

**Long-term Ecological Implications of the Use of Riparian
Buffer Strips in Forest Management: Vegetation Plot
Establishment and Baseline Data Collection in Eastern
Manitoba**



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Executive Summary

The use of forested riparian buffer strips for forest management is a common practice in Canada. However, for these strips to effectively meet the objectives they were put in place for, the trees must remain standing for the long term. Windthrow, a common occurrence after forest harvesting, greatly reduces the ability of buffer strips to meet their original objectives. In addition, blowdown may also affect the long term regeneration of forests in riparian areas. The baseline information from our study, coupled with long-term monitoring will help assess the long-term ecological implications of the use of forested riparian buffer strips in forest management.

Windthrow on cutblock edges is a well documented consequence of forest harvesting. Multiple factors cause mortality in trees ranging from climate, successional events, extreme weather events, insect damage, to wind stress. Although most factors causing mortality cannot be managed for, insect and increased wind stress are within the realm of control in forest management. Reducing boundaries with non windfirm trees is a key factor to reducing blowdown. Insect outbreaks may also weaken trees severely, increasing the likelihood of windthrow.

The Metcalf Lake area in Nopiming Provincial Park was harvested in 1998 and 2003, and a 100 metre treed riparian buffer was left in place around the lake. In 2008, ten tree health and monitoring plots using the Ecological Monitoring Assessment Networks (EMAN) protocols were established to look at windthrow and the long term health of the buffer area. Plots were divided between areas with high amounts of blowdown, and areas with lower blowdown rates. These plots allow for the long term assessment of the downed volume of wood, examining stand health, tracking regeneration, and assessing windthrow over time.

Jack pine (*Pinus banksiana*) was the dominant tree in the riparian forest stand, followed closely by black spruce (*Picea mariana*). White birch (*Betula papyrifera*) was present but not in significant amounts. The amounts of dead standing and fallen trees combined outnumbered the amount of live standing trees in blow-down plots for both jack pine and black spruce. In live-standing plots the opposite was true, with live standing trees outnumbering the combined amount of dead trees. Basal area of live trees in live-standing plots was much higher than dead trees in the plot, indicating most dead trees were small in size. Conversely, basal area in blow-down plots had a similar proportion of the number of live to dead trees, indicating that the deadfall was composed of large dominant and codominant trees.

The shrub layer was not very diverse in either of the two plot types. The majority of tree regeneration was from black spruce seedlings. Blow-down plots had less shrub diversity, with white birch regenerating in higher amounts. Live-standing plots had more shrubs present, with rose and raspberry present in higher amounts.

Ground cover was sparse in both plot types despite having a high percent transmission of sunlight. Blow-down plots had the highest light transmission, averaging approximately 90%. Live-standing plots had a lower average of 69%. The majority of ground cover consisted of moss, blueberry, bearberry and lichen. Moss was the most abundant, covering over 55% for both plot types. Blueberry was second highest in blow-down plots, with over 10% cover. Lichen and bearberry were more common in the live-standing plots, having over 15% and 10% cover, respectively.

Downed woody debris (dead trees on the ground) measured in the each plot type showed distinct differences. Blow-down plots had a larger proportion of downed trees in the first and second decomposition classes, while live-standing plots had a much higher percentage in the fourth decomposition class. This indicates that a large proportion of the downed woody debris in blow-down plots originated from more recently deceased trees compared to live-standing plots.

Windthrow was a significant disturbance regime found in riparian forests surrounding Metcalf Lake. The use of forested riparian buffer strips around water bodies to protect a myriad of forest values must be carefully weighed against the long-term ecological implications of disturbances such as windthrow and regeneration in riparian forests.

Introduction

Forest harvesting has been taking place for many years throughout Canada. Modern forestry practices have both improved the techniques and efficiency of harvesting leading to increased levels of harvest. While efforts to reduce the effects of forest harvesting on a whole variety of forest values (e.g., water quality, wildlife habitat, etc.) have increased significantly in the last two decades, much still remains to be done. One such area is the damage and mortality of trees surrounding cutblocks, either by breaking somewhere along the stem, or uprooting. This is known as windthrow.

Natural forces constantly act on trees. Wind, gravity, snow loads and weather events all play a part in causing natural tree mortality; however, there are often predisposed factors or disturbances that increase the formation of snags and cause windthrow (Nowacki and Kramer 1998). Predisposed factors include topography, climate, succession, and stand characteristics, although it is the disturbances such as wind stress and insects that allow for these factors to have a greater impact (Frey et al. 2004). Disturbances range from animal damage, insects, fungi, chronic or extreme wind stress, or extreme weather (e.g., drought). Not all factors affecting forest stands are possible to manage in a forest management context, however, some are. Climate, extreme weather, succession, and extreme wind events may seem impossible to manage for, although the effects of certain characteristics that affect mortality such as topography, insect outbreaks, and wind stress events can be minimized.

Insect outbreaks are often difficult to manage. Common insect pests in Manitoba include the spruce budworm, forest tent caterpillars, the common stem borer, and pine beetles. The common stem borer can kill or weaken live trees, making them susceptible to windthrow (Frey et al. 2004), and pine beetles breed in windthrow logs (Quesnel and Waters, 2002). Outbreaks can also be cyclical with windthrow, with one causing the other.

Topography and wind stress causing endemic windthrow are manageable, and are often considered in silvicultural practices (Stathers et al. 1994). The differences between catastrophic windthrow and endemic windthrow are that catastrophic windthrow can destroy an area in less than a day (Frey et al. 2004), most trees will be blown over within 30° of the storm's wind direction (Stathers et al. 1994), sound wood is often found where trees have snapped (Worrall et al. 2005), its occurrence is largely unpredictable and is impossible to manage. The area catastrophic windthrow occurs in is usually less than 0.1 hectares (Worrall et al. 2005), although recent examples (e.g., catastrophic windthrow in the Whiteshell Provincial Park in eastern Manitoba) resulted in thousands of hectares of forest damage. Endemic windthrow however, is caused by several factors not related to short intense wind events. Prevailing, lower velocity winds can impact single trees, clusters of trees, or areas with unstable or abrupt boundaries (Stathers et al. 1994). Endemic windthrow can occur in healthy trees, although large portions are often affected by the previous listed predisposed factors and disturbances (Stathers et al. 1994). In addition, endemic windthrow tends to be accumulative, or a cyclical process where snags and healthy trees fall onto other trees, damaging or killing them (Nowacki and Kramer 1998, Worrall et al. 2005). Over time with frequent prevailing winds, other predisposed factors, and the secondary damage

caused by previous trees falling on them, more trees will fall causing yet more damage, continuing the cycle.

Windfirmness is a term used to describe how well a tree is can withstand constant wind effects (Stathers et al. 1994). Windfirmness in trees may develop over time from exposure to wind in consistent directions such as seasonal prevailing winds, and after the creation of a new boundary (Burton 2002, Quesnel and Waters 2002). In newly formed edges created by logging, fires, or thinning, an increased amount of mortality from wind induced uprooting and stem snaps are noted (Burton 2002), however, this is usually not the case with trees growing along natural boundaries such as lake edges (Senecal et al 2004). Roots may be progressively broken during a storm (Burton 2002), until the tree uproots, pulling up the root plate and a large portion of attached soil. Factors affecting how easily a tree uproots include root mass, depth, root size on the windward side of the tree, properties of the soil, and root health (Peltola 1996). Conversely, whether a tree stem will break depends on its height to diameter ratio as trees with a higher ratio are more prone to snapping (Frey et al. 2004). Trees may increase their windfirmness by increasing their root depth and strength, or self pruning branches to improve wind dynamics (Burton 2002, Worrall et al. 2005). White and Black Spruce have a shallow root system, therefore, non-windfirm trees are susceptible to uprooting, although if roots interlock they may have less chance of uprooting (Burton 2002).

Another factor affecting windthrow is the stand structure. Thinner stands (i.e., stands with trees spaced widely apart) may be more susceptible to windthrow, as winds do not dissipate as quickly, allowing higher velocity winds to penetrate the stand more deeply than in dense stands (Peltola 1996). Thinner stands are more prone to effects of increased wind such as damage to root systems (Stathers et al. 1994), xylem vessels, and can reduce the available moisture decreasing photosynthesis (Frey et al. 2004). Thinner stands do have an advantage of eventually becoming more windfirm than dense stands, as well having a lower height to diameter ratio which affects the chance of windthrow (Frey et al. 2004).

Two factors contributing to windthrow in a forest management context are cutblock size and the use of relatively narrow forested buffer strips along water bodies. Larger cutblocks allow for increased wind speeds (Peltola 1996). While smaller cutblocks or gaps don't allow air speeds to reach those that are found above or upwind in large open spaces. Also, winds can return quicker to their upwind speeds if stands are shorter and or are less dense (Peltola 1996). This provides a challenge to forestry companies, as larger cutblock sizes provide for increased harvest and cost efficiencies.

The second factor is that it is a common practice in North America and is usually a regulatory requirement, to leave unharvested strips of forest between cutblocks and adjacent water bodies. These buffer strips are thought to offer protection to the water bodies as well maintain the riparian forests themselves. Riparian buffer strips are thought to protect water quality, eliminate potential movement of eroded soils from the cutblock to water, stabilize near water slopes, protect unique riparian habitats and wildlife, and to add aesthetic quality to the area when viewed from the water. However, riparian buffer strips are prone to the same windthrow forces as any other part of the adjacent forest to cutblocks and are a new edge on which wind can act. As a result, windthrow in forested riparian buffers can be a major problem, significantly decreasing the chances that the buffer strips can fulfill its original objectives. Future forest regeneration in these riparian areas may also be affected in the long-term. Forested buffer strips in areas adjacent to harvest areas are usually in a mature condition already. Without proper renewal (from fire or harvesting), regeneration could be compromised.

Recent surveys and studies are providing new information for silviculture practice, as this study aims to do. Trees in the area around Metcalf Lake in Nopiming Provincial Park in the Manitoba Model Forest were harvested in 1998 and 2003 by Tembec Industries, leaving a 100 metre forested riparian buffer around the lake. Tree health plots in the remaining riparian forest were set up to assess the long term health of the treed buffer around Metcalf Lake and to examine the long term ecological implications of using buffer strips as a forestry prescription. This study aims to provide initial baseline results and draw some preliminary conclusions for the data collected.

Methods

Plot Establishment and Site Selection

The Metcalf Lake area was initially surveyed for potential plots on July 30, 2008. Plots were established from August 5 to 13, 2008. A total of ten 20 by 20 metre plots were established in locations around Metcalf lake area. Five plots were established in what was considered “blow-down” areas, and five established in “live-standing” areas. Blow-down plots were in areas with a significant amount of tree mortality, either with standing dead trees or trees lying on the ground. Conversely, live-standing plots were established in areas that appeared to be in good health, with relatively less mortality compared to

blow-down sites. A general description of the plots, area, and detailed rationale for plot selection is provided in the results and discussion section.

Plot establishment was performed by marking one corner (A corner), measuring 20 metres, placing another corner pin (B corner) and recording the bearing of the line (AB line). The subsequent two corners (C and D) were placed by turning 90° and measuring an additional 20 metres to form a square (Figure 1). A GPS waypoint including latitude, longitude, and GPS accuracy were recorded at the A corner pin. See appendix I for a list of GPS locations and information for each plot.

EMAN protocols were followed for the monitoring of all of the data collection including the canopy-tree stratum, shrub and small tree layer, and ground vegetation layer, described in detail by Roberts-Pichette and Gillespie (1999). The protocols also can be found on the EMAN website (www.eman-rese.ca), however, the protocols posted online have been updated and differ slightly from those earlier described by Roberts-Pichette and Gillespie (1999). The protocols used will be generally described below to avoid confusion.

Canopy Tree Stratum

Tree Measurement: In each 20x20 metre plot, trees with a diameter at breast height (dbh) over 10 centimetres were measured, and tagged with aluminum tags. Also, trees dead and lying prone on the ground were measured and tagged in the same way as live trees. Stand name, plot number, and tree number were etched onto the tag and attached to the tree with a nail and hammer. The position of each tree in the plot was recorded by taking its X and Y coordinates with a laser measurer. In relation to the established plot boundary lines; the AB and CD lines were the Y axis, and the BC and DA lines were the X axis, best described by Figure 1. Mapping the location of each tree in the plot is important for a few reasons. Firstly, tags on trees may go missing, be destroyed, or be pulled off by curious humans. Secondly, trees may go missing, either by being cut down (e.g., for firewood), falling over, etc. Thirdly, it allows for a good overview of the plot using the EMANs online software to visually view the placement of trees. The EMAN software presents a graphical representation of the plot, showing relative dbh, species and location of each tree from a bird's eye view. See appendix II for a printout and view of the plots using the EMAN software.

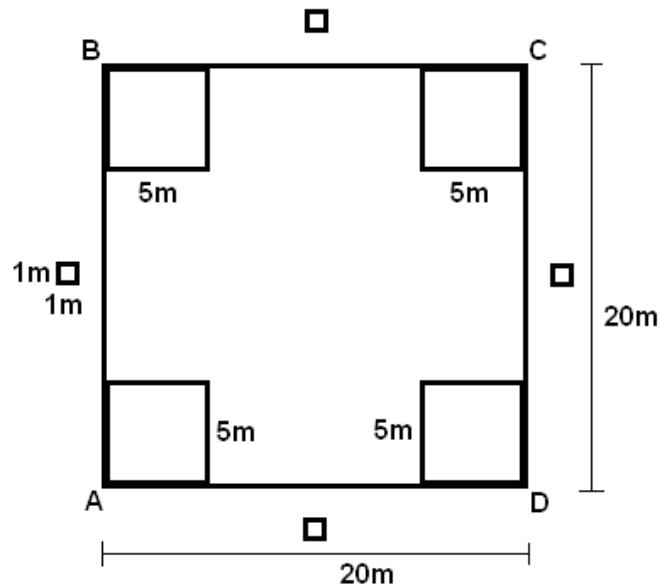


Figure 1: General 20x20 metre plot showing 5x5 metre nested shrub plots and 1x1 metre herb plots outside the plot.

Tree Calculations: Trees were grouped according to their species. Calculations were made for the number of live and dead trees, abundance for live and dead trees, basal area for live and dead trees, density and relative density, dominance and relative dominance, frequency and relative frequency, and importance value for each species and plot. Calculations involving dead trees were split into two categories, dead fallen and standing dead trees. The results were then averaged for each plot to give value that represents the area as a stand. Abundance and basal area were represented per hectare for ease of comparison to other datasets. Density and dominance were represented on a per metre squared basis. Relative density, relative dominance, frequency, and relative frequency were expressed as a percentage based on a comparison to the whole stand.

Abundance is the representation of the number of trees for each species per hectare of the stand. Basal area is the calculation of the dbh of each tree for a species represented as an area, summed and expressed per hectare for the stand. Density is defined as the average number of individuals of a species on a unit basis, or the abundance represented on a square metre basis instead of a per hectare basis for the stand. Relative density is the measure of one species density compared to all of the species. Dominance is the measurement of the area a species occupies in a stand on a unit basis, or the basal area represented on a per square metre rather than a per hectare basis for the stand. Relative

dominance is the dominance of a species compared to all of the species. Frequency is the distribution of a species in a stand, or the number of times a species occurs in the stand represented as a percentage. Relative frequency is defined as the distribution of a species compared to all other species. The Importance Value is an index made of the sum of the relative dominance, relative density, and relative frequency. It gives an indication of the structural role of a species in the stand, and is useful for comparing stands based on the species composition and stand structure (Dupont et. al. 2006; Roberts-Pichette and Gillespie, 1999).

Tree Health: A very coarse classification was used to categorize the tree health for each species. The classifications were: alive standing (as), alive broken (ab), alive leaning (al), dead standing (ds), dead broken (db), or dead leaning (dl). The results are presented as a percentage of each category by species. Dead trees lying prone on the ground were measured and given the classification of dead fallen (df). Dead fallen trees are discussed in the downed woody debris section.

Crown Rating: Crown rating is the degree of mortality of the fine branches found in the crown of the tree and gives a more detailed assessment of tree health. Trees were grouped by species and given a rating of 1 to 5. Each rating is defined by the percentage of fine branch mortality, where category 1 is a healthy tree with less than 10% mortality, category 2 is a tree that has light to moderate decline of 10 to 50% branch mortality, and category 3 is a tree that has severe decline with more than 50% branch mortality. The last two categories, 4 and 5, are for dead trees that are dead naturally or dead due to human causes, respectively. Also, all ratings were for standing trees, not including any dead fallen that were measured.

Crown Class: Live trees were grouped by species and given a classification based on the overall height in relation to other trees and the amount of sunlight the tree crown received. Five different crown classes were used. Dominant: the individual is above other trees and receives full sunlight from the top as well sides; Co-dominant: the individual is approximately the same height as others in the canopy and receives full sunlight and partial sunlight from the sides; Intermediate: the individual is below the other trees and only a smaller portion of the top of the crown receives full sunlight, with little to no direct sunlight from the sides; Suppressed: the individual receives no direct sunlight and is below other trees in the canopy stratum and; Open: the tree is not near other trees and receives full sunlight from all sides. The results are presented as a percentage of each class by species.

Tree defects: All live trees were surveyed for defects present on the bole of the tree and given a numerical classification. Fruiting decay fungus bodies were classified as an 1, dry seams or frost cracks as a 2, wet or bleeding seams or frost cracks as a 3, open wounds as a 4, closed wounds or fire scars as a 5, canker damage as a 6, insect damage as a 7, pruned or human activity as an 8, and animal damage as a 9.

