Deadwood Estimates Based on Livewood and Deadwood Correlations under Natural Conditions in the Acadian Forest of Nova Scotia

Preliminary Report
to the Habitat Conservation Funding Committee
Department of Natural Resources, Kentville, Nova Scotia

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1.0 INTRODUCTION

The purpose of this report is to present the results, to date, of data collected during the summer of 2006 and 2007. The research was conducted under the Masters Program at Acadia University and in partnership with the Department of Natural Resources. The goal of the study, as outlined in the proposal to the Nova Scotia Habitat Conservation Fund in January 2007, was to estimate deadwood quantities under natural conditions for forests in different stages of development by examining correlations between livewood and deadwood characteristics. The purpose was to address regulation (4) of the Wildlife Habitat and Watercourses Protection Regulations which states: "A forestry operator shall ensure that levels of snags and coarse woody debris on all harvested sites are similar to natural patterns to the fullest extent possible"[1]. Most of the older forests in Nova Scotia lack a downed deadwood component which suggests the removal of deadwood (particularly large diameter deadwood) by foresters was a common practice in the past (Mosseler *el al.* 2003a). It is anticipated that the potential application of this research through the expansion of forestry regulations and subsequent implementation by forestry managers will promote appropriate deadwood retention for the ultimate preservation of endangered deadwood habitat and the wildlife that depend on it for food, shelter and for nursery needs. The retention of deadwood is also expected to increase the structural component necessary in the steady distribution of forest nutrients as well as water resources (McComb and Lindenmayer 1999, McCurdy and Stewart 2005, Mosseler *et al.* 2003a).

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[1] www.gov.ns.ca/just/regulations/regs/fowhwp.htm *in* Flynn, J.R. 2005. Thesis Research Proposal. Acadia University, Wolfville, Nova Scotia.

The contents of this report focus primarily on the methodology and results section of my research and represent the work completed to date. The information in this report is presented under several sections. Section 1.0 presents the results of a literature review that summarizes several points related to the impact of clear cutting on the Nova Scotia Acadian forests as well as several challenges associated with deadwood research. The premise on which this research is based as well as objectives to address the goal of this research concludes Section 1.0. Site descriptions, data collection methods particularly as they relate to downed deadwood and decay levels, as well as data summary procedures appear in Section 2.0. Section 3.0 presents the results of the data analysis to date by summarizing livewood and deadwood characteristics associated with early and late forest types as represented by the dataset. The manner in which the deadwood component is structured for analysis, so that the response of deadwood characteristics to advancing forest development, under natural conditions, as well as the manner in which livewood and deadwood correlations are to be analyzed, is also presented. Section 4.0 summarizes the report by describing early and late forests types in relation to stage of development and the approach in which deadwood quantities associated with Nova Scotia Acadian forest types may be predicted.

1.1 Clear Cutting Impacts on Livewood in Nova Scotia Acadian Forests[2]

There is a consensus in the literature and between government and non-government organizations that 1) the amount of late successional forests[3], particularly old growth, are

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[2] (Flynn 2008)

rare in Nova Scotia and 2) non-sustainable land clearing activities have led to the scarcity of older forests by altering the composition and structure at the landscape level over time, to a higher proportion of early successional Acadian forest types[4] (Bayne 2006, Department of Natural Resources 2008, Mosseler *et al.* 2003a, Seymour *et al.* 2002, Stewart *et al.* 2003, Wilson *et al.* 2001). Stewart (*et al.* 2003) indicates that 91% of the forests in Nova Scotia are currently in the establishment or thinning phase of natural succession (i.e. earlier stages of forest development), where even-aged forests less than 100 years old now dominate the landscape. Approximately 40-50% of the Acadian forests that covered the Maritime Provinces 400 years ago were late successional forest types (Mosseler *et al.* 2003a). While there is some inconsistency in the literature as to how much late successional forests remain in Nova Scotia, there is a consensus that short, frequent intervals between land clearing activities have resulted in a change in the Acadian forest composition from late to largely early successional forests (Mosseler *et al.* 2003a, Seymour *et al.* 2002, Spies *et al.* 1999).

1.2 Clear Cutting Impacts on Deadwood in Nova Scotia Acadian Forests[5]

When reviewing the literature for previous research related to deadwood quantities associated with different Acadian forest types, several things were noted: 1) that the removal of deadwood has been a common logging practice in the past (Mosseler *et al.*

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[3] Dominated primarily by what the literature refers to as late successional species: American beech (*Fagus grandifolia*), eastern hemlock (*Tsuga canadensis*), eastern white pine (*Pinus strobus*), red spruce (*Picea rubens*), sugar maple (*Acer saccharum*) and yellow birch (*Betula alleghaniensis*)

[4] Dominated primarily by early successional species some of which include: trembling aspen (*Populus tremuloides*), balsam fir (*Abies balsamea*), pin cherry (*Prunus pensylvanica*), red maple (*Acer rubrum*), white birch (*Betula papyrifera*), white spruce (*Picea glauca*) and wire (or grey) birch (*Betula populifolia*); where late successional species are largely absent, with the exception of red spruce. Red spruce is known to occur in both early and late stages of forest development.

[5] (Flynn 2008).

2003a), 2) there has been no specific research conducted to determine the impact of deadwood removal on dependent wildlife or to promote deadwood recovery (McComb and Lindenmayer 1999, Mosseler *et al.* 2003a) and 3) there has been no specific research to determine livewood and deadwood correlations within similar Acadian forest types and how they might differ in different stages of forest development.

The lack of deadwood research may be related to the extent of human disturbance (i.e. land clearing activity) in the Nova Scotia Acadian forests and the manner in which deadwood data is traditionally collected and analyzed. Research related to deadwood quantities may include residual deadwood from a previous forest condition, making reasonable estimates for deadwood quantities and subsequent predictions a challenge. To avoid this, most researchers restrict their studies to older forests where there is presumably little evidence of human disturbance. The trouble with this is that given the scarcity of older forests types in Nova Scotia coupled with the removal of deadwood from harvested sites in the past, the sample size representing the study area is small. This in turn has led to the development of criteria that would attempt to standardize older forest descriptions – perhaps as a way for policy makers to establish a balance between harvesting activities and conservation efforts (Mosseler *et al.* 2003b, Lynds 1992) - and as a potential way of broadening the sample size for research related to similar forest types in later stages of development.

One of the most interesting observations noted during the review of the literature was the manner in which deadwood data is collected and analyzed. First, deadwood decay characteristics are not quantified, quantitative deadwood decay research and subsequent descriptions for Nova Scotia Acadian forests have not been conducted (Mosseler *et al.* 2003a, Lynds 2006). Second, the traditional methodology used in collecting deadwood data is such that most downed deadwood estimates are reported in m³/ha (volume), so that most livewood and deadwood comparisons within and between study sites are not easily comparable, when livewood estimates for the same study area are reported in m²/ha (basal area) or trees/ha (density). And third, the deadwood component at a given area under study is traditionally analyzed as two aggregates (snags and coarse woody debris), which can be viewed in retrospect as "mixed bags" of not only standing and downed deadwood in various stages of decay but also deadwood resulting from the existing and possibly previous livewood conditions. The level of human disturbance for sites under study is largely determined from existing livewood conditions as well as site records including aerial photographs that most often indicate the disturbance history. However, for sites where the disturbance history is inconclusive or latent, reported deadwood estimates (m³/ha) may include residual deadwood quantities not associated with existing livewood, making the prediction of deadwood quantities based on natural conditions for different forest types a challenge.

Given the residual older forest types remaining and the extent of harvesting activity in Nova Scotia, it may be necessary when data collection occurs in stands with a known or latent history of human disturbance to segregate the standing (snags) and downed deadwood components so that the deadwood associated with the existing livewood can be isolated for analysis. This would be particularly important when attempting to correlate livewood and deadwood characteristics so that reasonable predictions about deadwood quantities occurring under natural conditions can be made for different forest types in later stages of development.

1.3 Research Premise[6]

For the purposes of this research, the two characteristics that distinguish early from late successional forest types over time are a greater proportion of long-lived tree species[7] and larger diameter trees. The research is based on the premise that for Nova Scotia Acadian forests in later stages of development, the occurrence of small scale gap dynamics does not reflect an overall change in forest types at the landscape level. Whereas large scale land clearing activity, known to either change the trajectory of forest development or set it back to an earlier stage, are shown at the broader forested area (Seymour *et al.* 2002). Standing and downed deadwood in forests at later stages of development where gap dynamics are the primary form of forest disturbance, are products of the life cycles and characteristics associated with the existing late successional tree species (Spies *et al.* 1999), where dead or dying trees that have reached (or are nearing) their maximum longevity fall to the ground. However, downed deadwood in forests at earlier stages of development that are not a function of the existing livewood will have characteristics that differ from the present livewood. It is assumed that for early forest types in which natural disturbance is occurring, the presence

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[6] (Flynn 2008).

[7] Long-lived is a term that was assigned to certain tree species comprising this dataset, where assignment of the term was based on the life histories of those species (see Table 1 in Flynn 2008 for life history characteristics). Species denoted as long-lived in this study are: eastern hemlock, red spruce, white pine, American beech, sugar maple and yellow birch.

of small diameter livewood together with larger diameter deadwood, is rare in the Nova Scotia Acadian forest and would reflect a relatively recent large scale human or major natural disturbance. For the purposes of this research, the deadwood component associated with early successional forest types in which this condition occurs would not be considered as representing, collectively, deadwood characteristics that have occurred under natural conditions.

1.4 Research Hypothesis[8]

There is a stronger relationship (near 1:1) between livewood and deadwood characteristics at all levels of decay in later stages of development compared to earlier stages of forest development. The tree characteristics to be analyzed in this study are diameter and density for long-lived tree species in different stages of decay.

1.5 Research Predictions[9]

Predictions arising out the hypothesis are as follows: 1) for standing deadwood in low and high decay, the median diameter for long-lived livewood and long-lived deadwood is expected to increase as stage of forest development advances so that the relationship between them nears 1:1, 2) for standing deadwood in low and high of decay, the density of long-lived livewood and long-lived deadwood is expected to decrease as stage of forest development advances so that the relationship between them nears 1:1, 3) for downed deadwood in low and high decay, the median diameter for long-lived livewood

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[8] (Flynn 2008).
[9] Ibid.

and long-lived deadwood is expected to increase as stage of forest development advances so that the relationship between them nears 1:1 and 4) for downed deadwood in low and high decay, the density of long-lived livewood and long-lived deadwood is expected to decrease as stage of forest development advances so that the relationship between them nears 1:1.

1.6 Research Objectives[10]

The objectives of this study are to 1) develop a scheme for characterizing stages of development for Nova Scotia Acadian forest types using livewood and deadwood characteristics, 2) quantitatively describe stands in the Acadian forest of Nova Scotia using tree species composition, diameter, basal area and density, for livewood and deadwood including decay levels for deadwood and 3) understand the relationship between livewood and deadwood characteristics in the Acadian forests of Nova Scotia under natural conditions so that deadwood amounts can be predicted for forests in different stages of development.

There were several practical considerations given to achieving the objectives of this research. First, sample trees of a larger size in order to target the older trees in the stand so that estimates can be based on mature livewood; second, target the downed deadwood component occurring as a result of current forest conditions by applying a relascope to select the snag (standing deadwood) counterpart of the downed deadwood and third,

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[10] (Flynn 2008)

segregate the deadwood data so that only the standing and downed deadwood resulting from existing forest conditions are analyzed.

Procedures applied in the achievement of these objectives are described under the Methodology and Results Section of this report.

2.0 METHODOLOGY[11]

2.1 Study Site Selection

Three sites were selected for data collection. Two of them, located in the County of Kings, contain a known late successional component. The third study site, located in the County of Lunenburg, is represented by an early successional forest.

Site selection, within the County of Kings, was based primarily on the GPS position of eastern hemlock (*Tsuga canadensis)* stands determined from data compiled by Benjamin (2006a) where eastern hemlock dominated the canopy by more than 50% and stood at least 17 meters in height. The GPS coordinates of those stands were applied to a digital map[12] of the County of Kings and were used to isolate appropriate sites for data collection. The late successional component at each of the two sites selected for study was visually assessed in the field for continuity, stand size and for evidence of large-scale human activity prior to data collection. The sites selected for study were Site 1 – Wolfville Watershed Property and Site 2 – Allison Coldwell Road Site (Figure 1.).

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[11] (Flynn 2008).

[12] Digital map source: Nova Scotia Department of Natural Resources. 2006. http://gis4.gov.ns.ca, using ArcExplorer 9.1.

