, so the amount of deadwood present in a stand can vary (Runkle, 1991). All deadwood recorded were greater than 10 cm in diameter (Table 3). The basal area range for the red maple stands is 5-11 m^2/ha and the range for the sugar maple stands is 2-3 m^2/ha. This shows a trend that the red maple stands are more stocked with standing dead trees than the sugar maple stands, which have a substantially lower amount per hectare. The snag quadratic mean dbh range for the red maple stands is 16.08-31.99 cm and the range for the sugar maple stands is 25.15-34.51 cm. The trend shows that both stands have similar diameters in their larger snags, but the red maple stands contain more smaller diameter trees than the sugar maple stands (Table 3). The snag density range in the red maple stands is 32-502 stems/ha and the range for the sugar maple stands is 9.33-28 stems/ha. The red maple and sugar maple stands are displaying completely different trends when it comes to the density of snags present. The red maple stands contain a great density of snags, which can be attributed to the red maple stands being more stocked than the sugar maple stands. This increases competition among trees, which in turn increases mortality rate (Jimerson, 1989). The range of downed volume for the red maple stands is 50.90-55.23 m^3/ha and the range for the sugar maple stands is 36.23-117.40 m^3/ha. The trend shows that the sugar maple stands have more than double the amount of downed volume than the red maple stands. This is the result of the IR stand being an outlier possibly due to a large disturbance event causing mass mortality.

3.3 All Stands

Below is a compilation of the data that was collected on three red maple/yellow birch stands and three sugar maple/yellow birch stands (Table 1). Structural attributes including species composition, height, diameter at breast height, density, basal area, and deadwood were sampled to obtain an understanding of the structural dynamics occurring at within each group. Based on the provincial definition of old growth, all stands were identified as old growth.

3.3.1 Live Tress

The basal area for all six sites averaged 30.0±5.0 m^2/ha (range 23-35 m^2/ha). This basal area average is comparable to the numbers found in a study of tolerant hardwoods stands in Nova Scotia at 35.1 m^2/ha (Stewart, et. al. 2003). The stands with the highest basal areas are GV, BL, and CD. The stand with the highest basal area also has the most stems per hectare (GV). The following two stands containing a high basal area have less than half the stem density of GV, however the stems have larger DBH, which is contributing to the high basal area. McGrath (1997) states that hardwood stands are fully stocked with a basal area of 40 m^2/ha, and that higher the basal area, the more competition between species is present. Therefore, the stands I gathered data on are considered to be 75% stocked, on average (range 58-88% stocked). The stands that are more stocked indicate that the climatic species present can persist under low light conditions (Pallardy, 2008).

The density in the six stands averages at 725±432.05 stems/ha (range 457-1600 stems/ha). The average density of the six stands is not representative of the stands as Table 1 shows that GL is triple the density of another stand (BL) with the other four stands falling under the average density. According to Spies and Franklin (1991), it is characteristic of old growth forests to have a lower density of trees than mature forests do because small, young trees are prevalent in younger forests. This explains why the density is so high in the GV stands, because it is the youngest of the six stands. Besides the two outlier stands, this statement proves true, as the older the stand, the less dense it is. The old reference ages of the stands are in a close range of one another (32 years), so differences in density would be dependent on other factors such as disturbances rather than age as these stands are all classified under the same successional stage (Kneeshaw and Gauthier, 2003).

The quadratic mean diameter at breast height (dbh) averaged at 35.29±8.37 cm (range 25.33-46.72 cm). Four of the six stands are representative of the average value, whereas the stand with the highest quadratic mean dbh is almost double the quadratic mean dbh of the stand with the lowest diameter value. With the exception of the CB, there is a correlation between increasing basal area and decreasing diameter within the stands. As a stand becomes denser, the rate of tree growth slows as resource availability decreases and competition increases (Mcgrath, 1997). These diameter values are comparable with other studies of old growth forest stands in Nova Scotia such as the study done by Stewart et. al (2003) who's average quadratic mean dbh for sampled hardwood sites was 34.2 cm.

The height of the six stands averaged at 16.56±2.81 m (13.22-19.75 m). The heights of the six stands are on the lower end of the potential height average the trees can reach. In the Stewart et al., (2003) study, the height of a hardwood stands averaged at 22.1 m. The three species present in the six stands have the capacity to reach heights of 21 to 30 m and although individual trees have reached heights higher than the average of the stand, the multi-aged characteristics of the stand takes into account the younger, smaller trees present (Leak et. al, 2014). The stands with lower average sites can be associated with the species composition of the stand as red maple species don't carry the capacity of growing to heights like sugar maple and yellow birch do (Leak et. al, 2014).