Shrub and Small Tree Stratum

The current EMAN protocol was not followed exactly for shrubs and small tree subplots, but used as a rough guideline. The MBMF has used an earlier version of the shrub and small tree protocol to establish monitoring plots for the last several years. To be consistent with previous MBMF plots, we chose to keep using the older protocols. Notable changes include: all shrubs and saplings (<4cm dbh) were recorded with no minimum height restriction, and; heights were not recorded into height classes but rather to the nearest decimetre. Also, the four 5 by 5 metre subplots were placed inside each corner of the larger 20x20m tree plot.

Most woody non tree species were recorded and classed as a shrub. All seedlings (4-10cm dbh) were tagged similar to regular trees, however crown ratings and crown classes were not recorded. Only saplings had their height recorded. The results are grouped by species and the average number for the stand is represented. See appendix III for a list of all shrub species surveyed.

Ground Vegetation Stratum

The ground layer vegetation stratum included all species of vegetation growing in four 1x1 metre subplots. This included ground moss, lichen, ferns, grasses, sedges, fungi, and herbaceous and woody species. For each species present in the subplots, percent cover was estimated. Percent cover was not exclusive and did not add to 100% for each plot due to multiple layers of vegetation being present at one time. All plants hanging over but not originating in the subplot were ignored. The average percent cover and frequency for each species was calculated for the stand. Appendix III has a list of all species found in the subplots. As it was possible to miss some species due to the small area monitored (4m²), any species inside the 20x20 metre plot not found in the 1x1 metre herb subplots were identified and their presence recorded. This gave a more accurate assessment of the presence of ground vegetation species in the entire 20x20m plot, allowing for a better picture of species composition of the entire forest stand.

Downed Woody Debris

Downed woody debris did not follow the EMAN protocols. EMAN recommends running 45.15 metre line transects from 3 of the 4 corners of the 20x20m plot; however, for this survey a more intensive approach was taken by measuring all downed trees within the 20x20 metre plots. All deceased trees over 10 centimetres fallen or lying prone, were measured and tagged as per the standing trees. This will allow the long term tracking of windthrow and death in the plot. All trees can be tracked throughout the plot including if they die, their decomposition over time, the number and abundance of live versus dead, and the amount of basal area for alive versus dead trees. Decomposition was rated on a scale from 1 to 5, with 1 being the least decomposed (fine twigs and bark present), to 5 being the most decomposed (no or little bark present, twigs and major branches absent, discoloured grey, soft and powdery).

Tree Height

In each plot five height measurements were taken of dominant or co-dominant trees. Species selected for measurement reflected the proportion present in the plot, e.g. a high proportion of jack pine were measured if there were large number of jack pine present in the plot. Trees were measured using a Sunto Clinometer model PM-5/360PC that measured the height of a tree based on the percentage of the distance from the tree. Heights were averaged in each plot, and then further averaged to reflect the average canopy height of the stand.

Tree Age

Five trees were cored per plot using an increment borer to determine the average tree age in each plot. The same trees used to determine tree height were cored since they were the tallest, thus likely the oldest in the plot. Each average age of the plot was then further averaged to give the approximate age of the dominant trees in the stand.

Light Transmission

Light transmission was measured in each plot by comparing the amount of light transmitted inside the plot under the canopy to an open, non-shaded area. Five measurements in random locations were taken

per plot, percent transmission calculated, and the values averaged. The results from each plot were further averaged to give an average for the entire stand.

Results and Discussion

Site Description and Selection

The Manitoba Model Forest encompasses Nopiming Provincial Park, and includes our study area around Metcalf Lake. Metcalf Lake is centrally situated inside Nopiming Provincial Park, east of Springer Lake and north of Key Lake (Figure 2). The lake is accessible through the Springer Lake road, a former logging road that runs past a Department of National Defence training facility. The area receives irregular traffic, mostly during training or hunting seasons, as the road is not maintained.

The lake is within a few hundred metres of the road, and is surrounded by an approximate 100 metre wide buffer strip of trees. The lake itself is characterized by rocky granite shores around the north, west and south western edges. A marshy/peatland area exists on the south and south eastern edges of the lake, which is seen in Figure 3 by the increased size of the non harvested area surrounding the lake. Beyond the buffer strip, the forest has been harvested. Major species present in the area include jack pine, black spruce, and a small amount of white birch. Logging was not done in one single year, but occurred in 1998 on the south west and south east sides of the lake, and in 2003 on the north side of the lake. The cutblock forms a large open space that surrounds the small buffer strip that borders the lake. This allows for prevailing winds, storms, and large wind events to impact the buffer area more than if the cutblock did not exist. This open space, or large cutblock fetch, has likely allowed higher wind speeds to impact the forested buffer strip causing what we have labelled as blow-down sites. Live-standing sites were also found around the lake, but mainly in areas not subject to prevailing winds, or in sites that were possibly more windfirm.

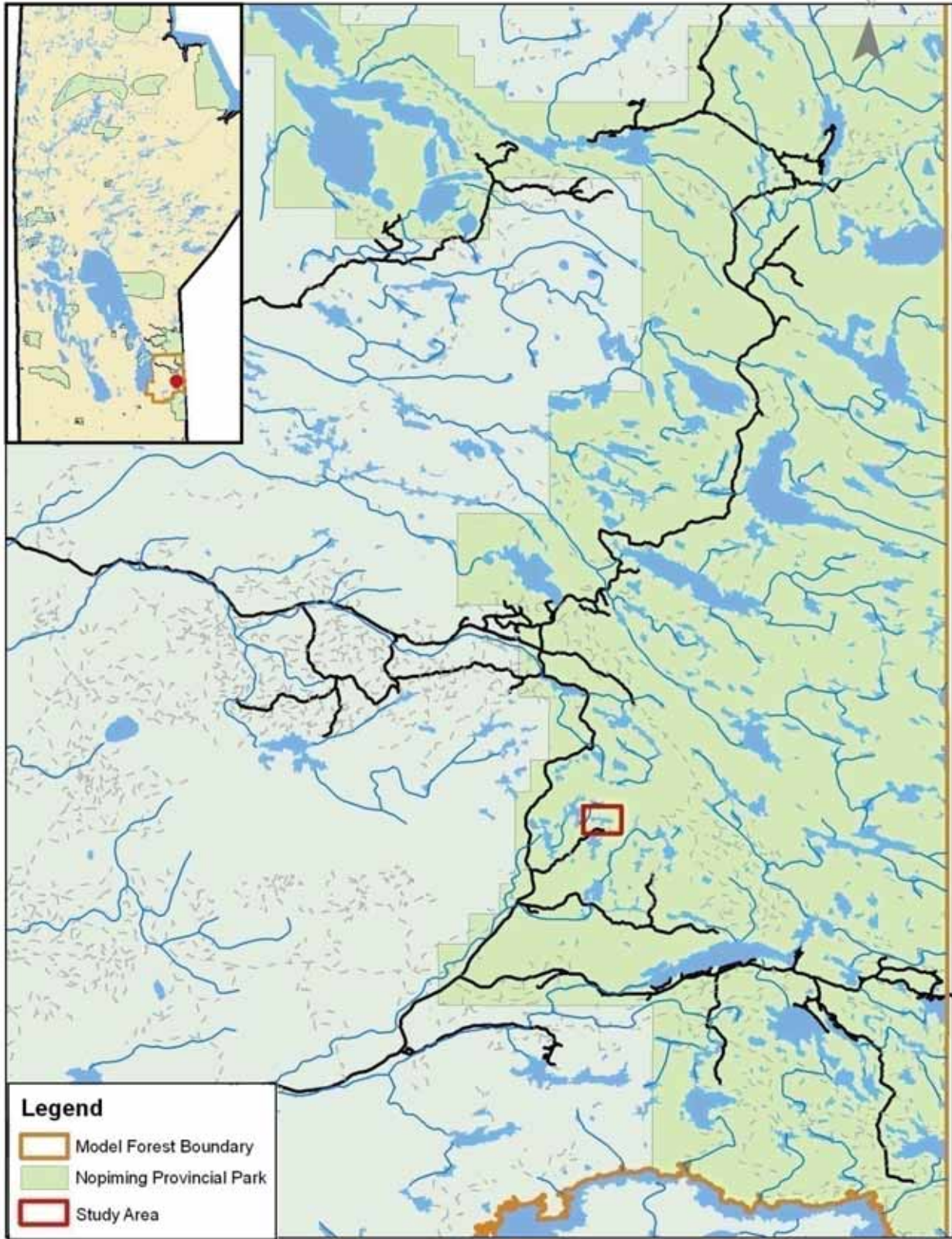


Figure 2: An overview of the study area outlined in red in Nopiming Provincial Park. *Inset: The study area in relation to Manitoba.*



Figure 3: Location of plots around Metcalf Lake, showing cut areas in pink and non cut areas in green.

The five blow-down sites, seen in Figure 3, were placed around the lake where there were obvious amounts of blowdown (Figures 4 and 5). All sites found were either on a western or northern exposure, which coincides with the regions northwest prevailing winds. Plots 1 and 2 were on the southwest edge of the lake. However, they most likely received wind from both the north and west directions due to their unique placement, unlike plots 3 to 5 which would have received only northern winds. Plot 1's unique placement on the edge of the cutblock allowed for northern, northwest and western exposure. Plot 2 was likely windfirm from the north being on the edge of the lake, however, the harvest allowed for western winds to impact the trees. Although trees may have been windfirm, they were likely only resistant to one direction, north, and not west.

Live-standing sites were chosen as their name suggests; a large portion of the trees were alive and standing. Sites were selected away from areas with high tree mortality, and conversely turned out to be placed mostly on south facing cutblock edges (Figure 3). No specific formula was used to determine if plots were considered to be live-standing or blow-down areas, but selected based on their appearance (Figures 6 and 7). All plots were originally intended to be placed evenly around the lake as the blow-down plots had been; however, this was not possible due to the amount of windthrow along the north side of the lake. The north buffer strip had few areas with low mortality for live-standing plot placements.



Figure 4: D. Martinson inspecting the dead trees in blow-down plot 1.



Figure 5: *(left)* Tagged blown down trees; *(right)* live trees in amongst the dead.

Plot 3 also was located more on a northwest cutblock edge where high amounts of tree mortality would normally have been expected. A possible reason for the more exposed site having low mortality was that trees were already partially windfirm to northwest winds, since a small bog exists to the north and northwest of the site. Although trees may not have been as windfirm, this gave trees a better chance than those to the south which had readily experienced windthrow.



Figure 6: The healthy live-standing plot 1 on top of a rock ridge, facing north towards Metcalf Lake.



Figure 7: A further back perspective of live-standing plot 1.

Canopy Tree Stratum

Tree Measurement and Calculations:

The difference between the live-standing (LS) and blow-down (BD) stands was readily apparent. Figure 8 shows the number of live and dead trees in the blow-down plots, and Figure 9 the live-standing plots. The primary tree species of the blow-down and live-standing plots was jack pine (*Pinus banksiana*; JP). There were equal amounts of live and fallen dead jack pine trees (39.5%) in blow-down plots. Also 21% of jack pine were standing dead trees. For live-standing plots there was 59, 19 and 22 percent for live, dead standing, and dead fallen jack pine trees. The number of black spruce (*Picea mariana*; BS) was closer to jack pine for the blow-down plots, averaging 39 for live and 53 percent for dead fallen trees, with few standing dead (8%) than live-standing plots. Live-standing plots had a substantially lower number with 67, 6, and 27 percent for live, dead standing and fallen dead trees. White birch (*Betula papyrifera*; WB) had more dead trees in the live-standing plots, however, the overall number of white birch trees was small. Unknown (Ukn) trees were trees that were either on the ground and too decayed to be correctly identified to species, or the species was accidentally not recorded for any live trees. The number of unknown trees was similar between the blow-down and live-standing plots.

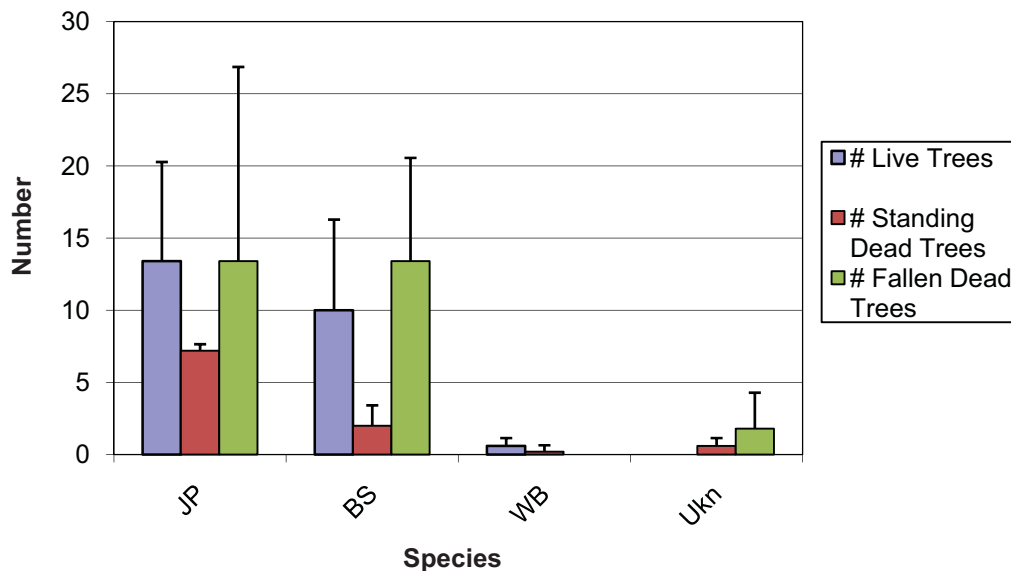


Figure 8: Average number of live and dead trees per species in the blow-down plots.

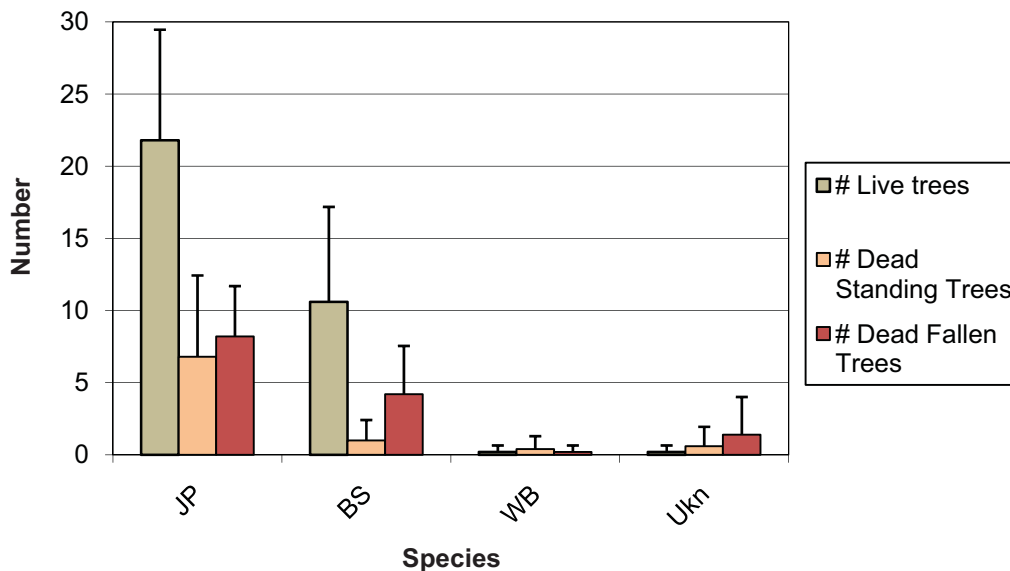


Figure 9: Average number of live and dead trees per species in live-standing plots.

For species abundance, jack pine was the dominant tree in both blow-down and live-standing plot types (Figures 10 and 11). Black spruce was nearly as dominant as jack pine in blow-down plots (Figure 10), having only slightly less alive trees and an equal amount of fallen dead trees. In contrast, black spruce was subdominant and not nearly as abundant as jack pine in the live-standing plots (Figure 11). White birch trees were present in both areas but were a very minor tree in the stand. These results suggest that black spruce could be as susceptible to windthrow as jack pine. However, other factors could account for the observed patterns; with the location of our plots a likely explanation. Before harvesting, the areas would have been considered an approximate heterogeneous jack pine and black spruce stand; however, after harvesting, the areas that were exposed to winds coincidentally had more black spruce by chance.