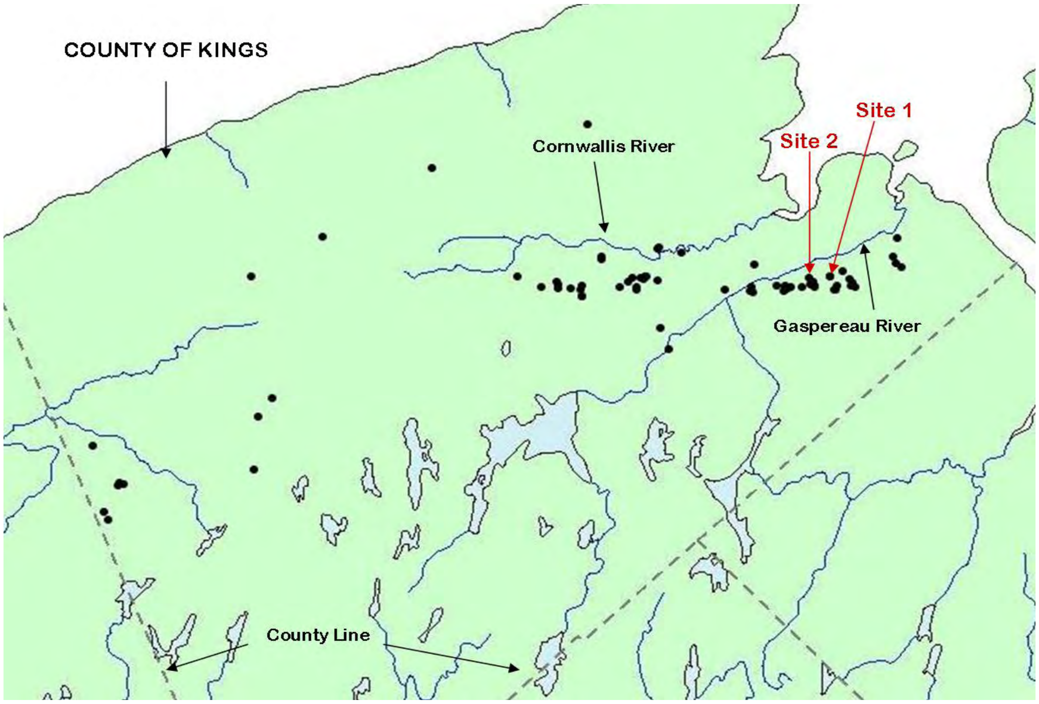

Figure 1. Digital map showing the distribution of eastern hemlock stands in the County of Kings, represented by black dots, and selected study sites. Site 1 – Wolfville Watershed Property and Site 2 – Allison Coldwell Road Site.

2.2 Study Site Description

2.2.1 Wolfville Watershed Property (Site 1)

The Wolfville Watershed Property (Site 1) is a patch of largely early successional forest, with approximately 15 ha of a late successional component occurring for the most part along steep ravines in the north eastern section (Flynn 2007). For the early successional component, species composition includes balsam fir, red maple, red spruce, trembling aspen, white birch and white spruce. American beech, eastern hemlock, red spruce, sugar maple, white pine and yellow birch with red oak (*Quercus rubra*) occurring to a much lesser extent, comprise the species composition for the late successional component. The topography is mostly gently undulating to undulating, with the exception of the steep ravines mentioned above. The Site is moderately well-drained, except for two areas situated in the south east and south western sections where a relatively small wet area and bog habitat are located respectively. There was little evidence of past human activity observed in the heart of the late successional component, with the exception of the remnants of a stone dam dating back to the late 1800s; situated on Duncanson's Brook near the north eastern edge of the property (Flynn 2007). Aside from a cement dam and accompanying access road initially installed by the Town of Wolfville in the early 1930s, historical records and aerial photos (1945, 1955, 1992 and 2002) showed no cleared areas in the late successional component, in which data collection occurred; albeit significant land use activity for other areas of the property was clearly indicated by several stumps – some moss covered – suggesting selective cutting in the past; aerial photos and historical records – the earliest of which indicated land clearing for agricultural purposes in 1874 (Flynn 2007).

The Watershed Property is currently used as a back-up water supply for the Town of Wolfville (Flynn 2007). In the fall of 2007, the Town of Wolfville in partnership with the Nova Scotia Nature Trust finalized negotiations that placed a conservation easement on the property so that the late successional component could be preserved in perpetuity (Stead 2007). A few months prior, the Department of Natural Resources (Kentville) updated their Significant Species and Habitat Map to include the Watershed Property

(Benjamin 2007), due to the discovery of Nova Scotia's red-listed[13] southern twayblade orchid (*Listera australis*) (Forsythe and Alliston 2007).

2.2.2 Allison Coldwell Road (Site 2)

The Allison Coldwell Road Site is comprised of late successional stands that gradually blend into the surrounding early successional forest. The late successional component is approximately 12 ha, spanning two parcels of privately owned land. Species composition include American beech, eastern hemlock, red spruce, sugar maple, white ash (*Fraxinus Americana*), white pine and yellow birch to a much lesser degree. The late successional component is situated on a well drained site with gently sloping topography. There was little visual evidence of past human activity, aside from the selective cutting as suggested by the presence of several moss-covered stumps. Historical records and aerial photos were either inconclusive or unavailable in determining the history of land use, albeit locals indicate that the deliberate setting of fires along the shores of the Gaspereau River as well as the surrounding area during the Acadian expulsion in 1755 is relatively well known. Unfortunately, research did not produce records to support this.

2.3. Data Collection Procedures

2.3.1 Sampling Design

Data collection followed a Plotless Sampling Design (also known as point sampling, horizontal point sampling, variable radius plot methodology and Bitterlich Method)

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[13] https://www.gov.ns.ca/natr/wildlife/genstatus/speciesssrch.asp

(Avery and Burkhart 2002). The Plotless Sampling Design employs an optical gauge (prism or relascope), where the probability of selecting trees is proportional to tree diameter rather than the frequency of tree occurrence – an aspect associated with the Fixed-Area Plot Design (Avery and Burkhart 2002, Jordan *et al.* 2004). Estimates obtained under the Fixed-Area Plot Design are based on the abundance of smaller diameter trees, where the probability of sampling small trees is greater, when compared to the abundance of larger trees over the same fixed area. For the purposes of this research, the nature of the Plotless Sampling Design to sample larger trees was considered an advantage (Bondrup-Nielsen 2006) when determining deadwood estimates based on livewood and deadwood correlations associated with larger diameter trees, common in older forest types.

It was noted in Sparks (*et al.* 2002) that the Plotless Sampling Design underestimated total stem density for trees with a diameter less than 11.43 cm when compared to the actual density of the area studies but percentage differences were proportional and constant across stand densities. Sparks (*et al.* 2002) acknowledged percentage differences between actual and estimated stand densities may have been reduced in their study by an increase in sample size. The optical gauge used in Sparks (*et al.* 2002) was a 10-factor prism. The optical gauge applied in this study was a 2 BAF relascope[14]. Research did not produce studies related to comparisons between actual and estimated stem density (tree diameter ≥ 10 cm) under the Plotless Sampling Design where a 2 BAF relascope was employed in the study.

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[14] 2 BAF is the basal area factor associated with the relascope used in this study, where the unit of measure for basal area is m²/ha (Avery and Burkhart 2002)

For Site 1, point samples were determined from the range of GPS coordinates in which this site fell. A plot radius factor of 0.357 m/1 cm DBH[15] (Avery and Burkhart 2002) and an estimated maximum tree diameter of 70 cm (Nilsson *et al.* 2003) were used to determine 25 meters as sufficient distance to avoid potential over-lap between point samples. Coordinates were arranged into 25 meter intervals, where each northing and easting column was re-arranged using the random function in Excel so that point samples could be positioned randomly over a property grid[16]. (The coordinates for nine point samples containing trees with diameters greater than 70 cm were re-examined post sampling and showed no overlapping point samples.). For Site 2, two unidirectional transects were laid from east to west approximately 50 meters from the eastern edge of the late successional stand, where a range of meters (32 to 94 meters) were randomly selected to represent point samples along the transects. A minimum distance of 32 meters between point samples was sufficient to avoid over-lapping point samples, as the maximum tree diameter at this Site of 81.8 cm multiplied by the plot radius factor of 0.357 (m/1 cm DBH) indicated 29 meters as a minimum required distance to avoid any point sample over-lap.

2.3.2 Data collection

Point samples were accessed in the field by way of a compass and hand-held Garmin 12 GPS unit, where a 2 BAF relascope was used to select trees for measurement. Data collected for all living and dead trees falling within the relascope range included the DBH

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[15] Plot Radius Factor of 0.357 m/1 cm DBH (diameter at breast height) is associated with a 2 BAF relascope.
[16] Property grid for Site 1 was produced by Benjamin (2006b).

(≥ 10 cm), a tally of selected living and dead trees by species, mortality status and decay levels for deadwood. Snags were recorded as standing deadwood when the breakage point was above breast height (1.4 meters). When the breakage point for snags occurred at a level below breast height, the log counterpart for that snag was located, where data collected from the log was recorded as downed deadwood - if the log fell within the relascope range. This was determined by "sighting-in" with the relascope the snag counterpart of the downed deadwood by extending (at eye level) a measuring tape equal to the diameter (at breast-height equivalent) of the log, over the location of the snag counterpart. When the log counterpart could not be located, the snag was recorded as standing deadwood. The manner in which downed deadwood was selected for data collection in this study circumvented the application of slope correction procedures. Under the Plotless Sampling Design, slope correction procedures apply to log dimensions associated with volume calculations for downed deadwood directly selected by the optical gauge when deadwood on the ground occur on sloped terrain (Jordan *et al.* 2004, Grosenbaugh 1952, Stahl *et al.* 2002). The method applied in sampling downed deadwood in this study circumvented a potential non-detection bias, a bias that Jordan (*et al.* 2004) associated with the application of inappropriate angles when sampling downed deadwood directly with a relascope in certain stands.

A penetrometer was used to measure decay levels for each dead tree tallied. The penetrometer used in this study was equipped with a spring-loaded narrow metal rod that extends from the tip of the penetrometer. When pushed against the tree (at breast height or equivalent for dead trees on the ground), the metal rod is forced back into the penetrometer, at a distance that depends on the structural integrity of the dead tree. The distance the metal rod is forced backward can be viewed through a narrow, horizontal slot in the body of the penetrometer. The metal rod was measured with a small ruler and was used to quantify levels of decay, in centimeters. An informal sampling of livewood in the field showed a constant penetrometer measurement of 2.5 cm, so that penetrometer measurements less than 2.5 cm indicated the decay level for standing and downed deadwood.

2.4 Data Summary Procedures

Sufficient sample size was determined by plotting cumulative basal area for livewood (Bondrup-Nielsen 2006), particularly for forests in later stages of development. Each point sample contained a minimum of 10 trees for livewood and at least one piece of deadwood. Tree species and diameters at breast height (DBH) were used to determine total basal area (m^2/ha) and estimate total density (trees/ha) by species for each point sample (Stewart *et al.* 2003) for livewood and standing and downed deadwood. Density was derived directly from the diameter (at breast height) of sampled trees using the following formula (Thompson *et al.* 2006):

$$\mathbf{2 / (\pi \text{ multiplied by radius}^2) \text{ multiplied by } 0.0001}$$

where the area of the individual tree multiplied by 10^{-4} ha, divided into 2 BAF represented trees/ha for a given diameter. Median DBH was based on 30% of the cumulative density values per point sample, in order to target larger diameter trees for analysis. Longevity proportions were determined from the proportion of total basal area represented by long-lived species for each point sample. Basal area was considered to represent a reasonable reflection of canopy dominance under the Plotless Sampling Design as tree selection is proportional to larger diameter trees or individual tree basal area (Stewart *et al.* 2003). The assignment of the term long-lived to tree species[17] at the point sample level was based on the life histories for the 13 species comprising the dataset, and resulted in a consistency with late successional species described in literature (Mosseler *et al.* 2003a). For decay values, penetrometer measurements were converted to percentages by way of the following formula:

(1 – penetrometer measurement / livewood penetrometer measurement of 2.5) x 100

where percentages represented the decayed portion of the tree. The percentages were arranged into decay classes (4 for standing deadwood and 5 for downed deadwood) and based on visual observations in the field, correspond to the qualitative decay classification system applied in Stewart (*et al.* 2003) (Appendix A this report). (It is noted that the application of quantified decay values to the established qualitative decay class descriptions in Appendix A has not been previously studied in the Acadian forest of Nova Scotia and was developed as a subjective comparison for the purposes of this report.). Each point sample was assigned a stage of development – early or late, where total basal area, total density, median DBH and the top four dominate tree species were examined in the assignment of stage of stand development. It is noted that point samples assigned an early stage of development also include those stands in mid-successional or thinning phases of forest development. Importance values based on relative basal area and relative density were calculated to determine dominate species per point sample. The point samples that represent stands in later stages of development correspond to

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[17] Species denoted as long-lived in this study are eastern hemlock, red spruce, white pine, American beech, sugar maple and yellow birch.

descriptions of older forest types studied in Stewart (*et al.* 2003) and Nilsson (*et al.* 2003) and will be described further in Section 4.0.