The six old growth stands sampled contained a broad range of diameter distribution, characteristic of uneven aged stands (Runkle, 1991). Data was recorded on the larger diameter trees normally found in old growth forests (Table 2). The stands' density of trees 40-50 cm in diameter averaged 56.3±39.1 stems/ha (range 0-118 stems/ha), and the stands' basal area of trees 40-50 cm in diameter averaged 10.2±7.25 m^2/ha (range 0-22 m^2/ha). Of the larger diameter trees, five out of the six stands had their highest density and basal area represented in the 40-50 cm diameter classes. The one stand that didn't have its highest density and basal area represented by 40-50 cm diameter trees, lacked any trees larger than 39.9 cm. The stands' density of trees 50-60 cm in diameter averaged 18.7±14.4 stems/ha (range 0-41 stems/ha), and the stands' basal area of trees 50-60 cm in diameter averaged 5.00±3.85 m^2/ha (range 0-11 m^2/ha). The 50-60 cm diameter class is the second highest in density and basal area representation. As Irland (2000b) states, old growth forests are seldom composed of only large, old trees as they contain many small and medium sized trees. The stands density of trees >60 cm in diameter averaged 6.33±6.50 stems/ha (range 0-16 stems/ha), and the stands' basal area of trees >60 cm in diameter averaged 2.00±2.10 m^2/ha (range 0-5 m^2/ha). Only four of the six stands sampled had trees that were ≥60 cm in diameter. This is the smallest representation of density and basal area for this diameter class, as the amount of larger trees becomes sparse. The largest diameters recorded exceeded 60 cm ranged from 66-95.5 cm.

3.3.2 Deadwood

The snag basal area (m^2/ha) of the six stands averaged at 4.67±3.39 m^2/ha (range 2-11 m^2/ha). This is about 16% of the basal area average of the live trees among the stands. The snag density of the six stands averaged at 125.7±194.3 stems/ha (range 9.33-502 stems/ha). This is comparable to the Forest Ecological Classification guide (2010), where the amount of snags in a tolerant hardwood forest measures at 180 stems/ha. In the Stewart et al. (2003) study, only one hardwood stand had similar snag density at 100 stems/ha. It is worth noting that the Giants Lake stand has approximately four times the density of the average density of the six stands, which may be the result of a major disturbance. On average, the density of snags was over five times less than the average density of live trees. The snag quadratic mean dbh averaged 28.4±6.78 cm dbh (range 16.08-34.51cm). This average is closely comparable to the average of the live tree quadratic mean dbh average of 35.29 cm. This infers that older, larger trees are the ones dying. The downed volume averaged 60.87±28.54 m^3/ha (range 36.23-117.4 m^3/ha). One stand (IR) had over two times the downed volume average, while the other five stands were close to the average.

CHAPTER 4: Conclusions

Both the red maple/yellow birch and sugar maple/yellow birch stands selected from the database of old forest scored stands all proved to be old growth and demonstrated to have age and structural characteristics similar to other old growth stands from across the Acadian forest region. Red maple has strong characteristics of a climax species in at least one tolerant hardwood stand in Nova Scotia. Due to low sample size, it is difficult to measure major differences between the age and structural characteristics between the red maple/yellow birch and the sugar maple/yellow birch stands. When exploring the individual red maple/yellow birch stands, red maple's structural parameters in the Georgeville stand are similar to those of climax species status in tolerant hardwoods, such as age class distribution, tree density, basal area, and deadwood. A definite statement at this time cannot be confirmed that red maple should be defined as a climax species as sample size was small and red maple's structural parameters differ when certain species are present. Research on red maple's age and structural characteristics need more replications to confirm and strengthen the hypothesis that red maple trees are a climatic species. It would add to research if red maple were studied in different forest groups of the province such as intolerant hardwood and wet deciduous forest groups, specifically areas where there is less sugar maple to reinforce the hypothesis that the resilience of red maple is inhibited when sugar maple is present. An in-depth understanding of red maple's role and structure will help avoid a possible missed opportunity to better old growth forest management, as red maple currently does not fit the criteria under the Nova Scotia policy definition and restrictions.

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