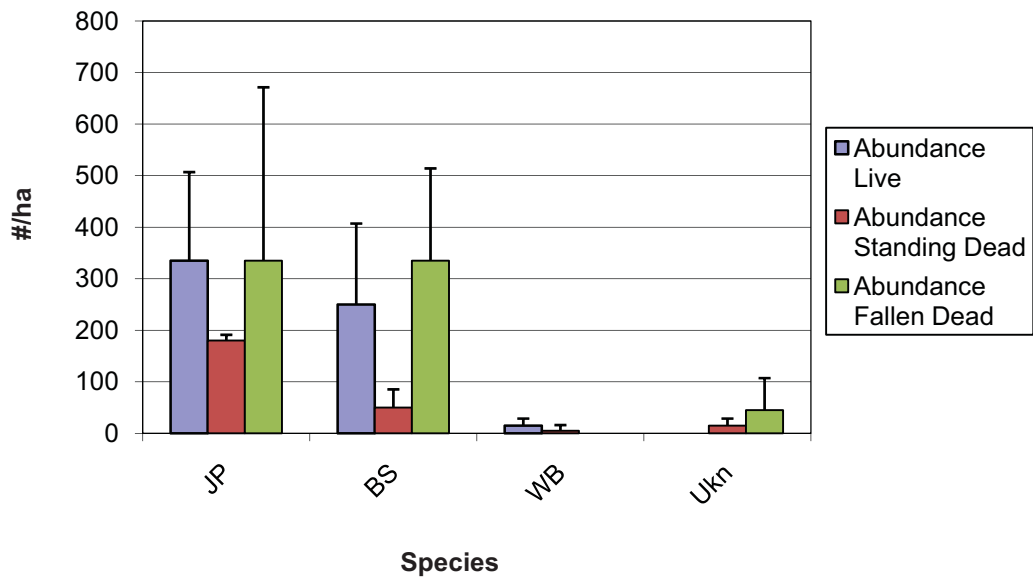


Figure 10: Species abundance of live and dead trees per hectare for blow-down plots.

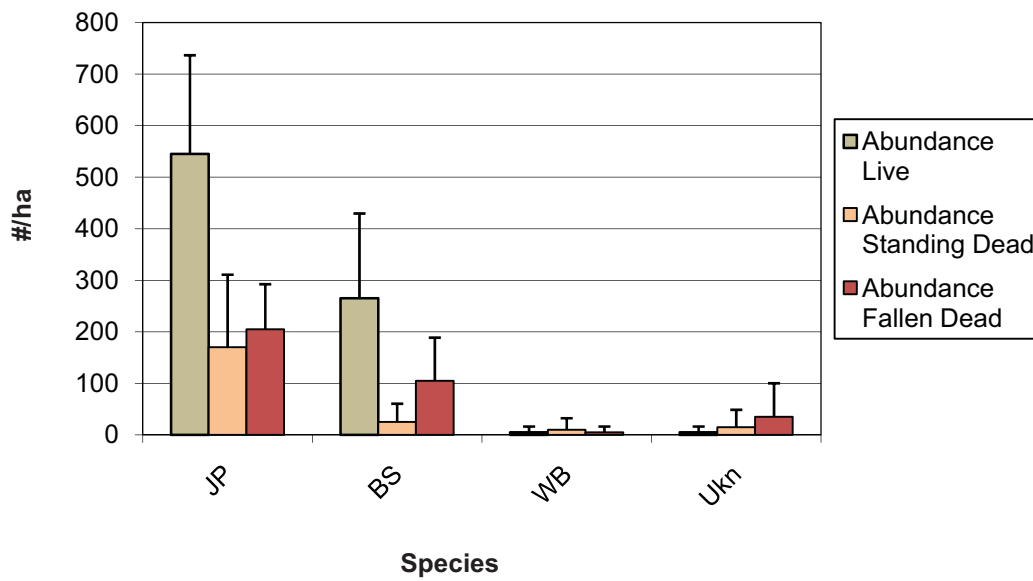


Figure 11: Species abundance of live and dead trees per hectare for live-standing plots.

Basal area showed a different picture than that of abundance or number of live and dead trees. Figure 12 describes the blow-down plots, showing that basal area of dead jack pine trees (standing and fallen dead combined) was slightly greater than live trees (within 2m²). Black spruce also had a similar ratio of live to dead basal area, with dead trees (standing and fallen dead combined) having slightly more than 2m² per hectare than live trees. Live white birch also showed a larger presence than in previous results, indicating that the few trees present were larger in size.

Conversely, Figure 13 shows that live jack pine trees had a much higher (more than double) basal area than standing and fallen dead trees combined in the live-standing plots. The amount of black spruce was much smaller overall, with both live and dead trees each having less than 5m² of basal area per hectare. Also, the basal area of live black spruce more than doubled the combined amounts of standing and dead fallen trees. Also, the total basal area of black spruce in live-standing plots was less than blow-down stands. The amount of white birch in live-standing plots was negligible compared to that of blow-down plots.

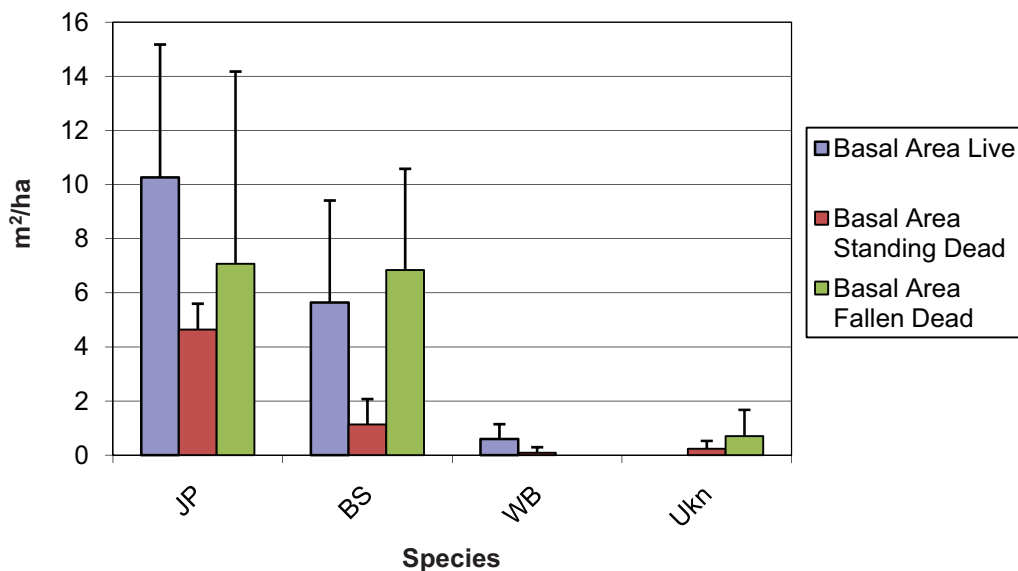


Figure 12: Basal area of live and dead trees per hectare for blow-down plots.

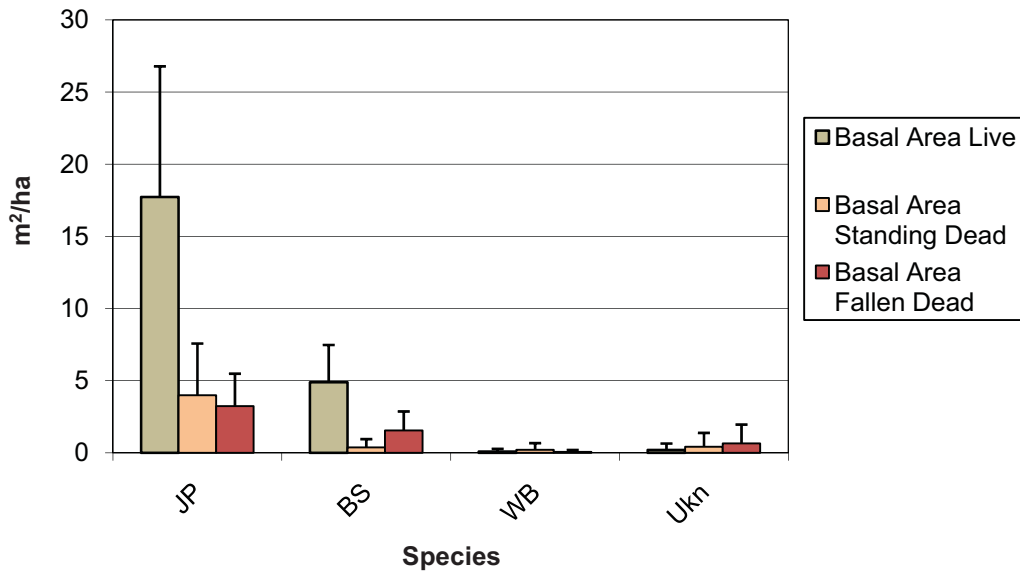


Figure 13: Basal area of live and dead trees per hectare for live-standing plots.

Density (Figure 14), relative density (Figure 15), dominance (Figure 16), and relative dominance (Figure 17) all followed similar trends in the blow-down plots. In all cases, jack pine had the highest numeric value, followed by black spruce and white birch. Although black spruce appeared to have a large presence in the blow-down plots above, it had less presence when compared between all species for relative density (Figure 15) and relative dominance (Figure 17). This was most pronounced for relative dominance, where black spruce was less than half that of jack pine.

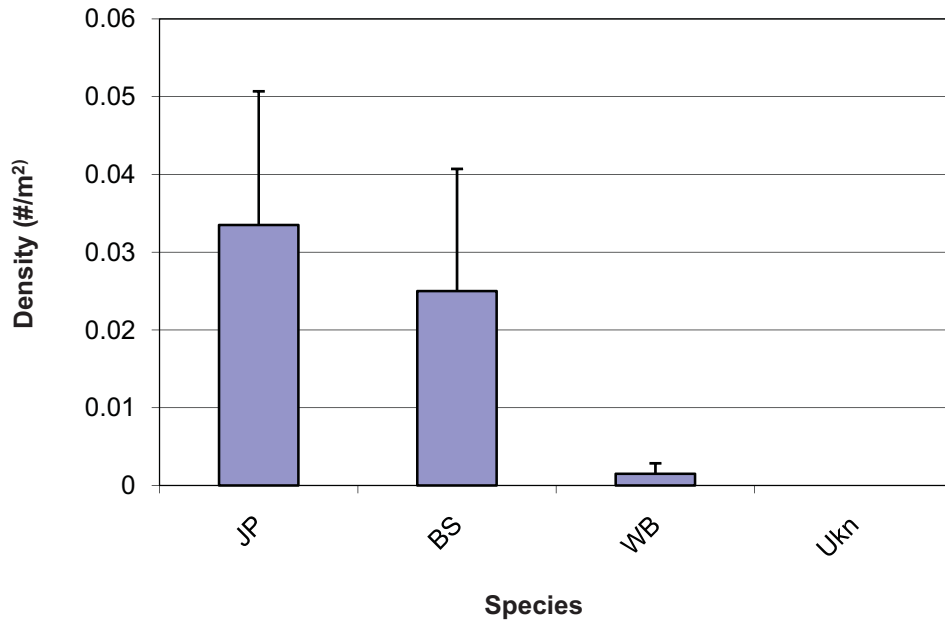


Figure 14: Density of live trees in the blow-down plots.

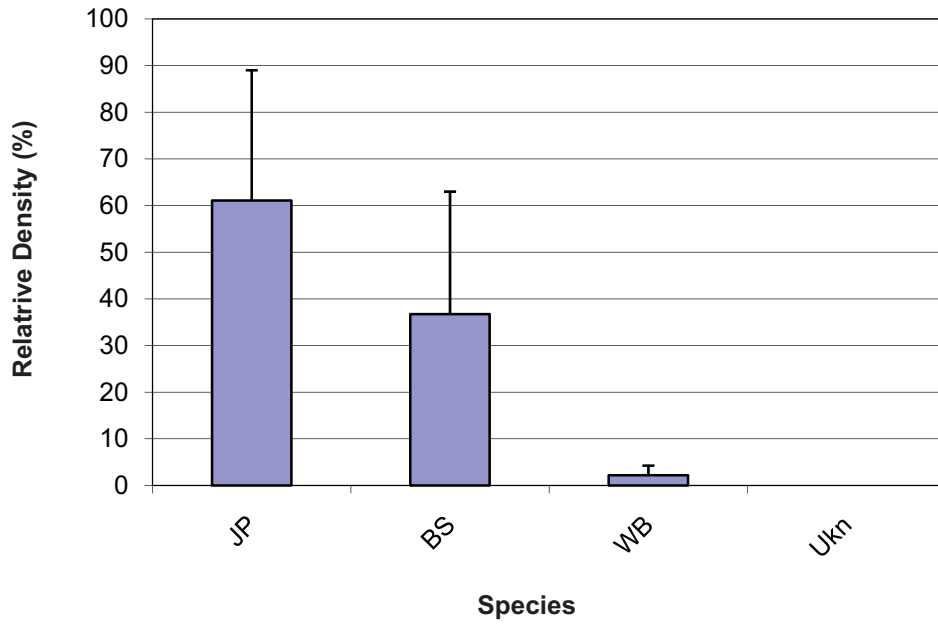


Figure 15: Relative density of live trees in the blow-down plots.

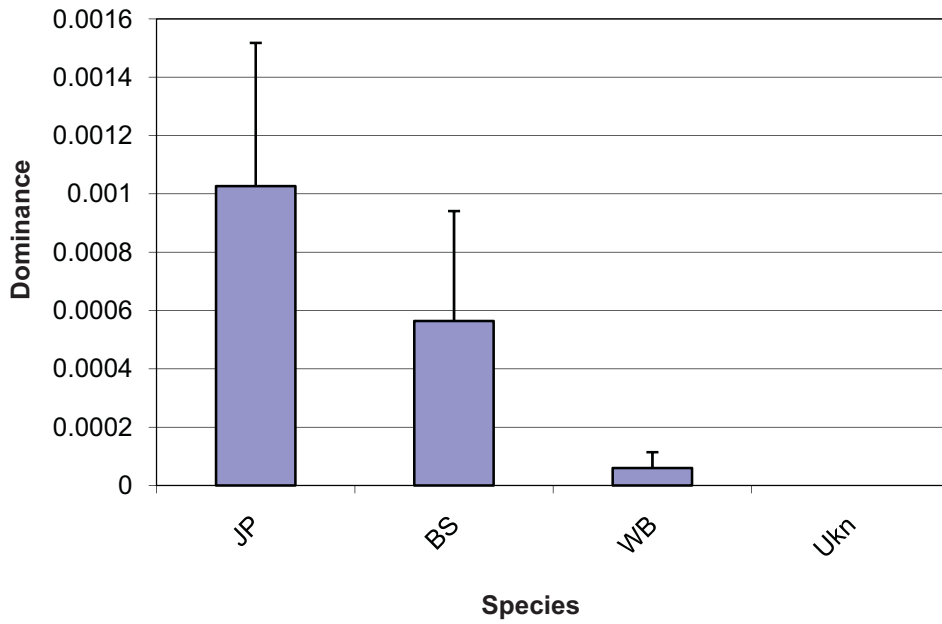


Figure 16: Dominance of live trees in the blow-down plots.

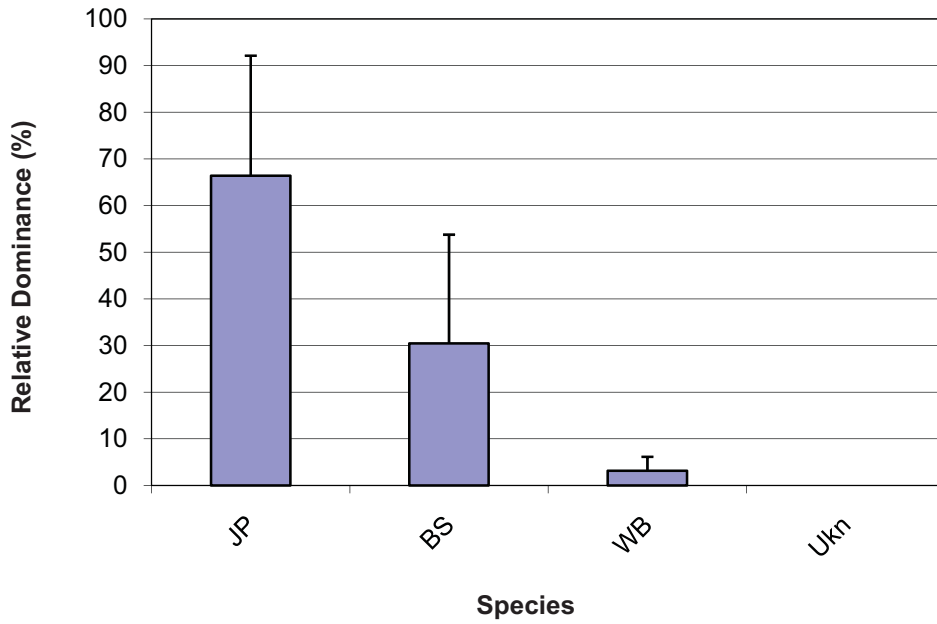


Figure 17: Relative dominance of live trees in the blow-down plots.

Live-standing plots also followed a trend. Black spruce was less than half the values of jack pine In terms of density (Figure 18), relative density (Figure 19), dominance (Figure 20), and relative dominance (Figure 21). Jack pine in all cases had the highest numeric value, with white birch and unknown species having negligible amounts.

Compared to blow-down plots, live-standing plots had a higher density of jack pine and black spruce (Figures 14 and 18), and had a higher relative density for jack pine (Figures 15 and 19). Jack pine was also 75% more dominant (Figures 16 and 20), and more relatively dominant, with black spruce relatively less dominant (Figures 17 and 21).

These results indicate that Jack Pine was the dominant tree in the stand; however, black spruce plays an important secondary role. It would be a mistake to call this stand only jack pine dominated, as black spruce plays too much of a role to be ignored. White birch and the unknown tree species, however, are only a minor component.