3.0 RESULTS[18]

3.1 Stand Descriptions

There are 111 point samples that comprise the dataset; 92 of them are situated in the County of Kings and of that amount 19 represent stands in later stages of forest development. For stands located in the County of Kings, the total basal area for livewood is 2892 m²/ha. Deadwood represents approximately 37% (or 1066 m²/ha) of the total livewood basal area, where 44% (or 472 m²/ha) of that amount is downed deadwood. The Kruskal-Wallis p-values indicate a statistical difference between median density and median DBH for livewood and standing and downed deadwood in early and late forest types but show no statistical difference in the median basal area (Table 1).

3.1.1 Early Stages of Forest Development

For stands in early stages of forest development, the median basal area, median density and median DBH for livewood is 30 m²/ha, 1173 trees/ha and 18.2 cm respectively (Table 1.). The proportion of total basal area for livewood represented by long-lived species is approximately 39% (or 878 m²/ha), where 63% (or 554 m²/ha) of that amount is represented by red spruce. The species that dominate the livewood community, based on Importance Values, are balsam fir (33.61), red spruce (23.76), red maple (13.08), white birch (8.55) and trembling aspen (8.41). The Diameter Class containing the greatest density of livewood for stands in early stages of development is Class 1 (Figure 2.). The tree species dominating this class with the greatest total density is balsam fir

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[18] (Flynn 2008).

Table 1. Median basal area (BA) (m^2/ha), median density (DEN) (trees/ha) and median DBH (cm) for livewood and standing and downed deadwood in early and late stages of forest development. Kruskal-Wallis adjusted for ties, df = 1, (number of point samples)

	LIVEWOOD			STANDING DEADWOOD			DOWNED DEADWOOD		
Stage	BA	DEN	DBH	BA	DEN	DBH	BA	DEN	DBH
Early (73)	30	1173	18.2	6	275	20.0	4	160	19.9
Late (19)	32	436	34.2	2	43	33.2	4	78	32.8
Kruskal -Wallis	H = 1.68 P = 0.195	H = 43.72 P = 0.00	H = 44.36 P = 0.00	H = 8.34 P = 0.004	H = 14.16 P = 0.00	H = 13.47 P = 0.00	H = 0.25 P = 0.617	H = 9.97 P = 0.002	H = 9.97 P = 0.002

(32,193 trees/ha), which comprises 1/3 of the total density for livewood for stands in early stages of development.

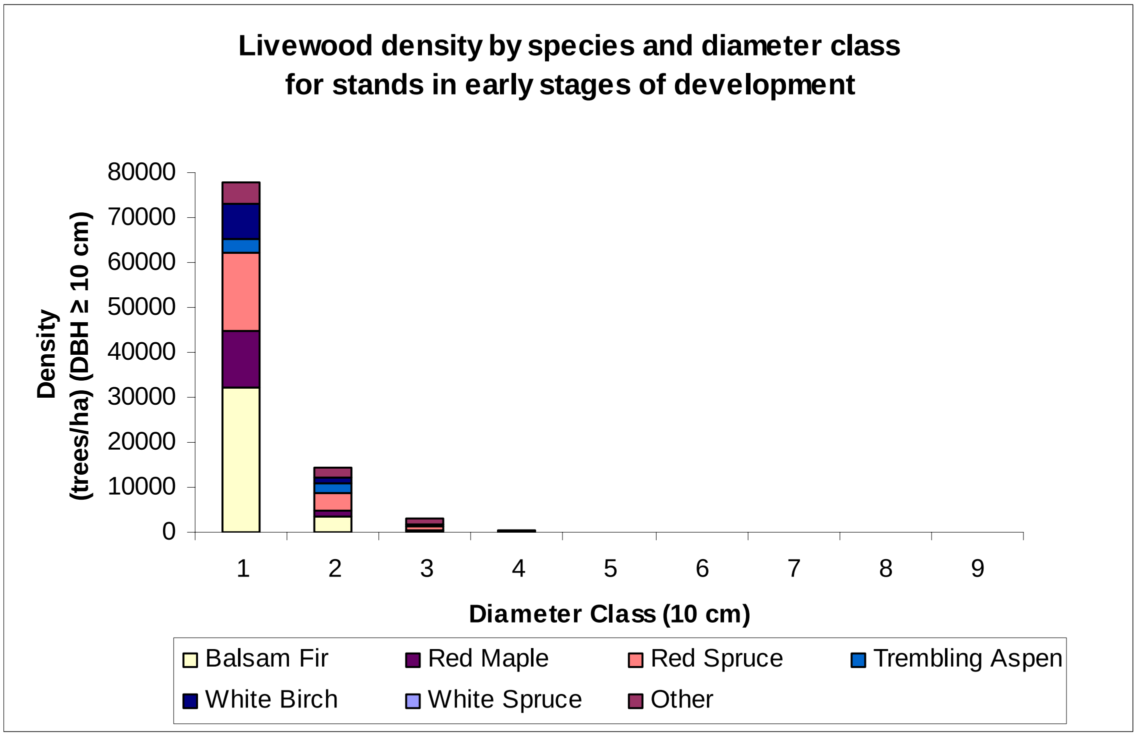

Figure 2. Distribution of total density for livewood by species and diameter class (10 cm)

The median basal area, median density and median DBH for standing deadwood for stands in early stages of development is 6 m²/ha, 275 trees/ha and 20.0 cm respectively (Table 1.). The proportion of total basal area for standing deadwood represented by long-lived species is approximately 32% (or 166 m²/ha), where 85% (or 142 m²/ha) of that amount is comprised of red spruce. The dominate species for the standing deadwood community, based on Importance Values, are balsam fir (58.56), red spruce (25.61), trembling aspen (4.43), white birch (3.18) and red maple (2.81). The Diameter Class containing the most standing dead trees per ha is Class 1 (Figure 3). For this Diameter

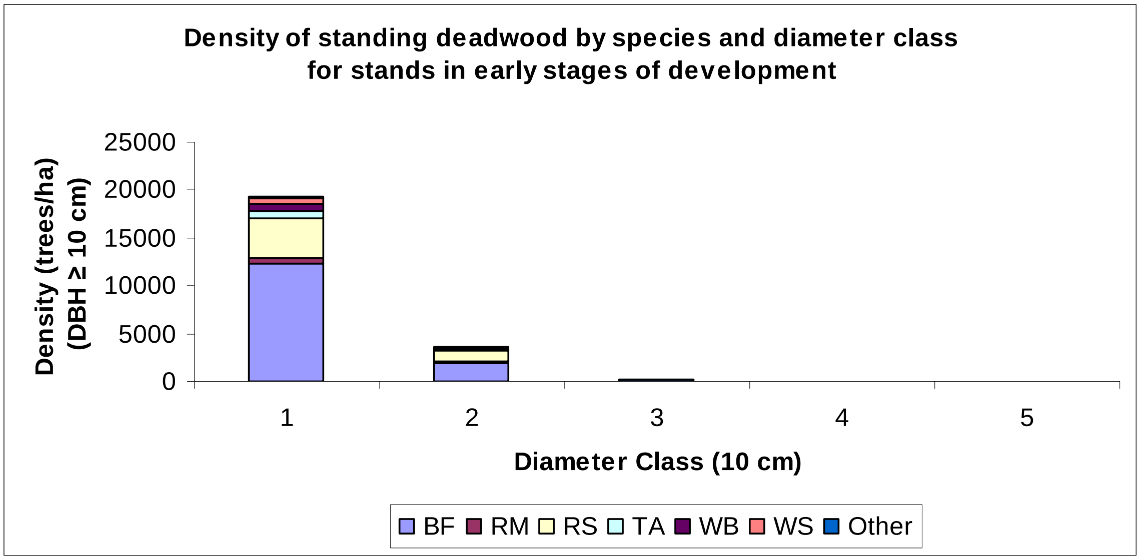

Figure 3. Distribution of standing deadwood density by species and diameter class (10 cm)

Class, balsam fir has the greatest density, with approximately 12,250 trees/ha comprising more than 1/2 of the total density for standing deadwood. Decay Class 1 (low decay) has the highest density of standing deadwood (Figure 4), with balsam fir dominating this class with a total density of 9,171 trees/ha.

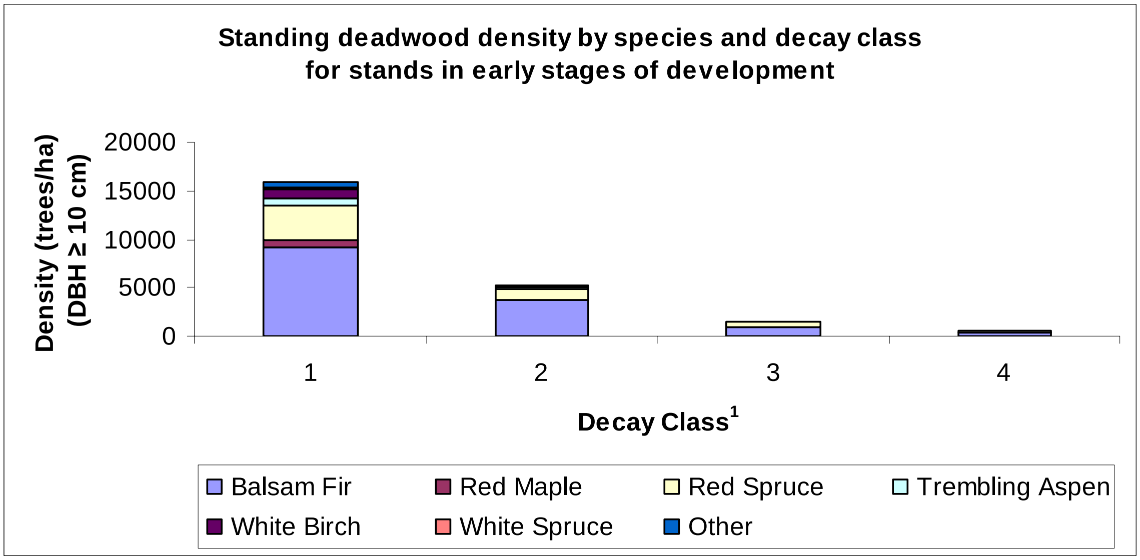

Figure 4. Distribution of standing deadwood density by species and decay class (10 cm)
[1]Decay class descriptions (Appendix A)

For stands in early stages of development, the median basal area, median density and median DBH for downed deadwood is 4 m²/ha, 160 trees/ha and 19.9 cm, respectively (Table 1.). The proportion of total basal area for downed deadwood represented by long-lived species is approximately 63%, where approximately 94% of that amount is comprised of red spruce. The species that dominate the downed deadwood community, based on Importance Values, are red spruce (55.72), balsam fir (28.84), trembling aspen (6.73), white birch (2.98) and red maple (2.34). The Diameter Class containing the most downed dead trees per ha is Class 1 (Figure 5). Red spruce has the greatest density in this class, with approximately 6,428 trees/ha, comprising approximately 40% of the total density for downed deadwood. Decay Classes 2 and 5 have the highest density of downed deadwood, where the total density of red spruce dominate both classes with 2,375 trees/ha and 1,504 trees/ ha respectively (Figure 6).

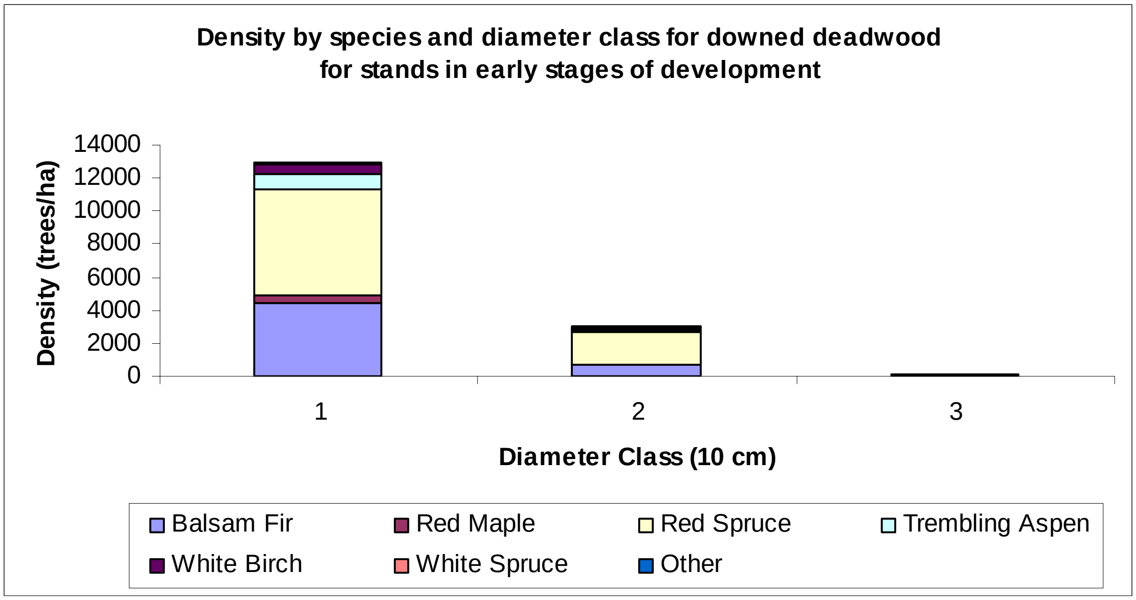

Figure 5. Distribution of downed deadwood density by species and diameter class (10 cm)

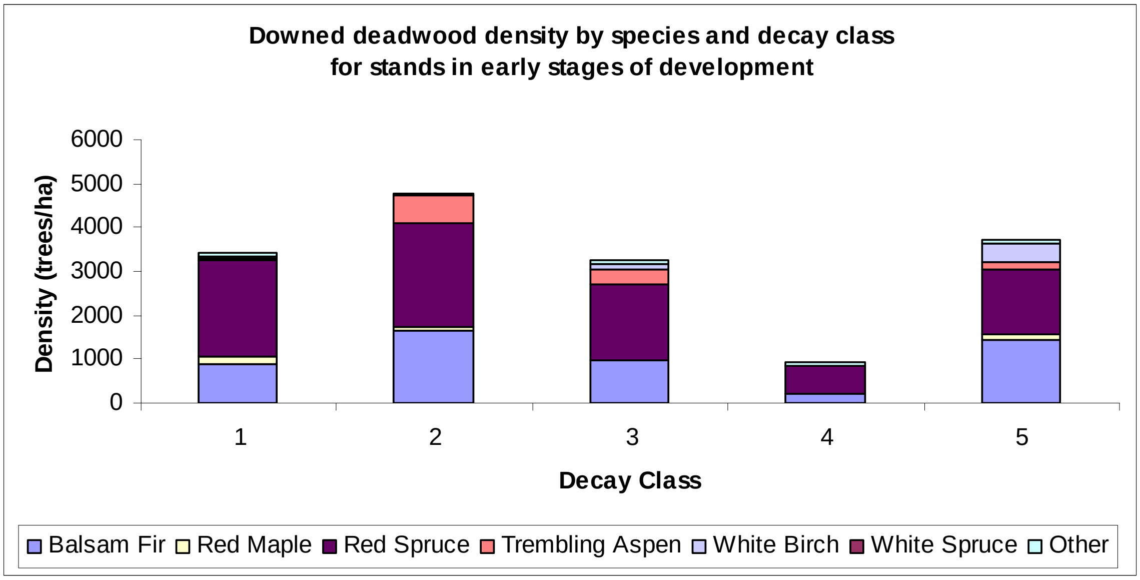

Figure 6. Distribution of downed deadwood density by species and decay class

3.1.2 Late Stages of Forest Development

For stands in late stages of forest development, the median basal area, median density and median DBH for livewood is 32 m²/ha, 436 trees/ha and 34.2 cm respectively (Table 1.). The proportion of total basal area for livewood represented by long-lived species is approximately 97% (or 612 m²/ha), where eastern hemlock represents approximately 74% (or 452 m²/ha) of that amount. The species that dominate the livewood community, based on Importance Values, are eastern hemlock (68.17), red spruce (14.41), sugar maple (6.54), red maple (2.87) and red oak (2.56). The Diameter Class containing the greatest density of livewood for stands in late stages of development is Class 2, where tree diameters range from 20.0 to 29.9 cm (Figure 7.). Eastern hemlock has the greatest density under this class, with approximately 4,900 trees/ha.

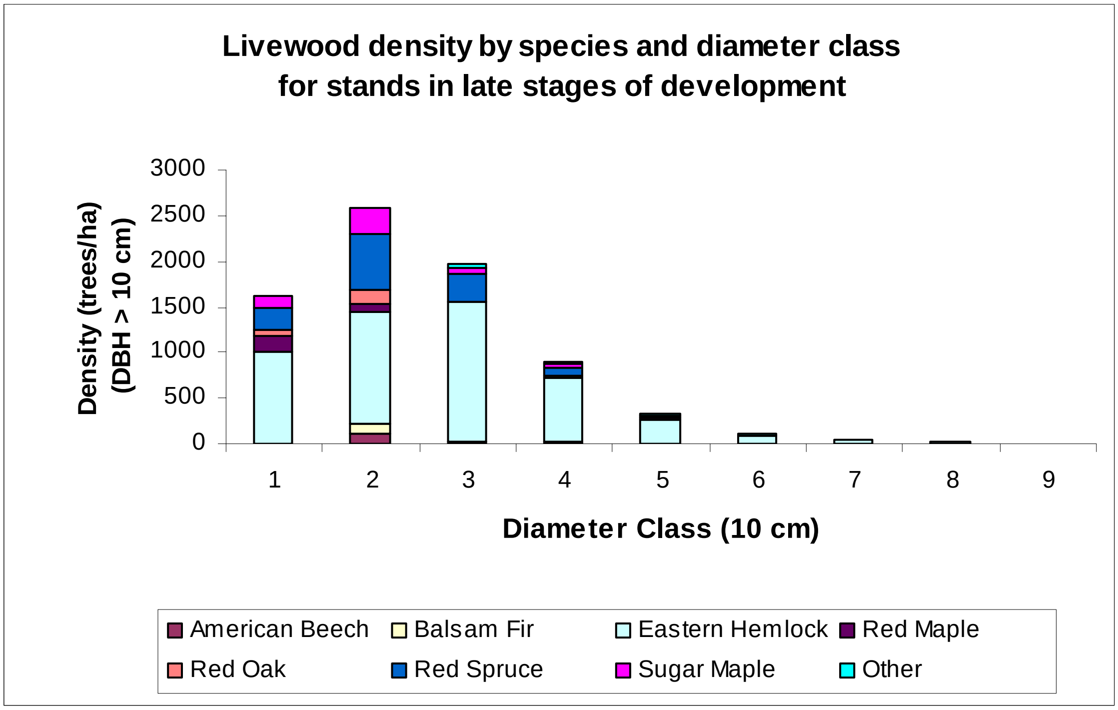

Figure 7. Distribution of livewood density by species and diameter class (10 cm)

The median basal area, median density and median DBH for standing deadwood for stands in late stages of development is 2 m²/ha, 43 trees/ha and 33.2 cm respectively (Table 1.). The proportion of total basal area for standing deadwood represented by long-lived species is approximately 62% (or 48 m²/ha), with balsam fir comprising the remainder at approximately 38% (or 30 m²/ha). The species that dominate the standing deadwood community, based on Importance Values, are balsam fir (45.74), red spruce (34.81), eastern hemlock (13.82), American beech (3.90) and white pine (1.72). The diameter class containing the greatest standing deadwood density is Class 1, where balsam fir with a total density of approximately 745 trees/ha dominates this class (Figure 8). Decay Class 1 contains the highest density of standing deadwood, where balsam fir dominates this class with a total density of approximately 924 trees/ha.

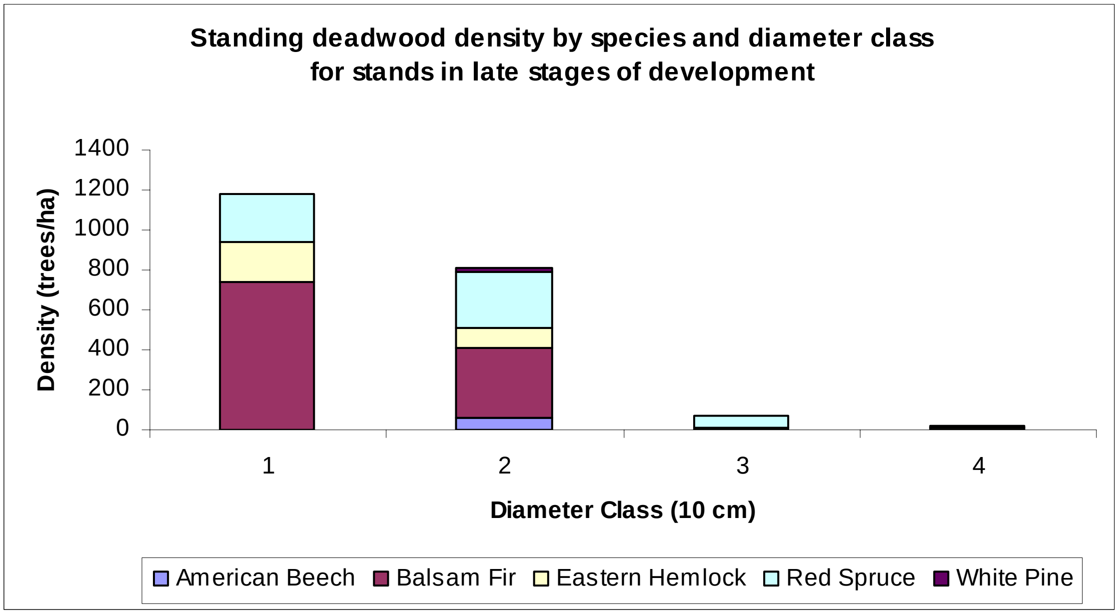

Figure 8. Distribution of standing deadwood density by species and diameter class (10 cm)

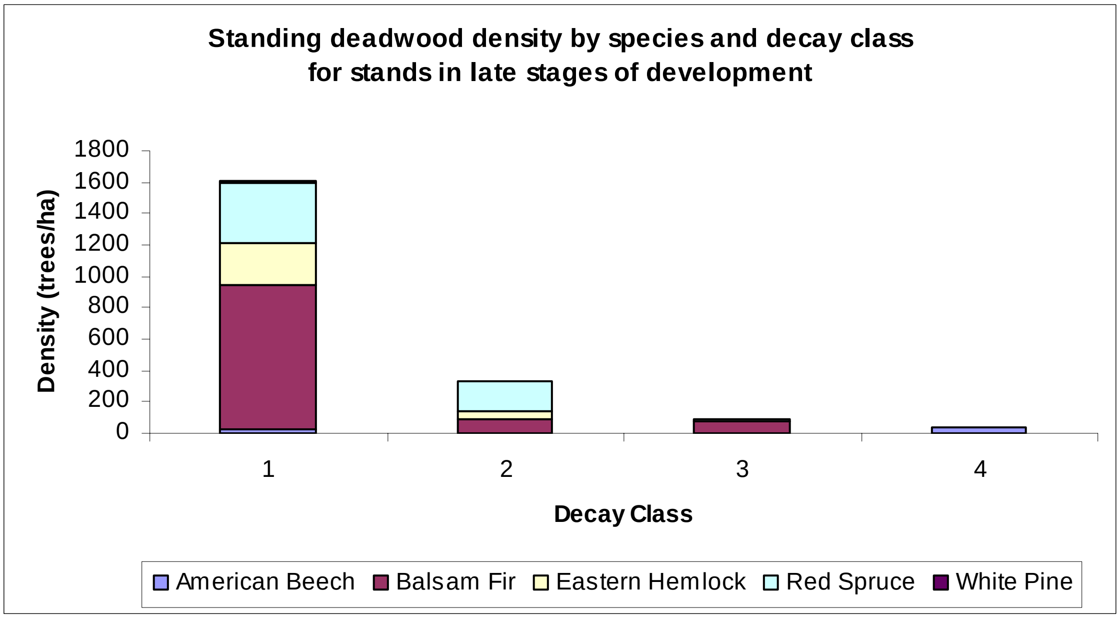

Figure 9. Distribution of standing deadwood density by species and decay class

For downed deadwood, the median basal area, median density and median DBH are 4 m²/ha, 78 trees/ha and 32.8 cm respectively (Table 1.). The proportion of total basal area for downed deadwood represented by long-lived species is approximately 76% (or 58 m²/ha), where balsam fir represents the remainder of the total basal area by approximately 24% (or 18 m²/ha). The species that dominate the downed deadwood community, based on Importance Values, are red spruce (39.54), balsam fir (29.84), eastern hemlock (20.59), American beech (6.46) and sugar maple (3.57). The diameter class containing the greatest downed deadwood density is Class 2 (Figure 10), where balsam fir dominates the class with approximately 232 trees/ha. Decay Class 1 contains the most of downed dead trees per ha, represented by red spruce with approximately 327 trees/ha (Figure 11.).