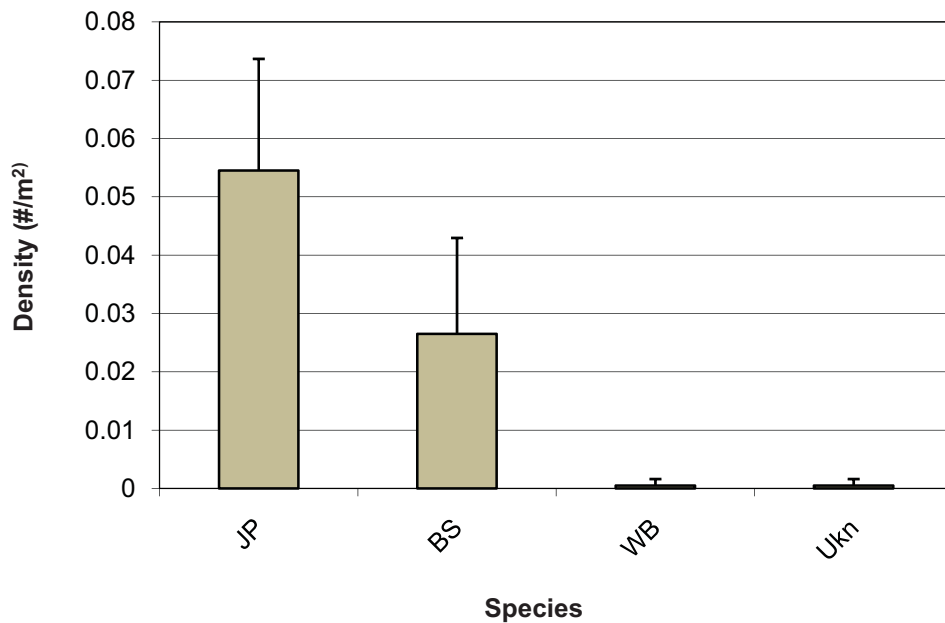


Figure 18: Density of live trees in the live-standing plots.

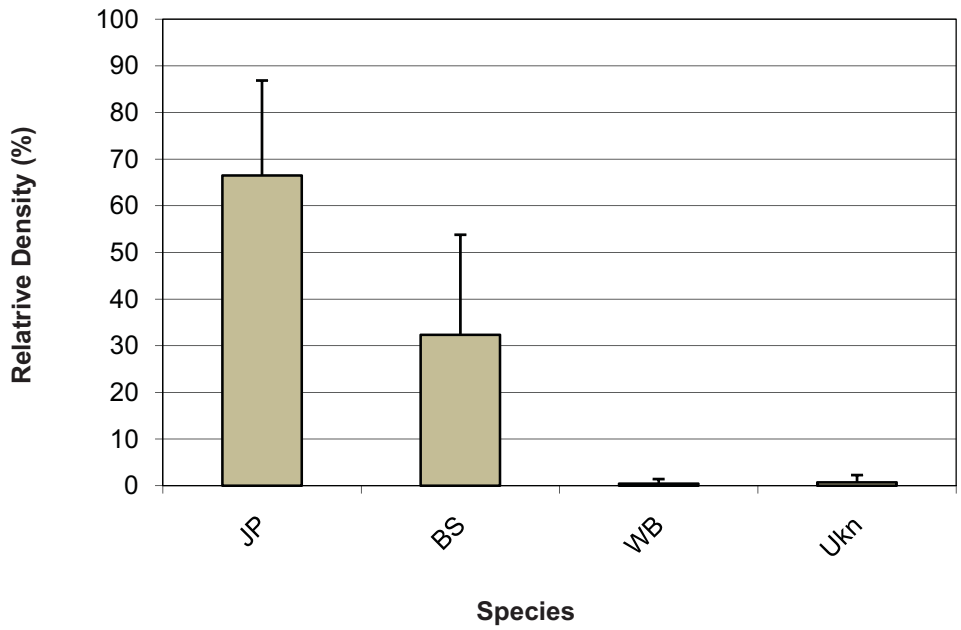


Figure 19: Relative density of live trees in the live-standing plots.

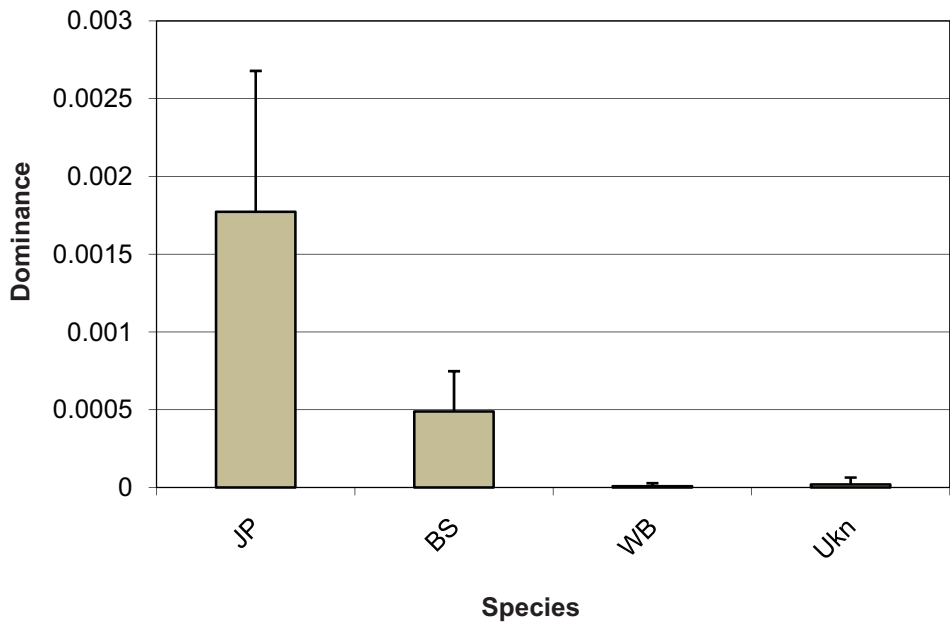


Figure 20: Dominance of live trees in the live-standing plots.

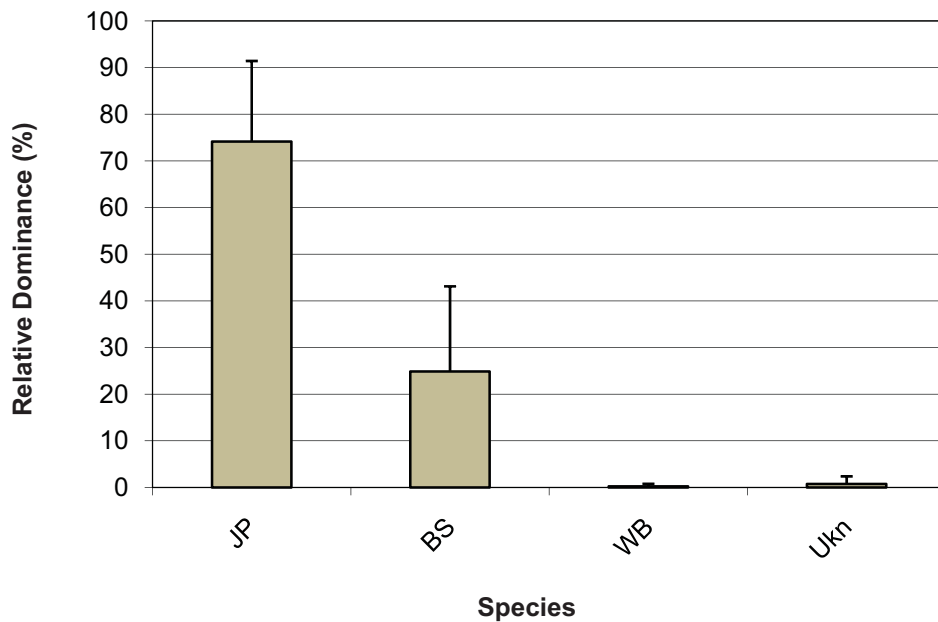


Figure 21: Relative dominance of live trees in the live-standing plots.

The frequency of tree species in blow-down and live-standing plots was identical (Figures 22 and 23). Both jack pine and black spruce were found in all of the plots, with white birch found in one plot, and unidentifiable trees being found in two plots. Relative frequency of trees species in blow-down (Figure 24) and live-standing (Figure 25) plots were very similar but not exactly the same. Blow-down plots had approximately 40% jack pine and black spruce, with 7% and 12% of white birch and unknown, respectively. The live-standing plots had a slightly higher proportion (41%) of jack pine and black spruce trees, with slightly less white birch and unknown tree species.

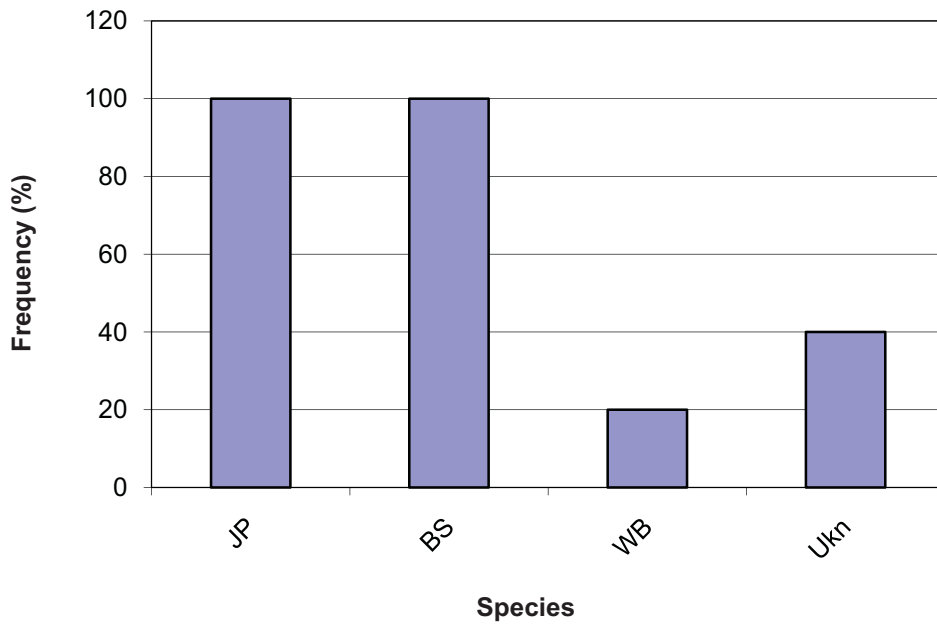


Figure 22: Frequency of live trees in the blow-down plots.

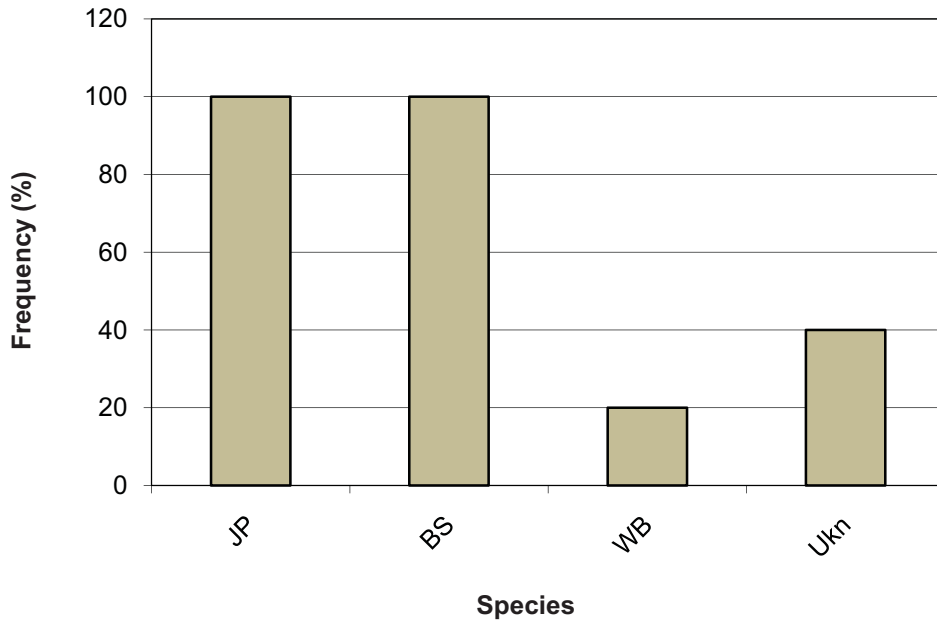


Figure 23: Frequency of live trees in the live-standing plots

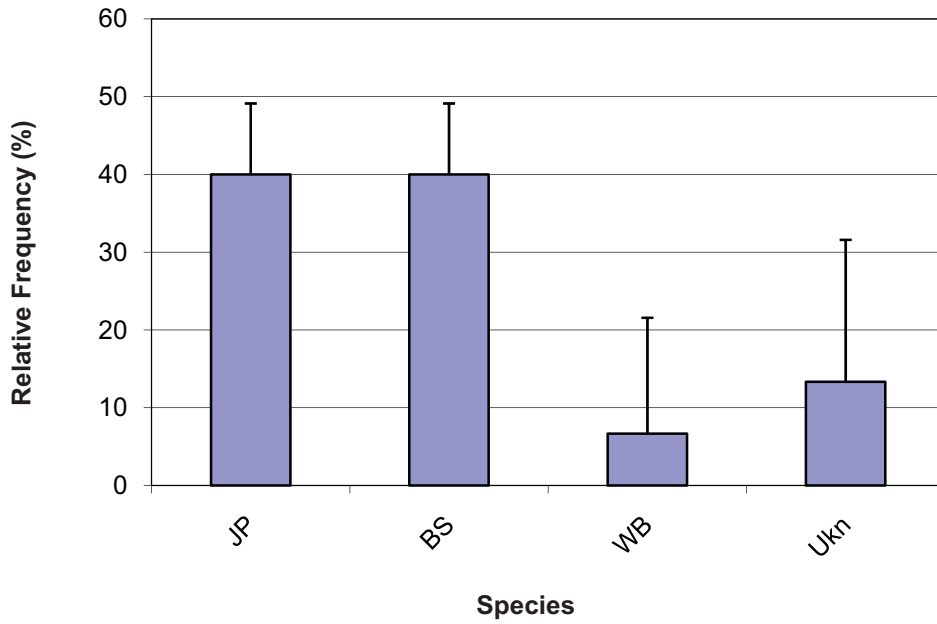


Figure 24: Relative frequency of live trees in the blow-down plots.

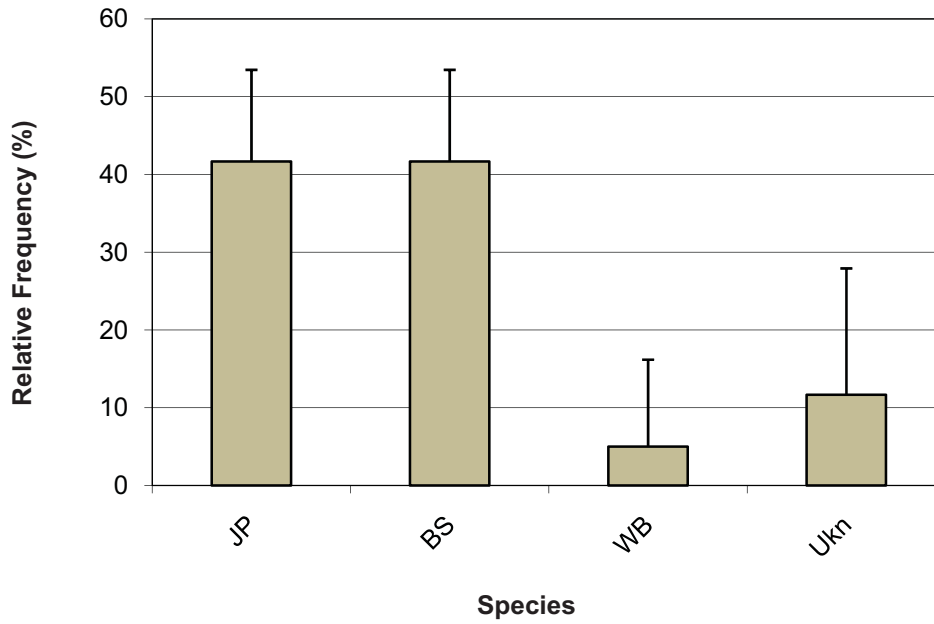


Figure 25: Relative frequency of live trees in the live-standing plots.

Importance values show the structural role each species plays in a stand. It is made up of the sum of relative density, relative dominance, and relative frequency, with a possible maximum of 300 (100 % added for three indexes). Both blow-down (Figure 26) and live-standing (Figure 27) plots had similar importance values for each species, with only small differences. In both cases, jack pine was shown to be the most important tree in the stand, with a numeric value of roughly 167 in blow-down plots and 182 in live-standing plots.

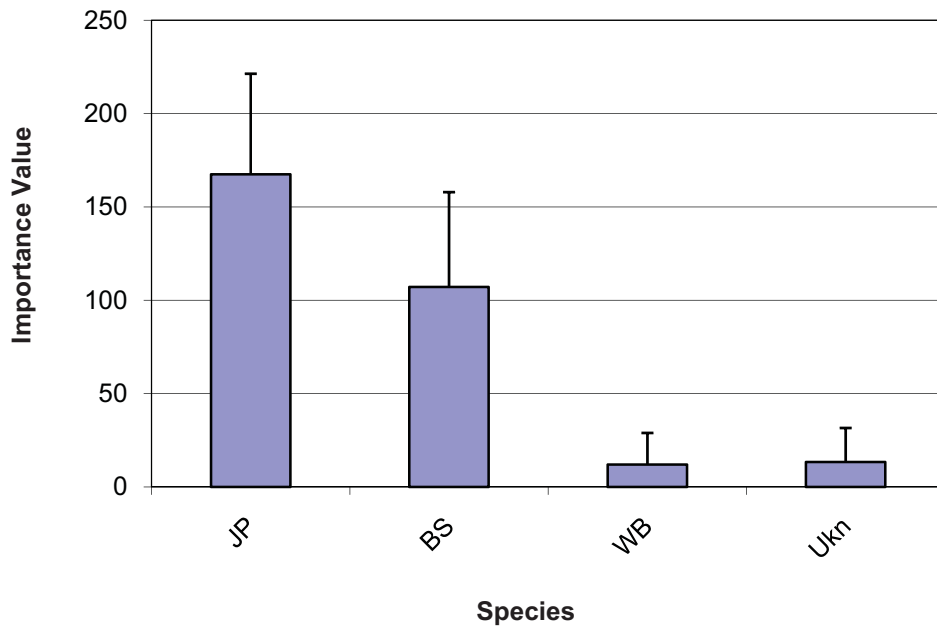


Figure 26: Importance values per species for blow-down plots.