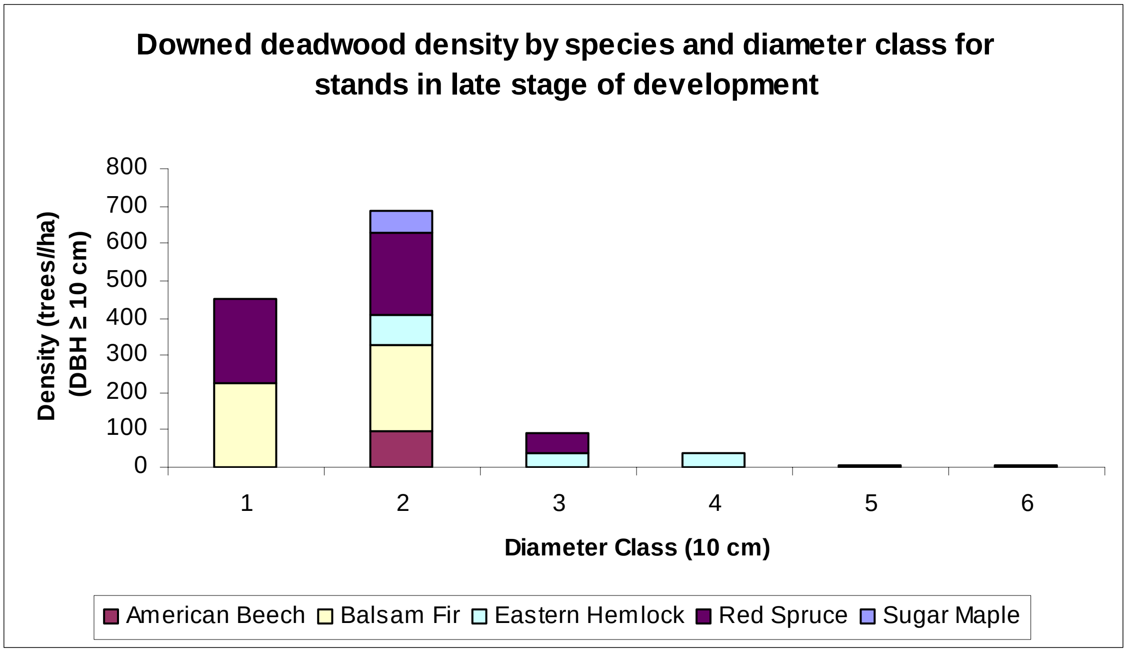

Figure 10. Distribution of downed deadwood density by species and diameter class (10 cm)

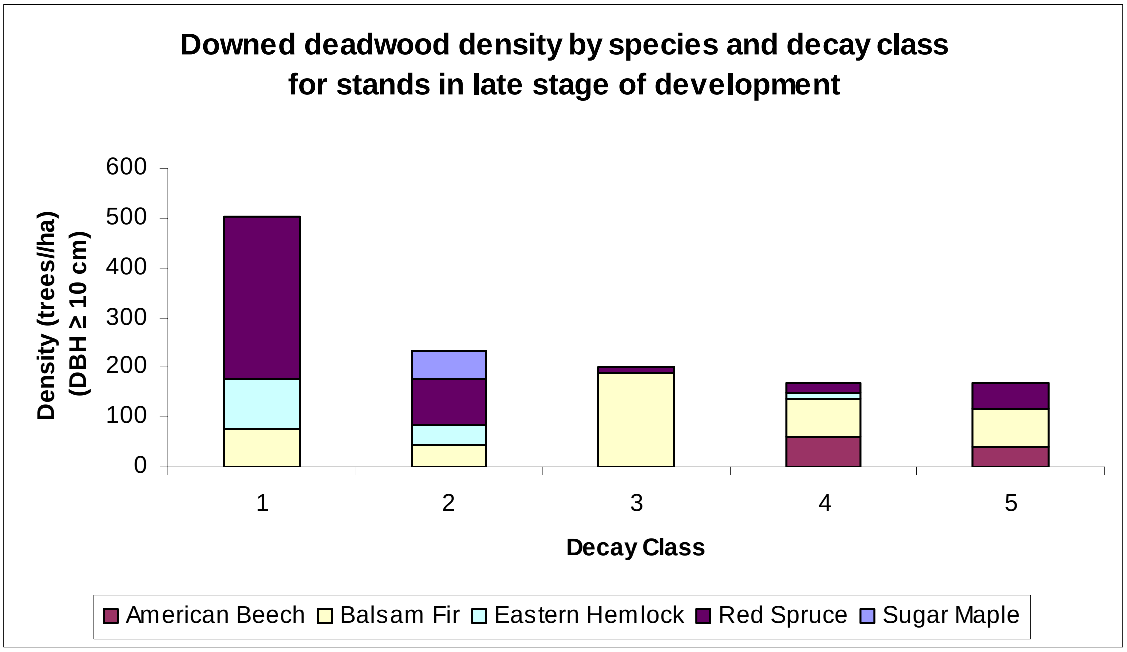

Figure 11. Distribution of downed deadwood density by species and decay class

3.2 Stage of Development Index

A stage of development index, based on livewood characteristics, was developed to approximate stand age by arranging point samples along a forest development continuum and was considered the best method for addressing the objectives of this research. It is understood that depending upon the level of human activity at a given area under study stands may follow different developmental trajectories (Seymour *et al.* 2002) so that the index in this research is not intended to represent stand age per se or a direct progression in stage of development from one point sample to the next. The index represents a manner in which point samples can be ordered from early to late stages of development, so that the response of livewood and deadwood variables in terms of advancing forest development can be analyzed.

The index assumes that as forests progress from an early to late stage of development, the total basal area for long-lived livewood, as well as the median diameter for all livewood, will increase with advancing forest development. For this dataset, the stage of forest development is represented by the following index:

(longevity proportion multiplied by median diameter) / 100

where the longevity proportion is denoted by the proportion of total basal area represented by long-lived livewood (i.e. long-lived total basal area/total basal area). The denominator of 100 represents a constant in which index values and corresponding point samples are aligned between 0.00 and 1.00, where 0.00 would denote stands in earlier stages of development. An index value of 1.00 would potentially represent an old growth forest, if the index were denoted by the following values:

(1 multiplied by 100)/100

where 1 represents the longevity proportion and 100 in the numerator denotes the median livewood diameter in centimeters (Lauriault 1989).

The index also assumes that the median diameter for livewood as well as the total density for long-lived livewood will increase as forest development advances, and is supported by Figure 12 and Figure 13, respectively. The placement of the point samples in red, along the stage of development index in Figure 13, is due to the high concentration of red spruce and the assignment of the term long-lived to this species that ultimately determines the longevity proportion for those sample points in red. The high density values associated with these point samples are due to a low median diameter range (12.9 to 19.0 cm) that represent these early successional stands.

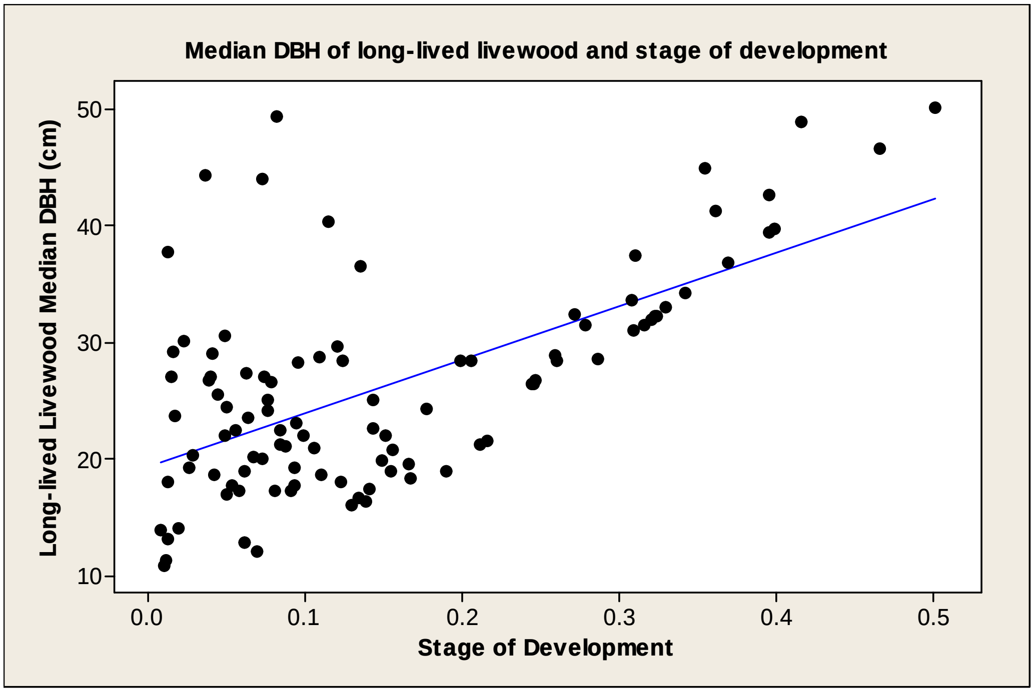

Figure 12. Scatterplot of median diameter for long-lived livewood and stage of development.

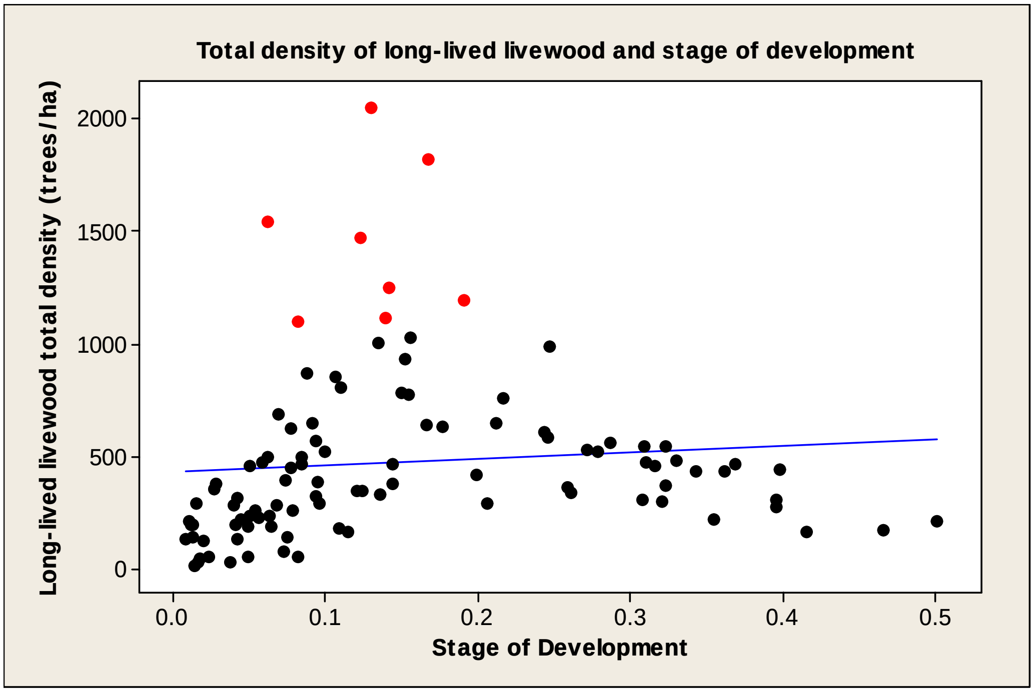

Figure 13. Scatterplot of total density for long-lived livewood and stage of development. Point samples with a relatively high density are shown by the red dots and indicate red spruce stands with a low median diameter.

There were several livewood characteristics examined when determining an index for stage of development. One of them was the maximum diameter (instead of median diameter) observed at each point sample. When applied to the index formula, a number of early successional stands were arranged further along the index suggesting these stands were more advanced in terms of their assigned early stage of development which was incompatible with the summarized variables used in the initial assignment of an earlier successional stage. A closer examination of the dataset including aerial photos crossed-referenced with point sample positions in the field indicated land clearing activity within close proximity of the point samples under question. The distribution of total basal area and total density by species and diameter class for each point sample indicated the presence of a proportionately small number of trees occurring in larger diameter classes for several point samples. The conclusion was that for some point samples the largest tree represented a true legacy tree, a tree which had been left on site at the time land clearing activity occurred. Due to the possible presence of legacy trees at some of the point samples, application of maximum diameter (instead of median diameter) to the index formula for this dataset was not considered a reasonable representation of stage of stand development.

Median diameter was also considered, without longevity proportions, as a means of approximating stand age for subsequent correlation analysis. Initial visualizations by way of various scatterplots to examine the response of livewood and deadwood variables in relation to increasing median livewood diameter did not produce a pattern in which to support the use of median diameter as a way of approximating stage of development. In addition, it is known that tree size and stand age may not be well correlated as indicated by cores taken from smaller-sized trees for stands appearing on relatively poor sites (Bondrup-Nielsen 2006).

A stage of development index in which the longevity proportion based on total density (instead of total basal area) was considered inappropriate for the purposes of this research due to the direct relationship between tree density and diameter, as density values were derived directly from diameters in this study.

3.3 Exploratory Analysis

3.3.1 Decay Class Categories

There was a departure from the manner in which penetrometer measurements were applied in classifying decay for standing and downed deadwood as described in Section 2.4, due to the small number of downed deadwood present in high decay. Alternatively, histograms were used to arrange the deadwood component under two decay classes – low and high decay, where penetrometer measurements ≥ 2.0 and 1.7 cm denoted low decay and penetrometer measurements < 2.0 and 1.7 cm indicated high decay for long-lived standing and long-lived downed deadwood, respectively (Appendix B).

3.3.2 Segregation of Deadwood Component

In preparation for correlation analysis, scatterplots were applied to identify the standing and downed deadwood for long-lived species in low and high decay that may have occurred as a result of previous forest conditions. In early stages of forest development, the median diameters for standing and downed deadwood are not expected to exceed the median diameter for livewood. For point samples in which this occurs, the deadwood (standing or downed) is assumed to be the result of a past forest condition, for stands in early stages of development. For long-lived standing deadwood in low decay, point samples where the median diameter is greater than the median diameter for long-lived livewood are shown in red in Figure 14.

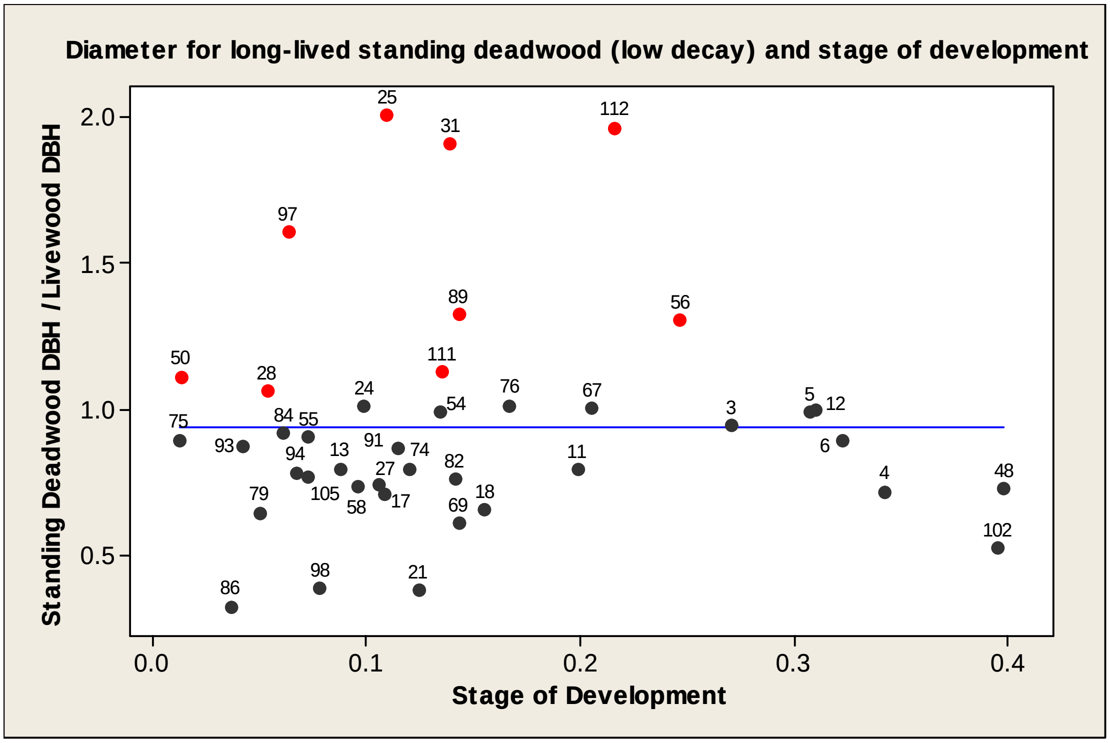

Figure 14. Scatterplot of median diameter for long-lived standing deadwood in low decay and stage of development, where points in red indicate median diameters for deadwood exceed median diameters for livewood, for long-lived species.

When point samples in red are removed, the scatterplot indicates a positive relationship where median diameter for long-lived standing deadwood in low decay increases with advancing stage of development (Figure 15).

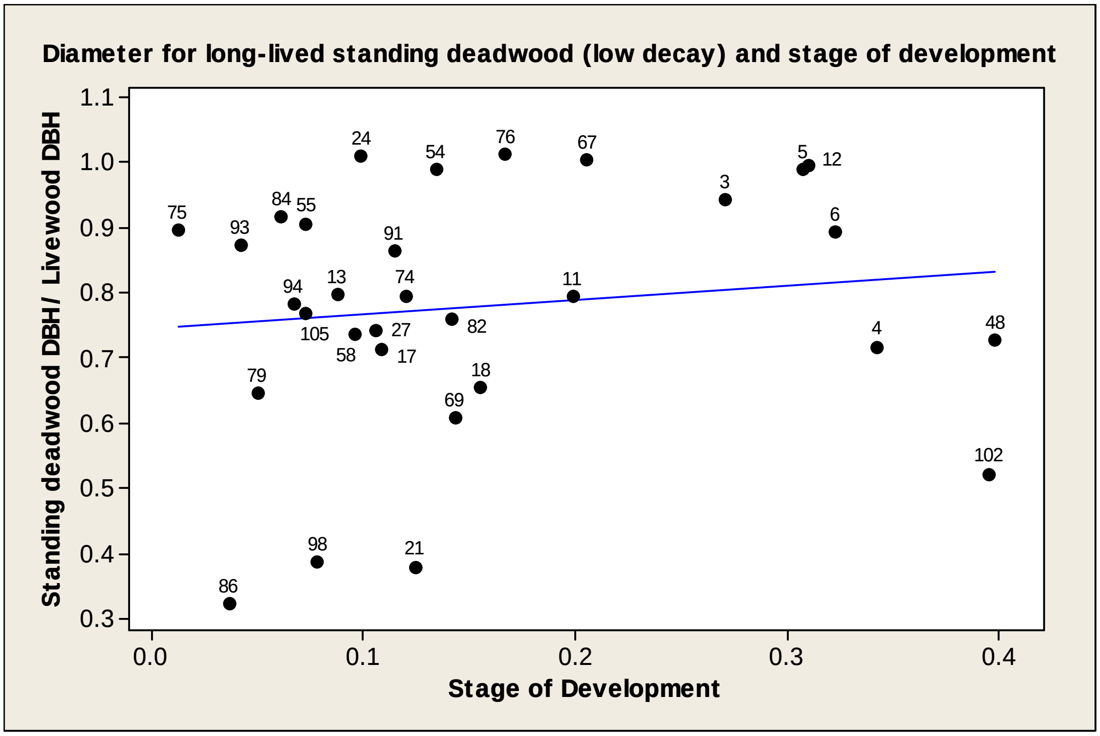

Figure 15. Scatterplot of median diameter for long-lived standing deadwood in low decay and stage of development, where points in red indicating median diameters for deadwood exceed median diameters for livewood, for long-lived species, have been removed.

Point samples where the median diameter for standing deadwood in high decay exceeds the median diameter for livewood, for long-lived species, are shown in red in Figure 16.

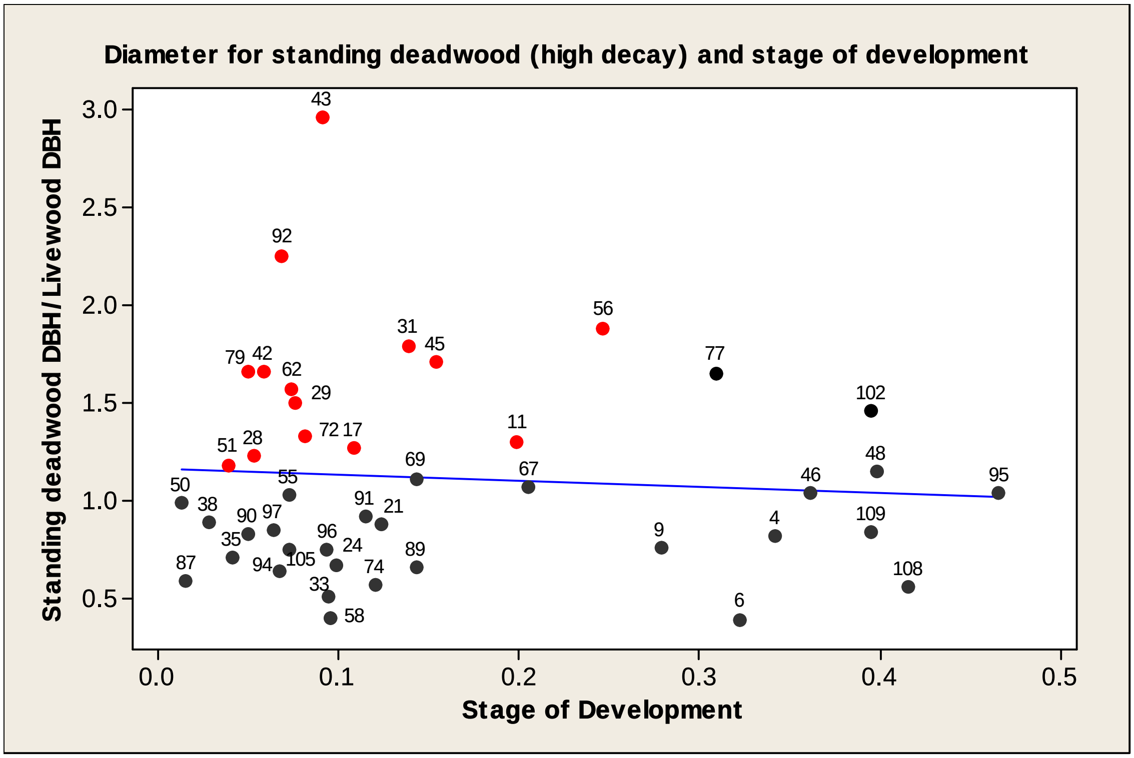

Figure 16. Scatterplot of median diameter for long-lived standing deadwood in high decay and stage of development, where points in red indicate median diameters for deadwood exceed median diameters for livewood, for long-lived species.

When point samples in red are removed, the scatterplot indicates a positive relationship where median diameter for long-lived standing deadwood in high decay increases with advancing stage of development (Figure 17.)

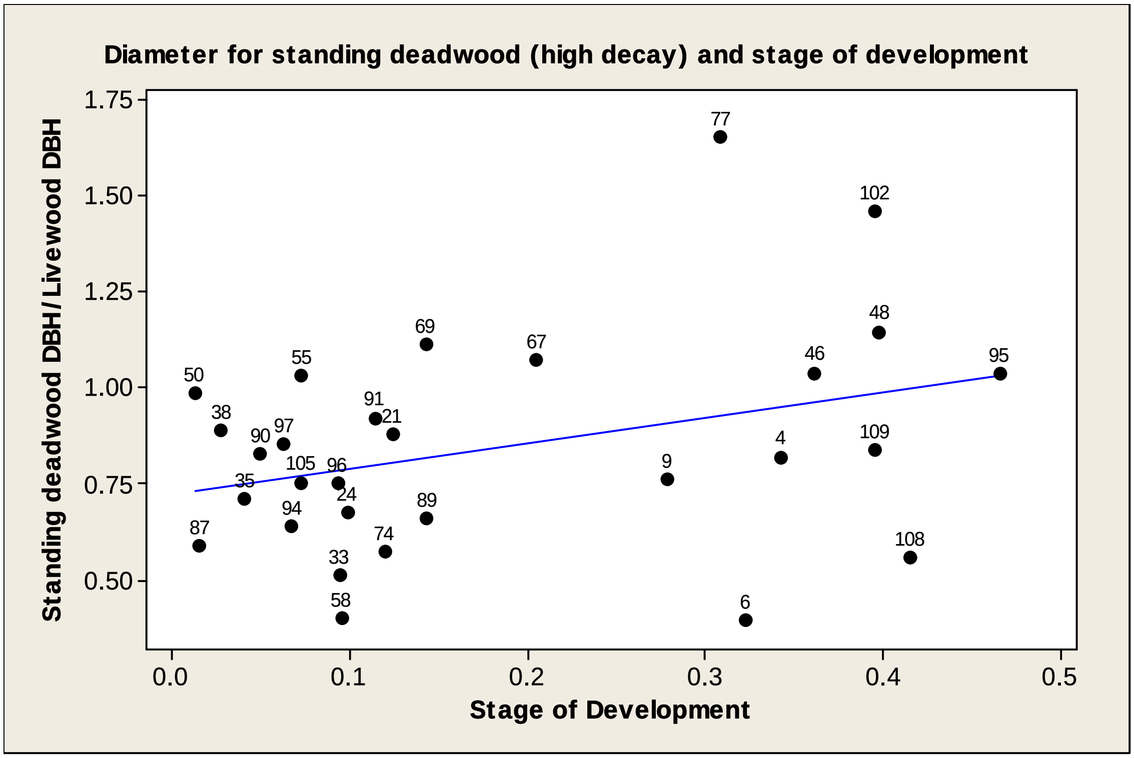

Figure 17. Scatterplot of median diameter for long-lived standing deadwood in high decay and stage of development, where points in red indicating median diameters for deadwood exceed median diameters for livewood, for long-lived species, have been removed.