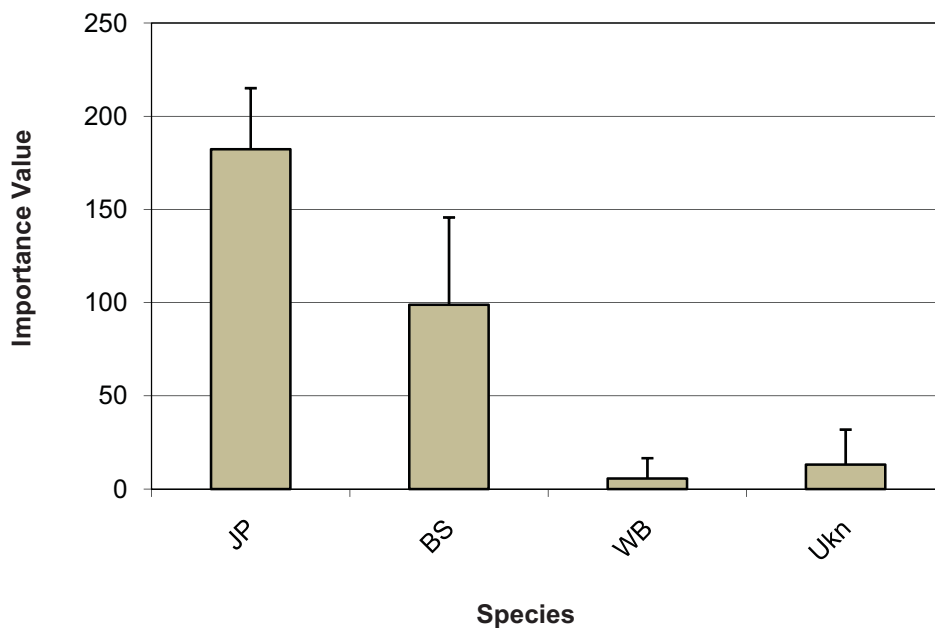


Figure 27: Importance values per species for live-standing plots

Tree Health:

Tree health was documented for each tree measured in the plot. Figure 28 shows the condition of each tree in the blow-down plots. The percentage of dead fallen (df) trees outnumber the alive standing (as) trees for all species except white birch, although there were only four white birch trees total in the plots. Furthermore, when the number of dead standing (ds), dead leaning (dl), and dead broken (db) are added with the dead fallen, the number of dead trees greatly outweighs the number of live trees in the plots again, except for white birch.

In contrast, there was a lower ratio ratio of dead trees to live trees in the live-standing plots (Figure 29). Jack pine and black spruce both had more than double the percentage of alive standing trees than dead fallen trees, and the number of live jack pine and black spruce trees greatly outweighed the combined amounts of dead trees. White birch conversely, has a higher percentage of dead trees, although there were few trees in the stand (4). Unknown trees had a higher percentage of dead trees, but that was expected. Unknown trees were mostly trees that were too old or decomposed to accurately identify to species.

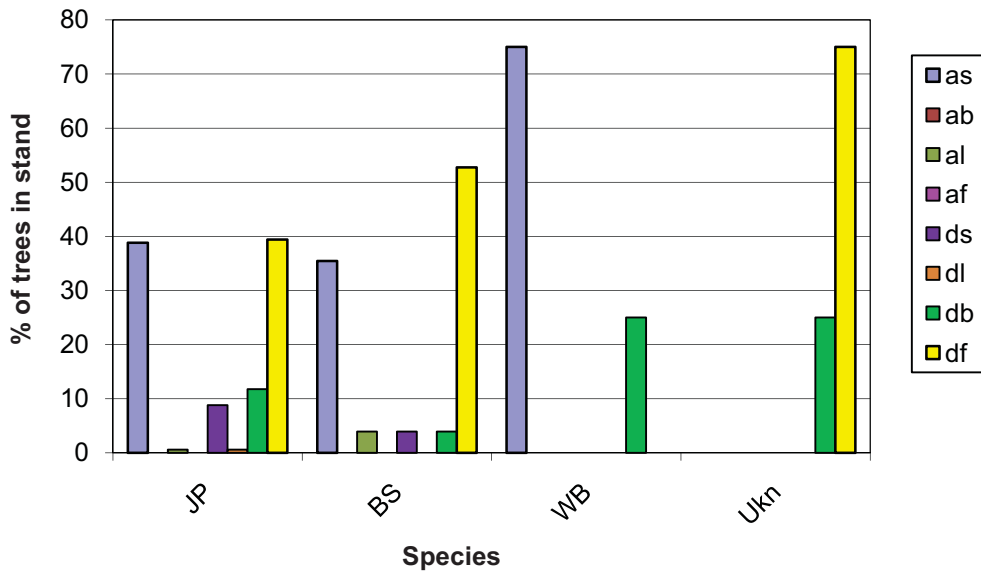


Figure 28: Tree health for each species of blow-down plots.

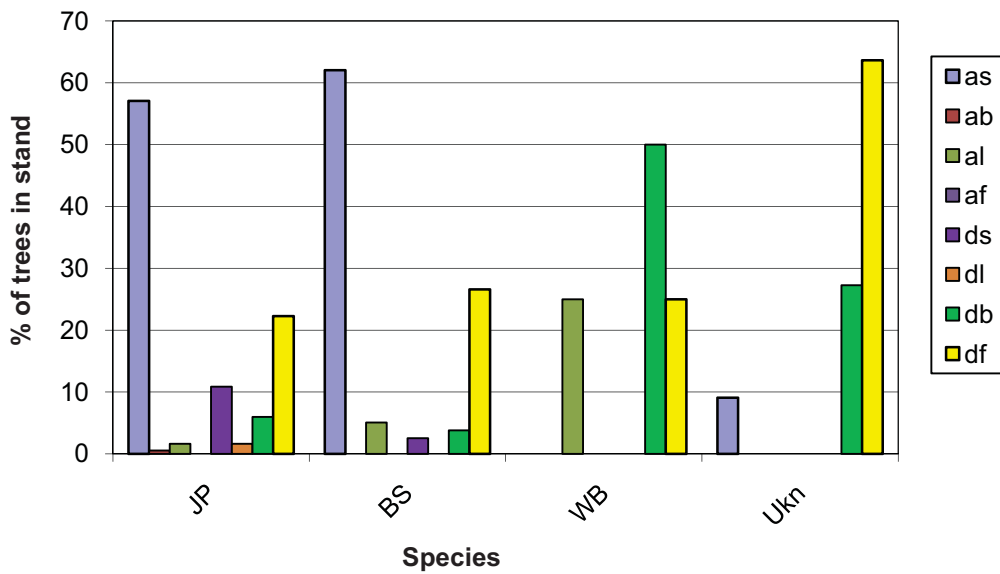


Figure 29: Tree health's for each species of live-standing plots.

Crown rating:

In addition to each tree being assessed for its general overall health, specific branch mortality (crown rating) was examined. This allowed for examination of how healthy each tree was. This is especially important considering a large portion of the trees were already dead. A major difference between measuring tree health and crown rating in the Metcalf Lake stand is that for crown rating, dead fallen trees were not included. Dead fallen trees were previously included to give an impression of the amount of the stand effectively lying on the ground from windthrow. Further discussion on the impacts caused by windthrow is discussed below in the downed woody debris section.

Figure 30 shows the crown rating for the blowdown stands. There was a similar percentage of healthy jack pine trees (class 1) and dead trees (class 4). Black spruce and white birch had a much higher proportion of healthy trees (class 1) compared to dead trees (classes 4 and 5). Unknown trees were all dead, as expected. The percentage of moderately declining (class 2) and severely declining (class 3) trees was not high for any species. Jack pine and black spruce had less than 20% of declining trees and both species hardly had any severely declining trees. One white birch had been cut down in the plots (class 5).

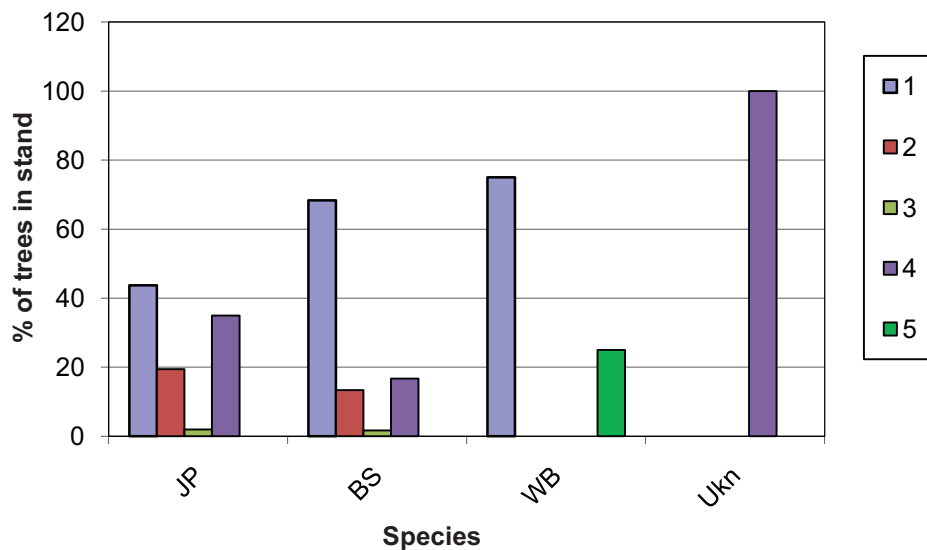


Figure 30: Crown ratings for each species in the blow-down plots.

In comparison, Figure 31 shows the live-standing plots. Jack pine and black spruce both had a higher percentage of healthy trees (class 1); however, the trend is more pronounced in black spruce. Jack pine had slightly lower percentages of trees in classes 2, 3 and 4, while class 2, 3, and 4 trees were uncommon in black spruce. White birch had a much lower percentage of healthy trees in live-standing plots, as demonstrated by a higher percentage of dead trees (class 4). There is also one unknown tree that was in a severely declining condition (class 3).

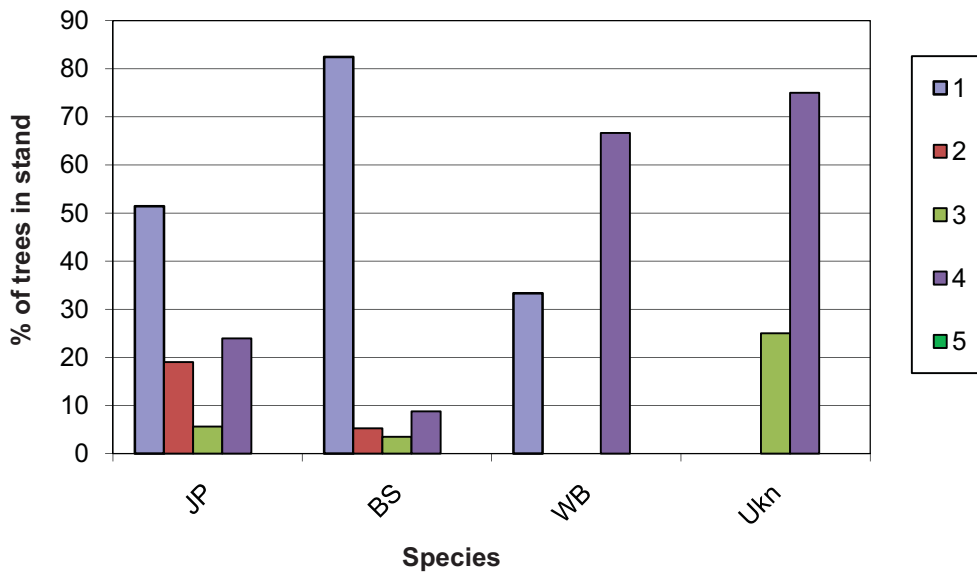


Figure 31: Crown ratings for each species in the live-standing plots.

Crown Class:

Crown class allows us to examine the vertical profile of species in a stand. Live trees, however, were only assessed, thus excluding snags and large broken stems. Therefore, this does not let us look further at windthrow, and does not let us assess whether broken trees or snags were large dominant trees, or smaller suppressed trees. Indirect analysis on windthrow was done later by looking at the number and basal area of dead fallen trees in downed woody debris.

In both the blow-down (Figure 32) and live-standing (Figure 33) plots, the diversity between classes was remarkably low. Jack pine had approximately 90% codominant trees in both the blow-down and live-standing plots, with the remaining percentage made of intermediate or open trees. Black spruce had a higher percentage of codominant trees in the live-standing plots (79%) than the blow-down plots (68%). In both plot types, the remaining percentage was made up of intermediate and a very small amount of open trees (live-standing only). All white birch was codominant in blow-down plots, and all were intermediate in live-standing plots. This does not tell us much however, since the number of live trees in each plot type was very few.

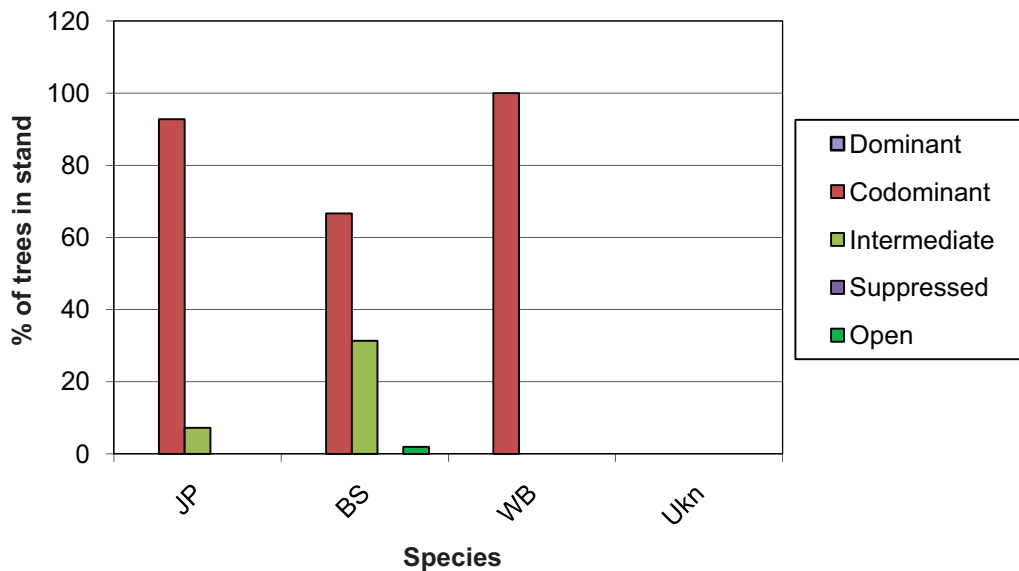


Figure 32: Crown classes for each species of the blow-down plots.

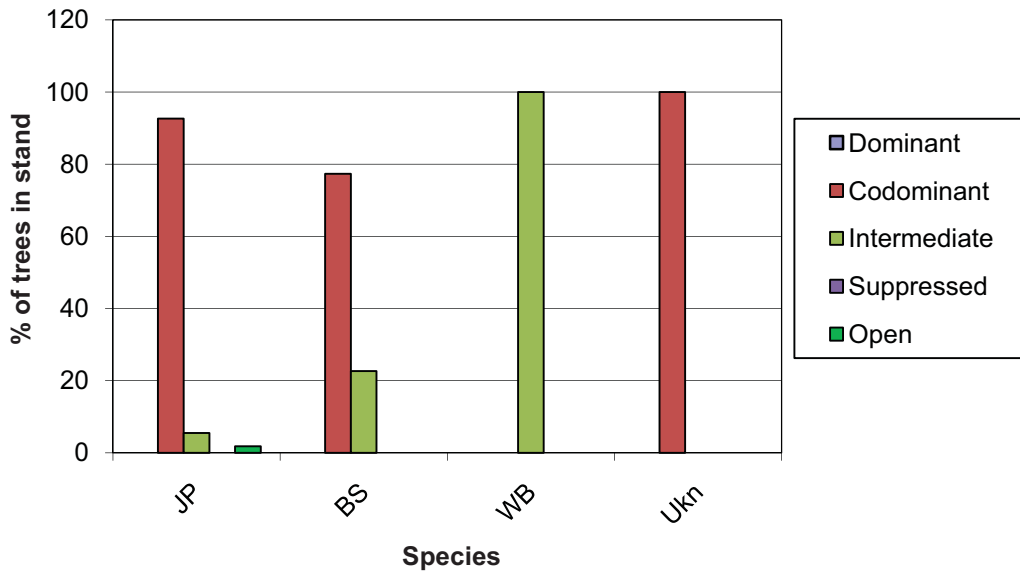


Figure 33: Crown classes for each species of the live-standing plots.