Point samples where the median diameter for downed deadwood in low decay exceeds the median diameter for livewood, for long-lived species, are shown by the red points in Figure 18. When point samples in red are removed, the scatterplot indicates a positive relationship where median diameter for long-lived downed deadwood in low decay increases with advancing stage of development (Figure 19.).

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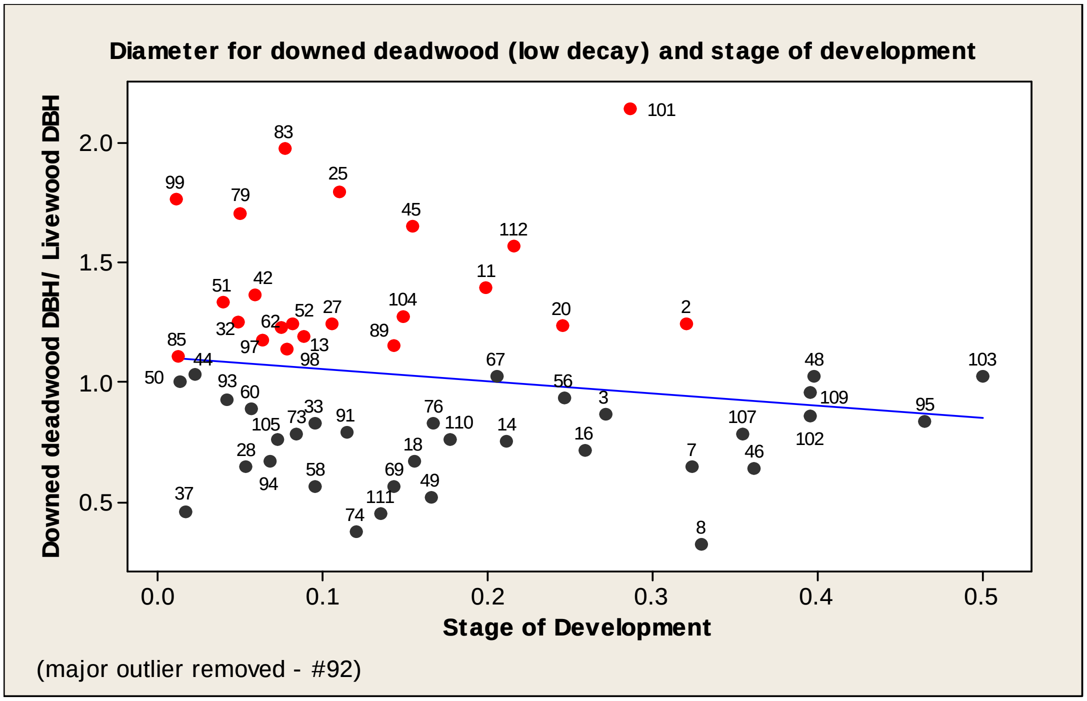

Figure 18. Scatterplot of median diameter for long-lived downed deadwood in low decay and stage of development, where points in red indicate median diameters for deadwood exceed median diameters for livewood, for long-lived species.

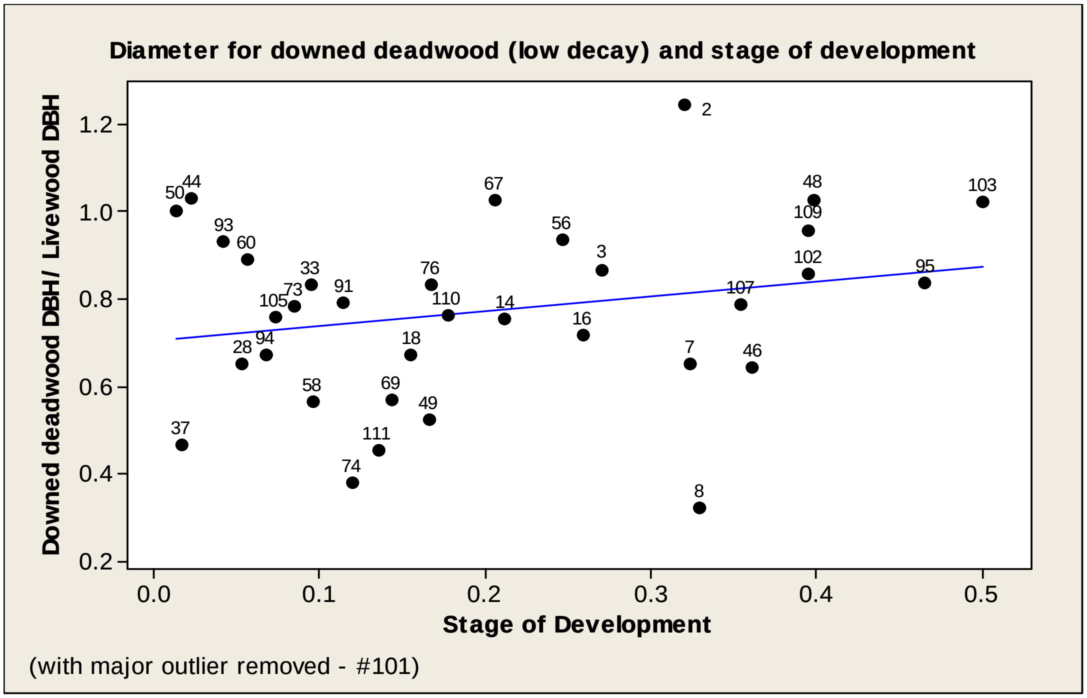

Figure 19. Scatterplot of median diameter for long-lived downed deadwood in low decay and stage of development, where points in red indicating median diameters for deadwood exceed median diameters for livewood, have been removed.

Point samples where the median diameter for downed deadwood in high decay exceeds the median diameter for livewood, for long-lived species, are shown by the red points in Figure 20.

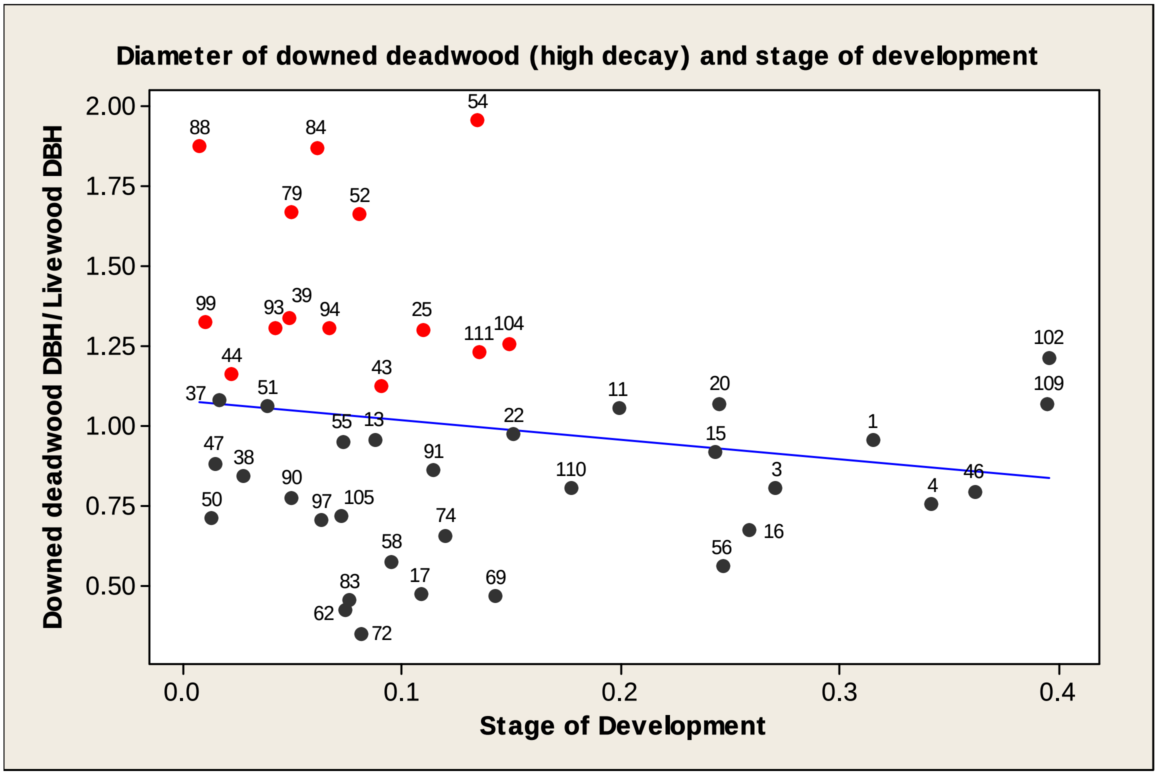

Figure 20. Scatterplot of median diameter for long-lived downed deadwood in high decay and stage of development, where points in red indicate median diameters for deadwood exceed median diameters for livewood, for long-lived species.

When point samples in red are removed, the scatterplot indicates a positive relationship where median diameter for long-lived downed deadwood in high decay increases with advancing stage of development (Figure 21.).

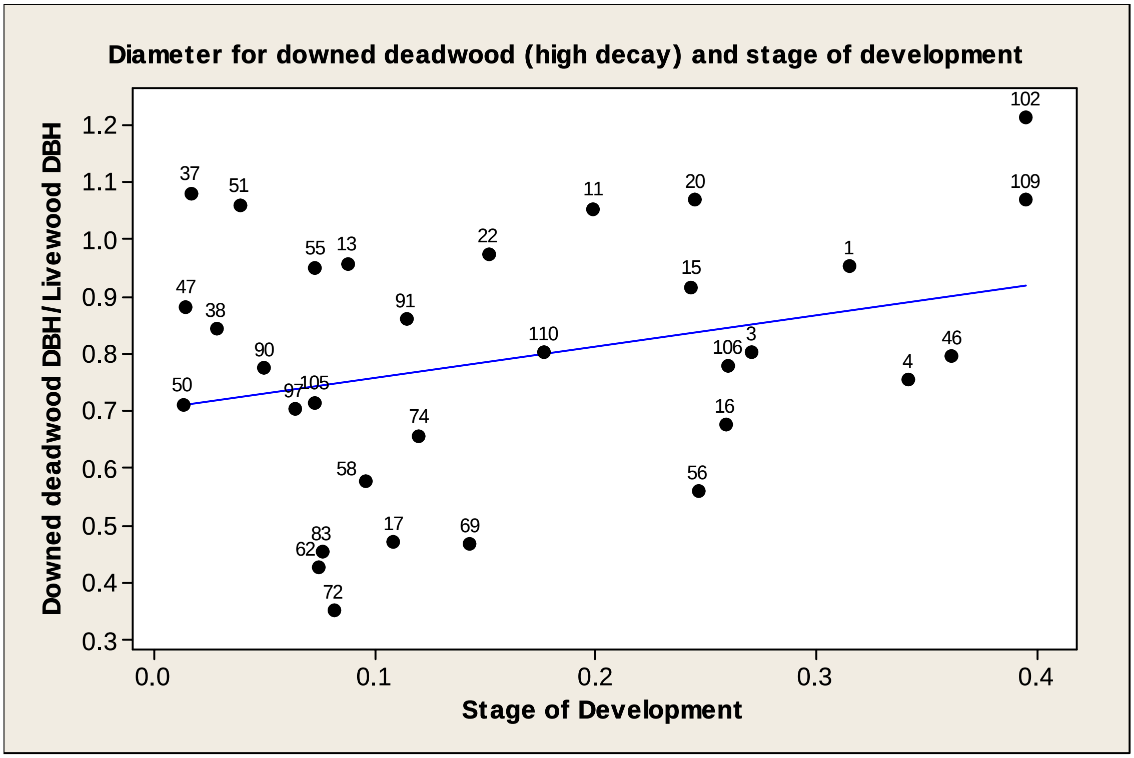

Figure 21. Scatterplot of median diameter for long-lived downed deadwood in high decay and stage of development, where points in red indicating median diameters for deadwood exceed median diameters for livewood, have been removed.

3.4 Data Analysis

The results of the exploratory analysis indicate a positive relationship between the median diameter of livewood and standing and downed deadwood in low and high decay, for long-lived tree species. Univariate regression analysis will be applied to determine whether diameter and density for long-lived livewood and deadwood are more correlated in later stages of development than earlier stages. Regression analysis is expected to indicate whether deadwood quantities occurring under natural conditions in different Acadian forest types can be predicted.