Tree Defects:

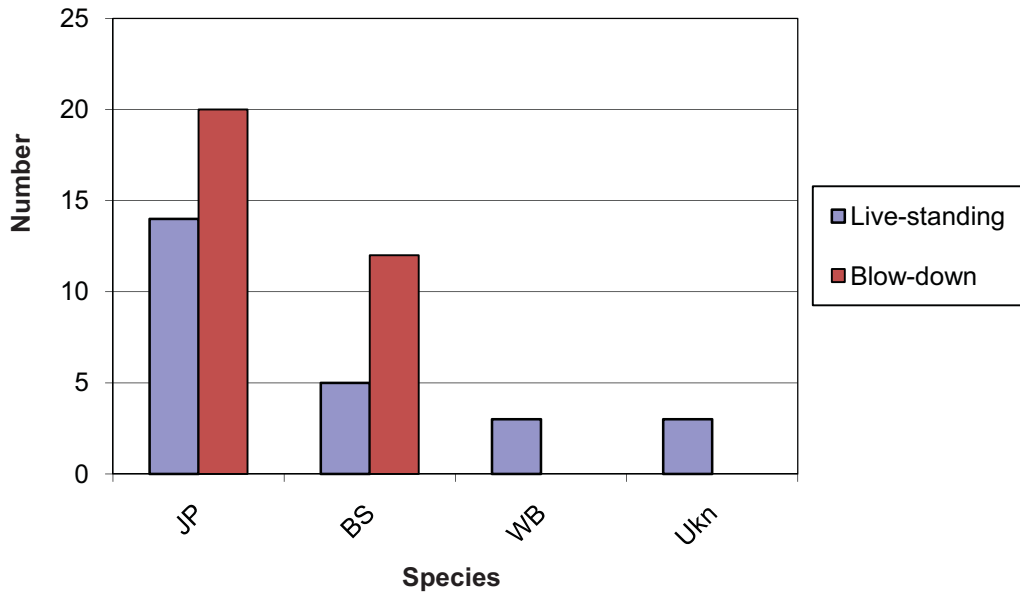


Figure 34: Number of tree defects in both the live-standing and blow-down plots per species.

The total number of defects found on trees was higher in blow-down plots than live-standing plots (Figure 34). In blow-down plots, fungal fruiting bodies, open wounds, closed wounds, canker damage, and animal damage were found. The same defects were found in live-standing plots, with the exception that no open wounds were found, and that dry seam or frost cracks were documented. Figures 35 and 36 describe the percentage of each defect that was found in the blow-down and live-standing plots respectively. Blow-down plots likely experienced more damage when trees fell, crashing into each other, hence the higher number of defects present. Also, due to windthrow, closed wounds were likely most prevalent defect due to falling trees injuring the live and standing trees.

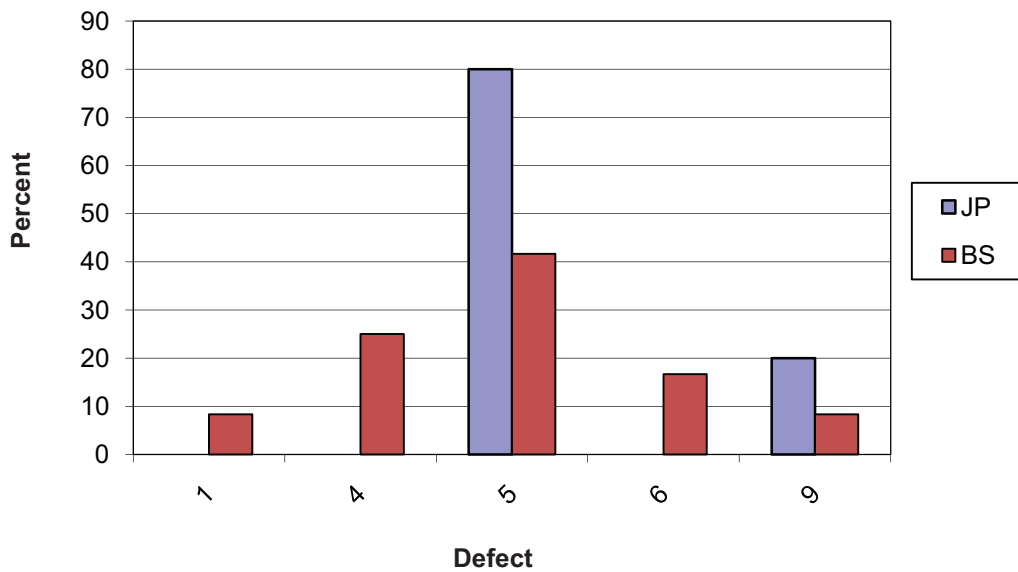


Figure 35: The percentage for each defect class found in blow-down plots.

(1 = Fungal fruiting bodies, 4 = open wounds, 5 = closed wounds or scars, 6 = canker damage, 9 = animal damage)

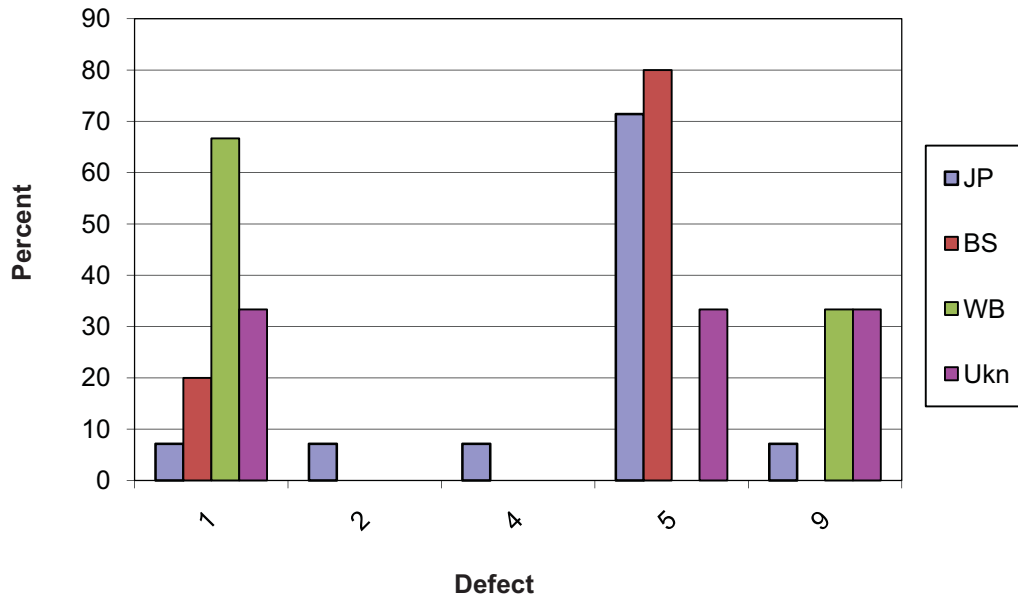


Figure 36: The percentage for each defect class found in live-standing plots.
 (1 = Fungal fruiting bodies, 2 = Dry seams or cracks, 4 = open wounds, 5 = closed wounds or scars, 9 = animal damage)

Shrub and Small Tree Stratum

The Metcalf Lake area was quite variable with respect to small trees and shrubs. Some 5x5 metre quadrats had a large number of plants, yet other areas had little to no vegetation due granite outcroppings and rock faces. In areas with soil, vegetation was not particularly dense (maximum 45 in one quadrat). Blow-down plots had an average of 32 plants per plot, and live-standing plots an average of 46 plants. Reasons for a denser understory layer in live-standing plots may be due to more growing space, as blow-down plots had a large amount of dead fall covering the ground (Figures 4 and 5). Another reason may be due to plot placement, as noted before, plots were not randomly selected.

Figure 37 shows the species composition for blow-down plots. The shrub layer of blow-down plots was dominated by black spruce, white birch, raspberry and rose. Several species that weren't considered shrubs but were found in the blow-down 5x5 metre quadrats included: common juniper, blueberry, *Ribes spp.*, and labrador tea. Figure 38 shows the species composition for live-standing plots, dominated by black spruce, rose, raspberry and lowbush cranberry. Common juniper, blueberry, gooseberry, and narrow-leaved meadow sweet were also found in the 5x5 metre live-standing quadrats.

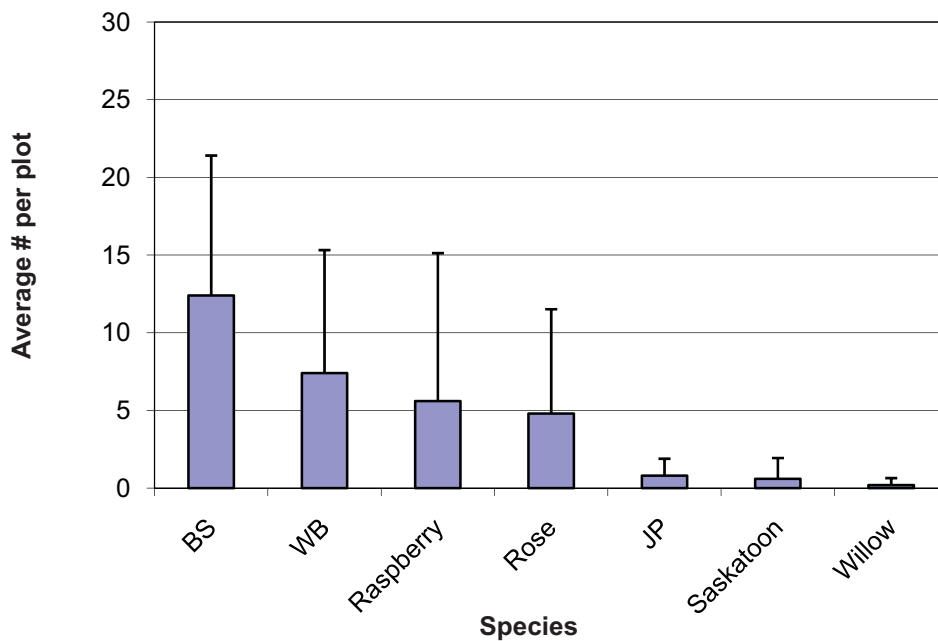


Figure 37: Small tree and shrub layer species composition for blow-down plots.

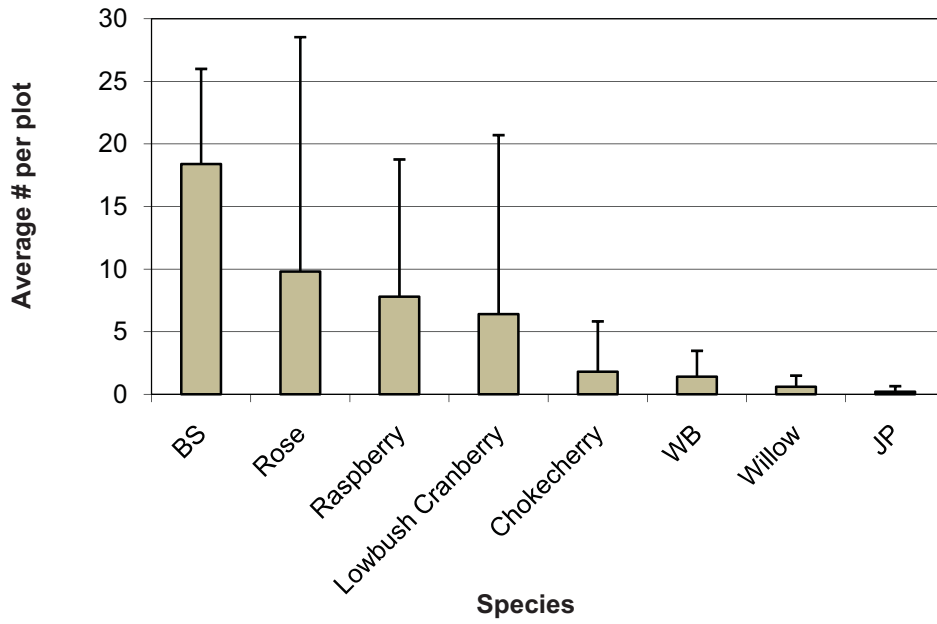


Figure 38: Small tree and shrub layer species composition for live-standing plots.

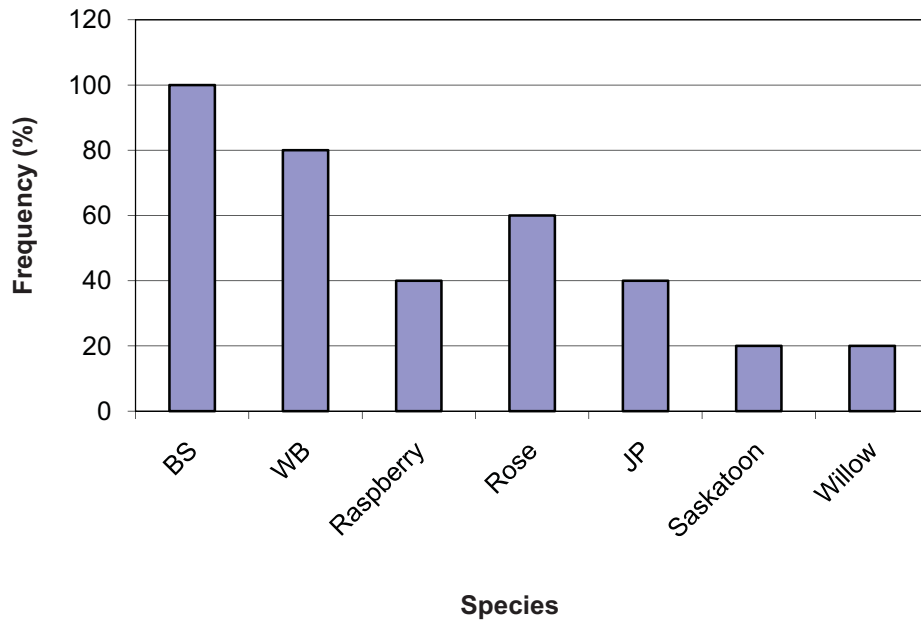


Figure 39: The frequency of small tree and shrub species in blow-down plots.

The frequency that each small tree and shrub species appeared in the plots is described in Figure 39 for blow-down plots, and in Figure 40 for live-standing plots. In both figures, the only species to appear in every plot was black spruce. White birch was the second most common species, appearing in 80% of the blow-down plots and 60% of the live-standing plots. The remaining species appeared less often, appearing between 20% and 60% of the time for both plot types. The figures showing frequency approximately matched their counterparts (number present versus frequency of appearance).

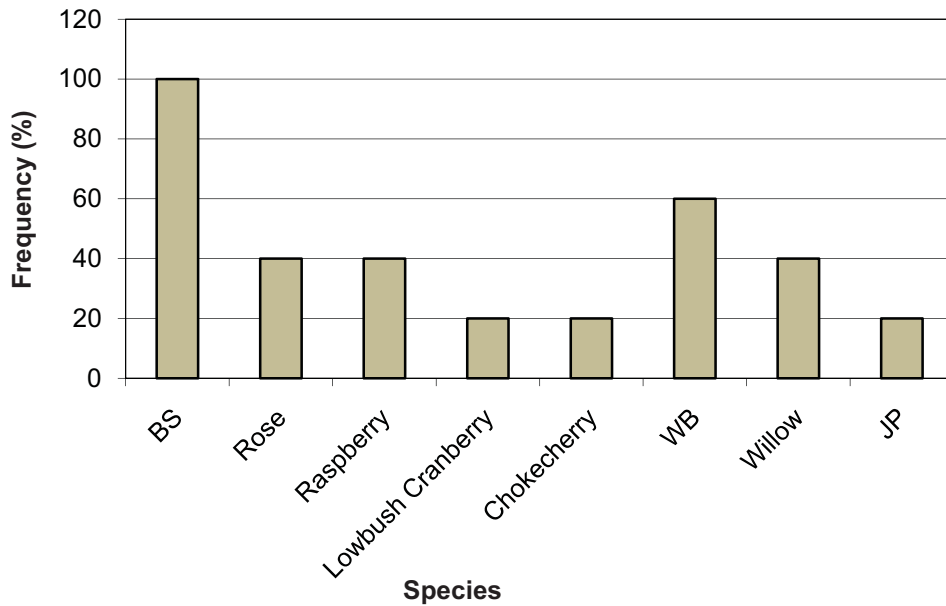


Figure 40: The frequency small tree and shrub species in live-standing plots.

Ground Vegetation Stratum

Figure 41 describes the percent cover of ground vegetation for blow-down plots. In declining order, moss (55%), blueberry (12%), bunchberry (6%), lichen (4%) and fringed black bindweed (3%) are the most prolific species in the plots. The vegetation plots were mostly open with little growing in them, with the exception of some blueberry. Also, it was common that dead trees were found shading the 1x1 metre subplots, or that the rocky substrate didn't allow for much to grow except moss and lichen. The remaining species all had less than 5% cover, indicating that their growth was limited and not very dense.

Figure 42 depicts the ground cover for live-standing plots. Like blow-down plots, moss had the highest percent cover with 58%, followed by lichen (15%), bearberry (11%), blueberry (6%), labrador tea (5%) and raspberry (4%). The remaining species all had less than 5% cover. The high percentage of moss and lichen also coincided with the fact that a large number of the 1x1 metre subplots ended up placed on rocky areas.

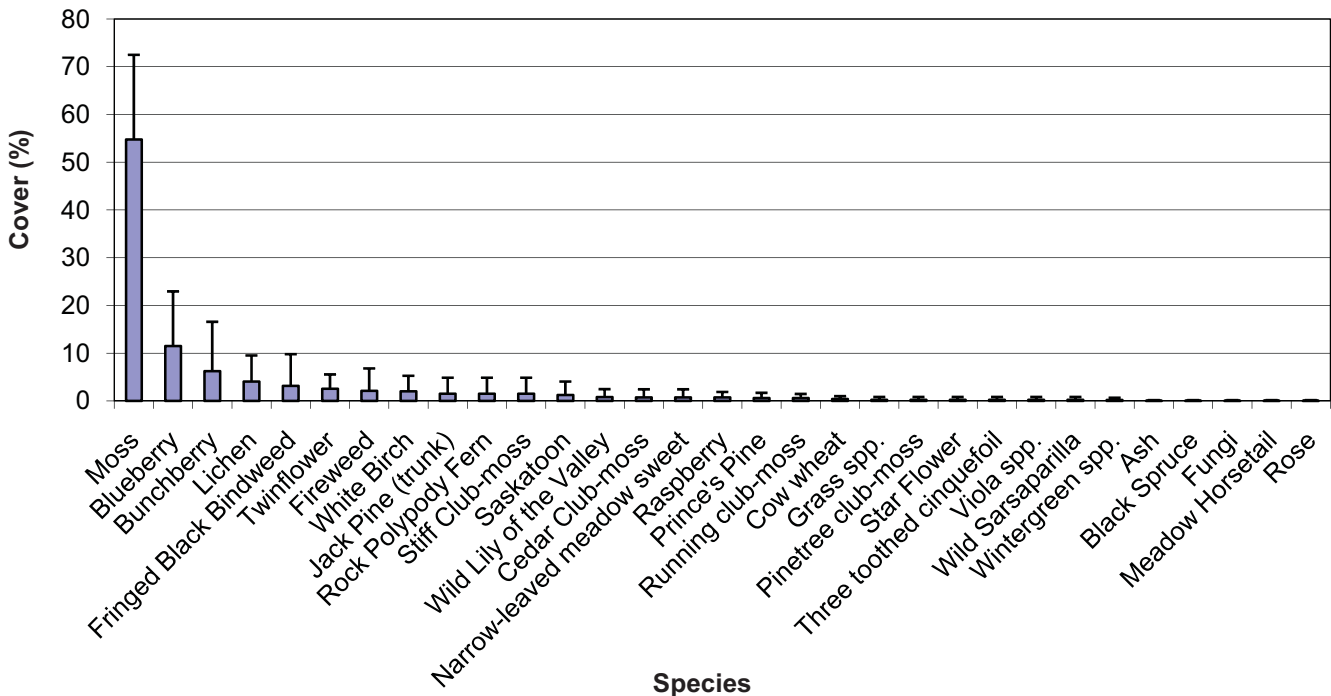


Figure 41: Species composition of the ground vegetation layer subplots for blow-down plots.

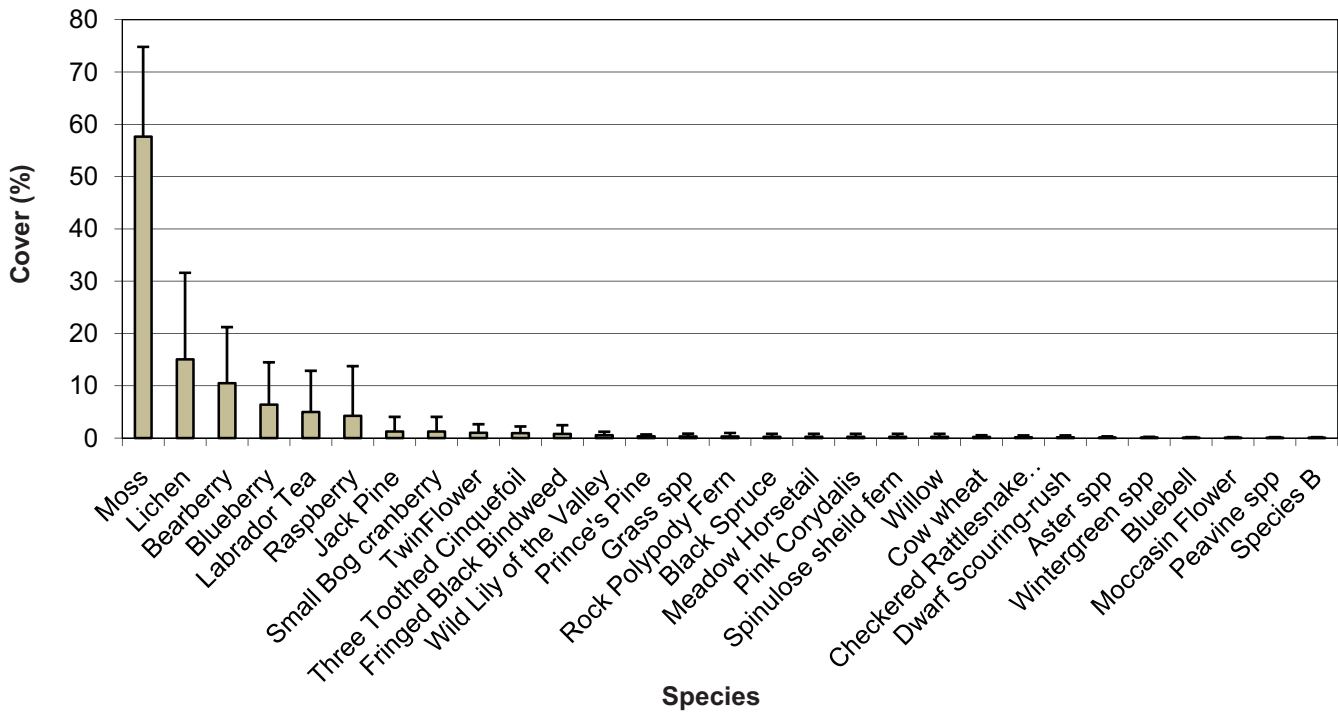


Figure 42: Species composition of the ground vegetation layer subplots for live-standing plots.

The frequency of plants found in the plots can be seen in Figure 43 for blow-down plots, and Figure 44 for live-standing plots. The frequency each species appears in blow-down plots approximately matches that of their percent cover (Figure 41); those species that are found with a higher percent cover show up more often. The frequency of species in live-standing plots is not as consistent as that of blow-down plots with respect to percent cover (Figure 42); however, the species that had a higher percent cover were usually found more often. Plants with a low percent cover that were found several times may only indicate that one or two plants were located in the plots, not giving a high percent cover.

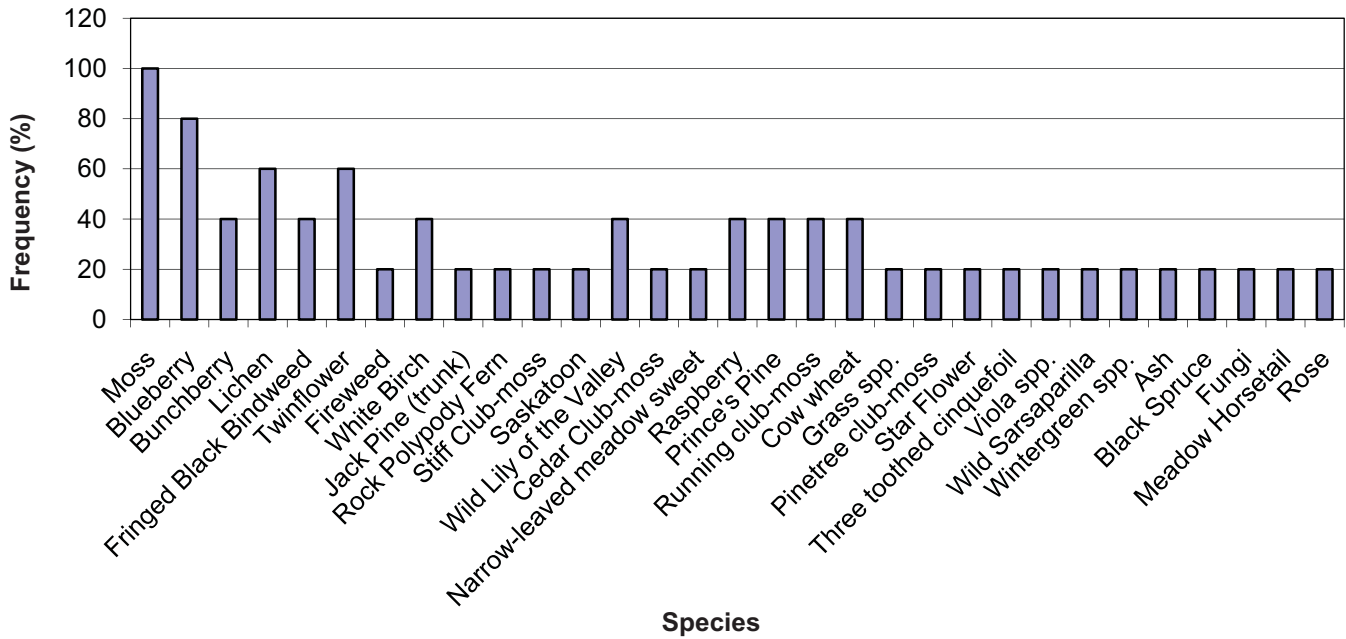


Figure 43: Frequency of species found in the ground vegetation subplots for blow-down plots.

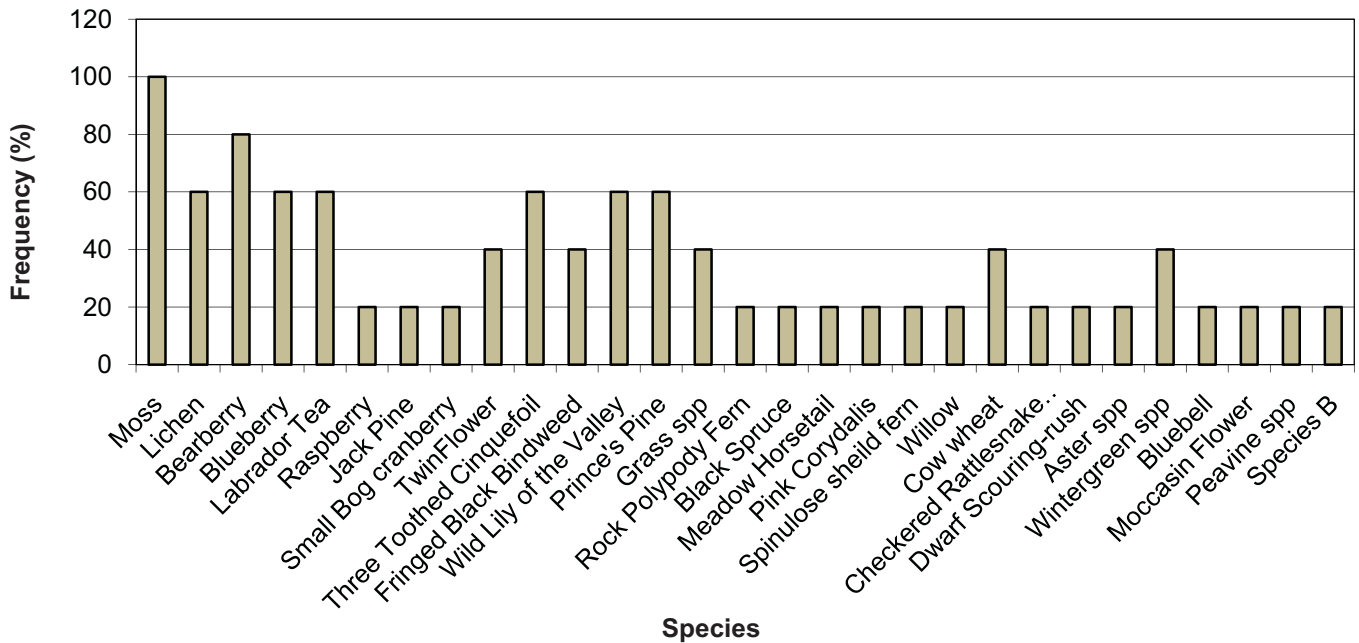


Figure 44: Frequency of species found in the ground vegetation subplots for live-standing plots.

Downed Woody Debris

Both plot types had similar distributions of the downed woody debris in terms of decomposition classes. However, downed woody debris in blow-down plots were less decomposed (i.e. more in classes 1 and 2, Figure 45), while live-standing plots had more downed woody debris in the higher decomposition class 4 (Figure 46). Blow-down plots had almost double the number of fallen trees in class 2 (29%) than live-standing plots (16%), also with a slight increase over live-standing plots in class 1 (9% versus 6%). Conversely, live-standing plots had double the amount of fallen trees in class 4 (33%) than blow-down plots (16%). Both plot types had similar amounts in decomposition classes 3 and 5, with blow-down having 35% and 11%, and live-standing having 36% and 10%, respectively. This suggests that a larger proportion of the blow-down plots trees died in recent years versus live-standing plots where a larger proportion died at a much earlier time.

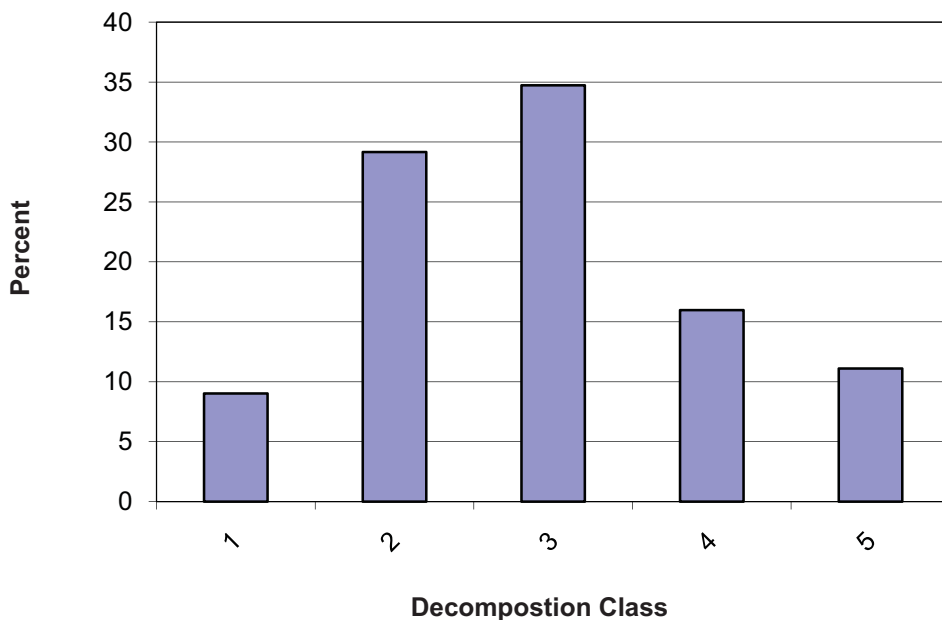


Figure 45: Percentage of dead fallen trees found in each decomposition class for blow-down plots.

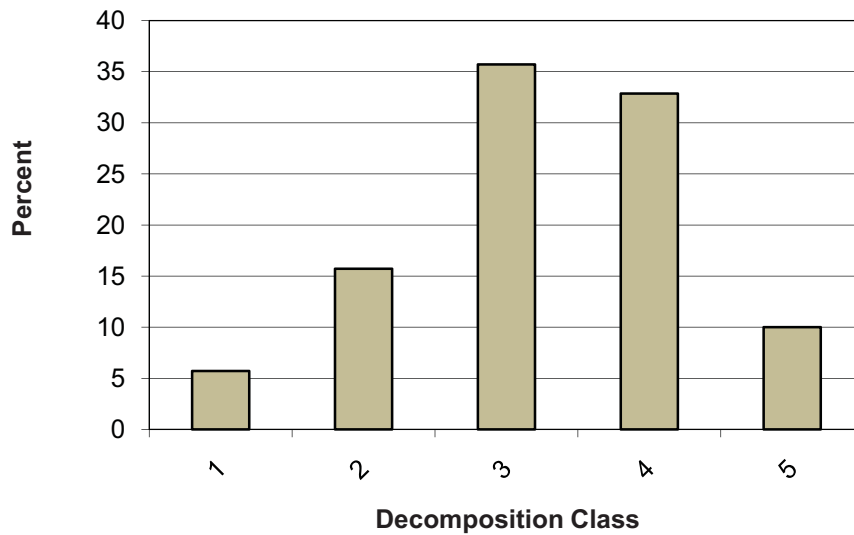


Figure 46: Percentage of dead fallen trees found in each decomposition class for live-standing plots.

Table 1: Percentages of the trees and basal areas for fallen trees in both plot types.

	Species	Live-standing	Blow-down
# Trees	JP	22.3	39.4
	BS	26.6	52.8
	WB	25.0	0.0
	Ukn	63.6	75.0
Basal area	JP	13.0	32.2
	BS	22.8	50.3
	WB	17.3	0.0
	Ukn	51.3	74.9

For comparison, Table 1 shows a summary of the percentage of basal areas and average number for dead fallen trees in each plot. Based on these results, there was a significant difference between the two stands, not only in live and dead trees as examined above, but in the percentage of dead fallen trees in each plot.