4.0 SUMMARY[19]

4.1 Stand Descriptions

The stands in early stages of forest development as represented by this dataset show a balsam fir-red spruce-red maple livewood community and a balsam fir-red spruce-trembling aspen community for standing and downed deadwood, typical of an early successional Acadian forest (Mosseler *et al.* 2003a). The density of species by diameter class follows a reverse-J distribution (Stewart *et al.* 2003) for the livewood and deadwood communities and is associated with forests in early stages of development, where peak distribution occurs in the smallest diameter range; and in the case of this dataset: 10.0 – 19.9 cm. For the decay classes, density distribution for standing deadwood also follows a reverse-J distribution with peak distribution occurring in Decay Class 1 (low decay). For downed deadwood density distribution is bimodal, with peak distributions occurring in Class 2 and 5 (high decay), where diameters range from 10.0 – 39.9 cm for Decay Class 5. The dataset indicates that for stands in early stages of development, early successional species dominate the livewood and deadwood communities, where tree diameters are less than 40 cm and most of the deadwood component is in a low level of decay with the exception of downed deadwood, where 23% of the total downed deadwood density is in advanced decay. A lower livewood Importance Value for trembling aspen compared to its Importance in the deadwood community as well as a low level of decay could suggest the species is not regenerating in the under story and is being replaced by red maple, as suggested by a higher red maple Importance Value for livewood than deadwood.

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[19] (Flynn 2008).

The dataset indicates that stands in later stages of development are represented by an eastern hemlock-red spruce-sugar maple livewood community, where a balsam fir-red spruce-eastern hemlock community comprises the standing and downed deadwood component. The density of species by diameter class for livewood is right skewed with peak distribution occurring in Class 2. Diameters for livewood range from 10.0 – 89.9 cm. For standing deadwood, diameters and density of species by decay class follow a reverse-J distribution with peak distribution for both diameter and decay in Class 1. Downed deadwood follows a unimodal diameter distribution with peak distribution in Diameter Class 2. The diameter range for downed deadwood is 10.0 – 69.9 cm. The dataset indicates that for stands in later stages of development, late successional species dominate the livewood and the deadwood communities, with the exception of balsam fir – which is expected for form part of the deadwood component for forests in late stages of development. Balsam fir is a component in the under story of an older forest and would not be expected to reach the canopy due to its low tolerance to shade (Mosseler *et al.* 2003a). The broad diameter distribution for livewood (Figure7), suggests an uneven-aged forest (Stewart *et al.* 2003), where standing and downed deadwood ranging in diameter from 10.0 – 69.9 cm are primarily in low levels of decay. When the longevity proportion based on deadwood basal area is examined for the late successional stands appearing along a forest continuum, the indication is that 13 (longevity proportion < 75 %) of the 19 point samples represent stands in later stages of development. The remaining stands appear to be in a state of transition from a mid-successional to late stage of forest development.

4.2 Deadwood Predictions

It was noticed that stand descriptions particularly for deadwood by decay class (4 for standing and 5 for downed deadwood) did not reveal evidence of residual deadwood associated with a past forest condition, as indicated by stands when examined along a forest continuum. This could suggest estimating deadwood quantities based on natural conditions when discrete groups are applied, may be inappropriate due to a possible latent deadwood component associated with previous forest types. Should the results of regression analysis indicate a greater correlation between livewood and deadwood characteristics in later stages of development, extrapolation procedures will be applied to estimate standing and downed deadwood quantities associated with them, and will form the basis of forest descriptions.

LITERATURE CITED

Avery, T. E. and H. E. Burkhart. 2002. Forest Measurements. 5th ed. McGraw Hill, New York. 456 pp

Bayne, D. 2006. Personal communication. Nova Scotia Nature Trust, Halifax, Nova Scotia

Benjamin, L. 2006a. Unpublished data. Department of Natural Resources, Kentville, Nova Scotia

Benjamin, L. 2006b. Unpublished property grid for the Wolfville Watershed property. Department of Natural Resources, Kentville, Nova Scotia

Benjamin, L. 2007. Written communication. Department of Natural Resources, Kentville, Nova Scotia

Bondrup-Nielsen, D.S. (Thesis Advisor) 2006. Personal communication. Acadia University, Wolfville, Nova Scotia

Flynn, J.R. 2005. Masters Thesis Research Proposal. Acadia University, Wolfville, Nova Scotia.

Flynn, J.R. 2007. Wolfville Watershed Preservation Report. Acadia University, Wolfville, Nova Scotia

Flynn, J.R. 2008. Deadwood estimates based on livewood and deadwood correlations under natural conditions in the Acadian forest of Nova Scotia (working title), Masters Thesis (in progress), Acadia University, Wolfville, Nova Scotia

Forsythe, B. and Alliston, G. (local naturalists). 2007. Personal communication. Wolfville, Nova Scotia

Grosenbaugh, G.H. 1952. Plotless timber estimates – new, fast, easy. Journal of Forestry 50: 32-37

Jordan, G.J., Ducey, M.J. and Gove, J.H. 2004. Comparing line-transect, fixed-area, and point relascope sampling for dead and downed coarse woody material in a managed northern hardwood forest. Canadian Journal of Forest Research 34: 1766-1775

Lauriault, J. 1989. Identification Guide to the Trees of Canada. Fitzhenry & Whiteside, Markham.

Lynds, A. 1992. Provisional ecological characteristics of old growth forests for Nova Scotia: an Acadian Forest perspective. Pages 339-344 *in* Drysdale, C., Bondrup-Nielsen, D.S., Munroe, N., Willison, S., Herman, T.B. and Eagles, P. (eds.). Science and the Management of Protected Areas: Development in Landscape Management

Lynds, A. 2006. Personal Communication. Department of Environment and Labour, Environmental and Natural Areas Management Division, Truro, Nova Scotia

McComb, W. and Lindenmayer, D. 1999. Dying, dead and downed trees. Pages 335-372 *in* Hunter, M.L., Jr. (ed.), Maintaining Biodiversity in Forest Ecosystems. Cambridge University Press, Cambridge

McCurdy, D. and Stewart B. 2005. Changes in deadwood structure following clear-cut harvesting in Nova Scotia softwood forests. Forest Research Report FOR 2005-1 No. 76, Nova Scotia Department of Natural Resources, Forest Management Planning, Halifax

Mosseler, A., Lynds, J.A. and Major, J.E. 2003a. Old growth forest of the Acadian forest region. Environ. Rev. 11: S44-S77

Mosseler, A., Thompson, I. and Pendrel, B.A. 2003b. Overview of old-growth forests in Canada from a science perspective. Environ. Rev. 11: S1-S7

Nilsson, S.G., Niklasson, M., Hedin, J., Aronsson, G., Gutowski, J.M., Linder, P., Ljungberg, H., Mikunsinski, G. and Ranius, T. 2003. Erratum to "Densities of large living and dead trees in old-growth temperate and boreal forests". Forest Ecology and Management 178: 355-370

Nova Scotia Department of Natural Resources. 2008. State of the Forest Report 1995-2005, Nova Scotia Forests in Transition. Nova Scotia Department of Natural Resources, Halifax

Stahl G., Ringyall, A., Gove J.H., Ducey, M.J. 2002. Correction for slope in point and transect relascope sampling of downed coarse woody debris. Forest Science 48 (1): 85-92

Seymour, R.S., White, A.S. and deMaynadier, P.G. 2002. Natural disturbance regimes in northeastern North America - evaluating silvicultural systems using natural scales and frequencies. Forest Ecology and Management 155: 357-367.

Sparks, J.C., Masters, R.E. and Payton M.E. 2002. Comparative evaluation of accuracy and efficiency of six forest sampling methods. Proc. Okla. Acad. Sci. 82: 49-56

Spies, T. and Turner, M. 1999. Dynamic forest mosaics. Pages 95-160 *in* Hunter, M.L., Jr. (ed.), Maintaining Biodiversity in Forest Ecosystems. Cambridge University Press, Cambridge

Stead, R.(Mayor). 2007. Personal communication. Town of Wolfville, Wolfville, Nova Scotia

Stewart, B.J., Neily, P.D., Quigley, E.J., Duke, A.P. and Benjamin, L.K. 2003. Selected Nova Scotia old-growth forests: Age, ecology, structure, scoring. The Forestry Chronicle 79 (3): 632-644

Thompson, I.D; Ortiz, D.A; Jastrebski, C. and Corbett, D. 2006. A comparison of prism plots and modified point-distance sampling to calculate tree stem density and basal area. Northern Journal of Applied Forestry 23 (3): 218-221

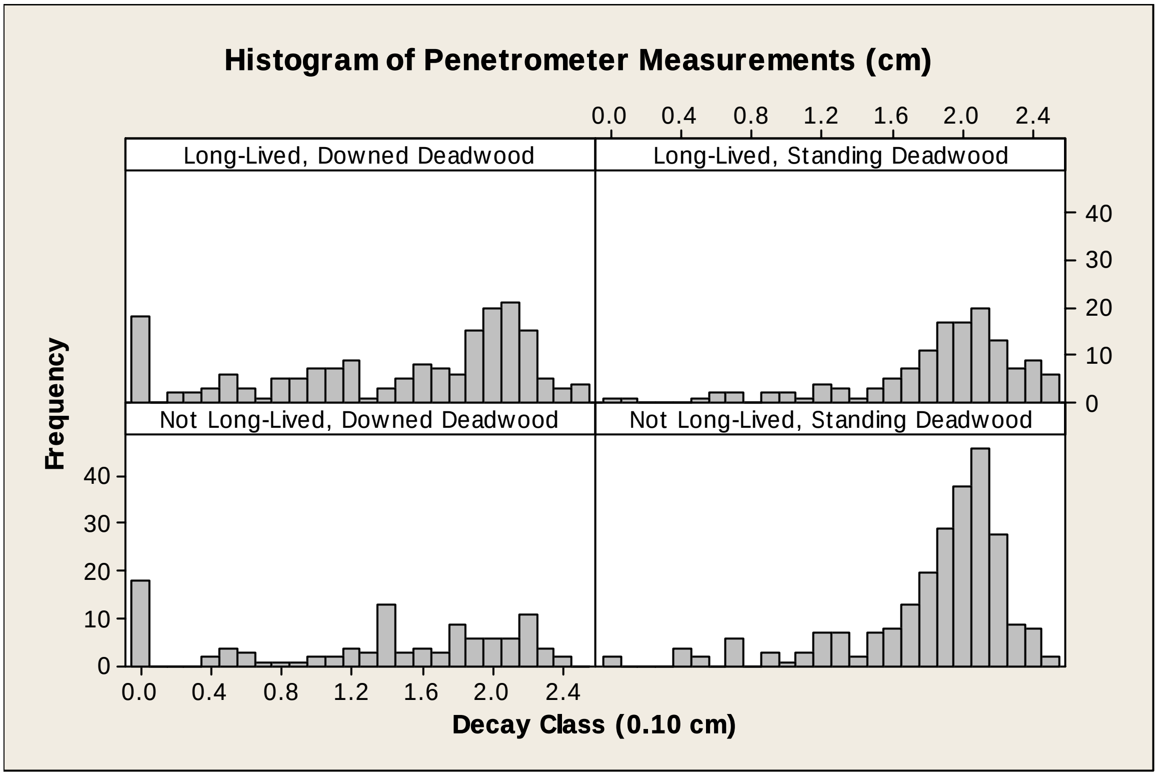
Wilson, S.J., Colman, R., O'Brien, M., Pannozzo, L. 2001 (revised 2002). The Nova Scotia Genuine Progress Index (GPI) Forest Accounts, Volume 1 Indicators of Ecological, Economic and Social Values of Forests in Nova Scotia. GPI Atlantic, Measuring Sustainable Development, Halifax

APPENDIX A

Decay Class	Qualitative Descriptions*	Standing Deadwood		Downed Deadwood	
		Tree Decay (%)	Penetrometer Measurements (cm)	Tree Decay (%)	Penetrometer Measurements (cm)
I	Freshly dead, bark intact, branches intact (including small), needle/leaf retention, bole sound, bole raised off ground on branches.	0 – 24.99	2.5 – 1.9	0 – 19.99	2.5 – 2.1
II	Beginning of decay but not well established in wood that was sound at time of death. Bark mostly intact, branch stubs, bole not raised on branches, bole mostly sound.	25 – 49.99	1.8 – 1.3	20 – 39.99	2.0 – 1.6
III	Rot becoming established at core. Bark loose and mostly flaked off, bole beginning to rot but maintaining structural strength - round, straight, not sinking into ground.	50 – 74.99	1.2 – 0.7	40 – 59.99	1.5 – 1.1
IV	Advanced decay. Bark mostly absent, bole mostly decayed with little or no wood present. Colonized with vegetation. Lacking structural strength - bole oval and bending to shape of ground. Last stage for snags, which will be rotted, wobbly and could be easily pushed over.	≥ 75.00	0.6 – 0.0	60 – 79.99	1.0 – 0.6
V	Rotted through, becoming humus. Sunken into mound on the ground, but retaining a woody character, not yet part of soil.	N/A	N/A	≥ 80.00	0.5 – 0.0

Appendix A. Qualitative decay class descriptions with corresponding tree decay percentages in 25 and 20 percent intervals for standing and downed deadwood respectively, and corresponding penetrometer measurements. * Stewart (*et al.* 2003)

APPENDIX B



Appendix B. Histogram of penetrometer measurements for long-lived and not long-lived standing and downed deadwood