Based on the amount of dead fallen trees on the ground and previous results, a large portion of the wind-felled trees in blow-down plots were of larger sized trees. This can be inferred indirectly looking at the percentage of the number of dead fallen trees and their basal area. If felled trees were smaller, there would be a high percentage difference between the dead fallen basal area and the number of

trees, indicating more trees fell with a smaller basal area. For blow-down plots, this is not the case, with approximately a 5% difference between the two for Jack Pine, and 2% for black spruce (Table 1). Live-standing plots had an approximate 10% difference for jack pine, and 4% difference for black spruce indicating that the trees that did fall were slightly smaller (more pronounced in jack pine).

Light, Tree Height and Tree Age Measurements

A summary of light transmission, average tree height, and average tree age is shown in table 2.

Transmission of sunlight was highly variable between the two plot types. The blow-down plots had a much higher percentage of transmission, of approximately 90%, compared to live-standing plots that had a transmission of 69%. Although these results look significant, the standard deviation was high. The live-standing plots had a standard deviation of more than 50% of the average. Despite this, it is possible that the blow-down plots received more light at ground level since there were less standing trees to reduce the percentage of transmission.

Table 2: Summary of blow-down and live-standing plots stand characteristics.

	<i>Blow-down</i>		<i>Live-standing</i>	
	Average	Std. Dev.	Average	Std. Dev.
% Transmission	90.18	40.89	69.00	37.29
Tree Height (m)	16.49	1.35	15.23	3.08
Tree Age (yrs)	98.55	1.60	98.79	8.01

The overall height of each plot type was similar. Blow-down plots had an average height of 16.49 metres, and live-standing plots were 15.23 metres.

The approximate age of the stand was consistent between the two plot types. Both blow-down and live-standing plots were an average age of 99 years old, although the live-standing plots tree ages were more variable.

Conclusions

Based on our study, a large amount of windthrow has occurred along the Metcalf Lake shoreline treed buffer area, although the distribution and location of the blowdown areas was patchy. Areas of windfirm forest (such as live-standing plot 3) are an example where a possibly partial windfirm stand survived being opened up to wind events. The lower decomposition classes of downed woody debris in the blowdown plots compared to the live-standing plots suggest that blowdown, although a natural phenomena, was exacerbated by the forest harvesting of adjacent upland areas. Ideally, monitoring plots should be established in riparian forest areas prior to harvest, and monitored for many years following harvest. In our study, we were only able to establish plots following harvest. Despite this, the long term monitoring of these plots will allow for an assessment of mortality in the remaining trees and how forest regeneration will take place in these riparian areas.

Regeneration of boreal forests takes place naturally through wildfire events. The creation of very old forest stands (in riparian areas) next to much younger forest stands (created through harvesting) may alter future wildfire distribution, leading to an un-natural over aging of riparian forests. Conversely, the opposite may be true. Over-aged riparian forests could cause premature or an intense burn for younger forest stands due to the overloading of woody debris in the adjacent over-mature stands. Both scenarios could have significant implications for the regeneration of these already mature to over-mature riparian forests. Regeneration following blowdown events in riparian area needs to be studied more in detail.

A possible recommendation for future forest management practices in riparian forests could be that instead of following strict guidelines (e.g. leaving a 100 metre boundary around lakes), industries could adopt the practices of establishing buffer boundaries based on natural stand or other boundaries. As seen in live-standing plot 3, the possible partial windfirmness allowed trees to survive in an area where they may have not otherwise. Other options such as basing buffer widths on topographical or elevation boundaries may reduce the wind speed that boundary trees receive. Additionally, leaving more uncut trees could help to avoid increasing the loading of dead woody debris into an area. This may have several benefits, such as reducing future fire risks, improving the standing seed source surrounding the cutblock, as well improving the aesthetics or image of the area post-harvest.

Future regeneration of riparian forests may be difficult to achieve in areas of significant blowdown. As mentioned above, this may call for either wider buffer widths or more detailed planning around water

bodies. Recently, many have questioned the utility of standard buffer strips given the high potential for blowdown. Other prescriptions such as variable widths based on specific soil, topographical and other criteria, or following natural disturbance (e.g. fire) patterns are being evaluated across Canada.

There is a dichotomy of views on the utility of forested riparian buffer strips in forest management. Some would argue that buffer strips help to protect a multitude of forest value such as water quality, aesthetics, etc. (although buffer strip width is an important determinant of this). If riparian buffer strips are to meet their intended objectives, it is clear that the trees must remain standing in the long-term. However, others would contend that by maintaining forested buffer strips, we are artificially promoting the aging of forests near water. This is something that would not normally occur, particularly in the boreal forest. The use of some amount of disturbance through forest harvesting in riparian forests may promote better regeneration of riparian forest stands, providing that the forest management techniques do not cause catastrophic consequences such as slumping of slopes and soils into water bodies. There are tradeoffs to both approaches and an area of active debate in Canada. In Manitoba, this has recently resulted in the creation of new draft riparian management guidelines for forestry that incorporate both traditionally viewed “protection” and “disturbance” prescriptions. Long-term monitoring will be critically important in assessing the success of such guidelines.

References

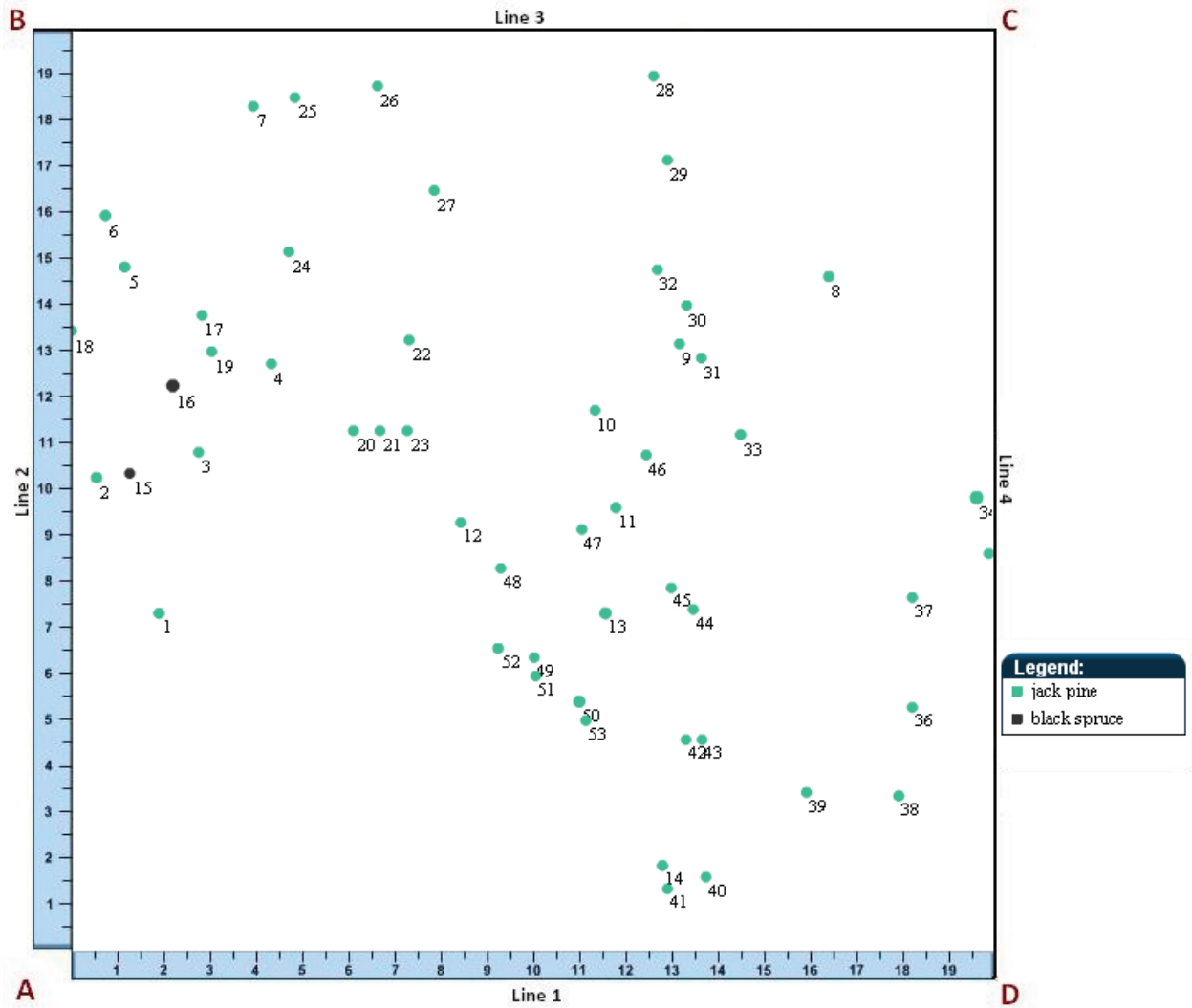
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Appendix I: List of Study Plots and GPS Locations

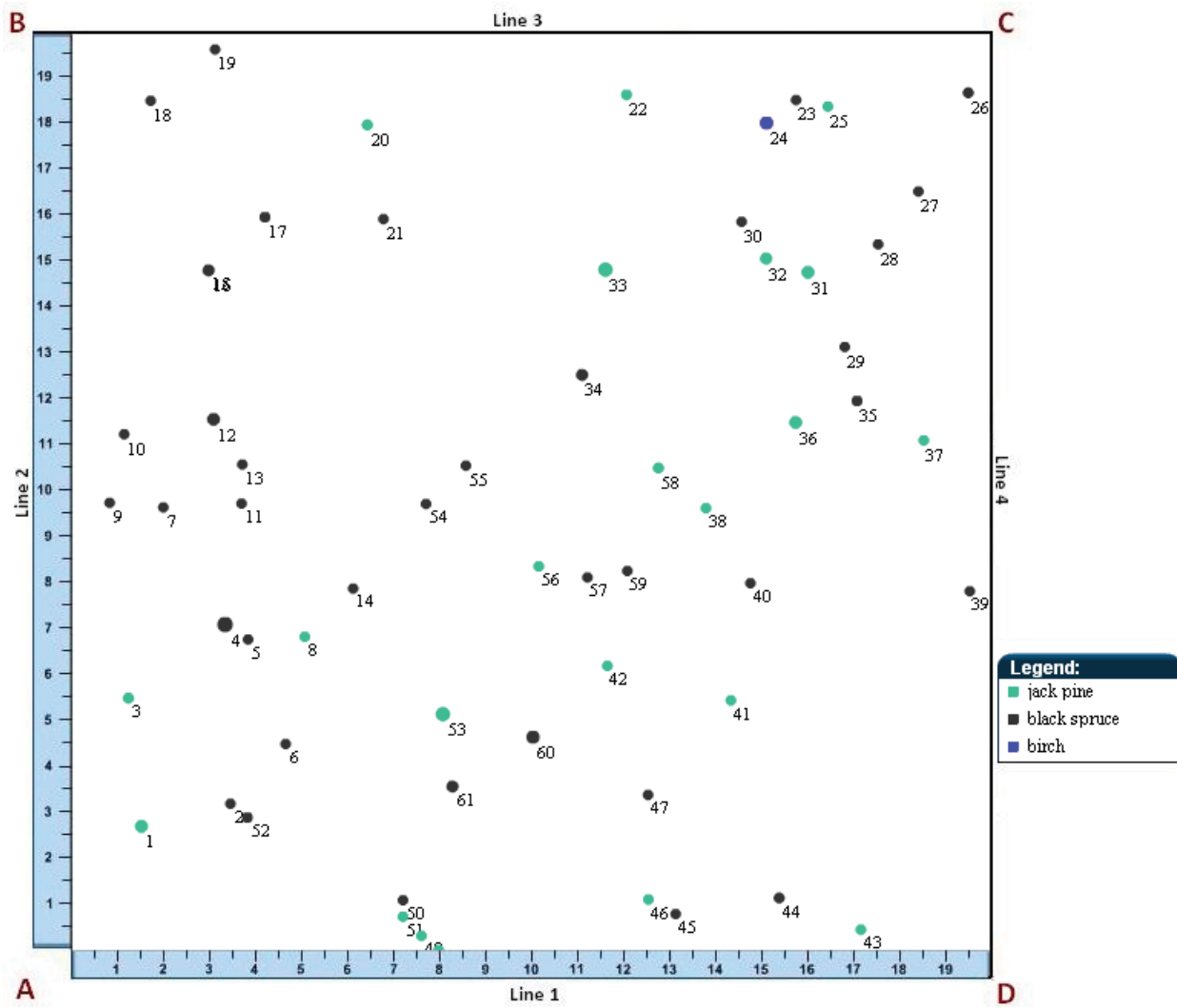
Stand	Plot No.	Latitude	Longitude	Accuracy (\pm m)	Bearing	Date Sampled (m/d/y)
MetRip BD	1	50° 32' 25.5"	095° 24' 53.3"	2.1	56°	08/05/2008
MetRip BD	2	50° 32' 28.7"	095° 25' 13.0"	2.6	196°	08/07/2008
MetRip BD	3	50° 32' 40.8"	095° 25' 08.1"	2.7	26°	08/07/2008
MetRip BD	4	50° 32' 38.5"	095° 24' 36.4"	5.3	86°	08/12/2008
MetRip BD	5	50° 32' 36.4"	095° 24' 24.5"	3.7	36°	08/12/2008
MetRip LS	1	50° 32' 31.7"	095° 24' 53.9"	6.4	150°	08/06/2008
MetRip LS	2	50° 32' 29.6"	095° 25' 04.5"	2.3	162°	08/06/2008
MetRip LS	3	50° 32' 38.5"	095° 25' 18.0"	1.9	287°	08/08/2008
MetRip LS	4	50° 32' 40.0"	095° 24' 53.8°	2.3	5°	08/11/2008
MetRip LS	5	50° 32' 31.1"	095° 25' 00.8"	2.0	186°	08/13/2008

Appendix II: Study Plot Maps Showing Tree Species and Orientation

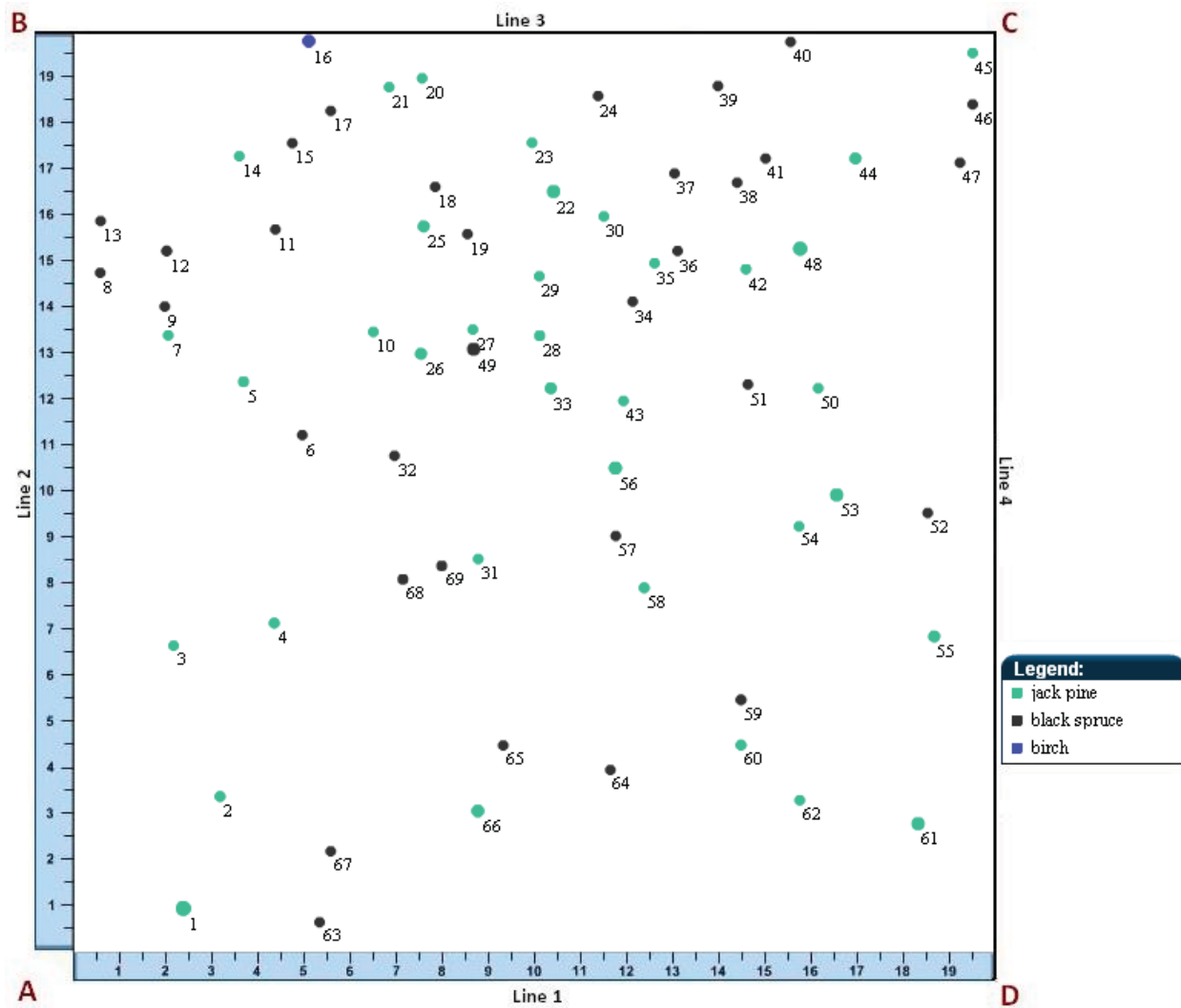
Metcaf Lake Riparian Blow-Down Plot 1



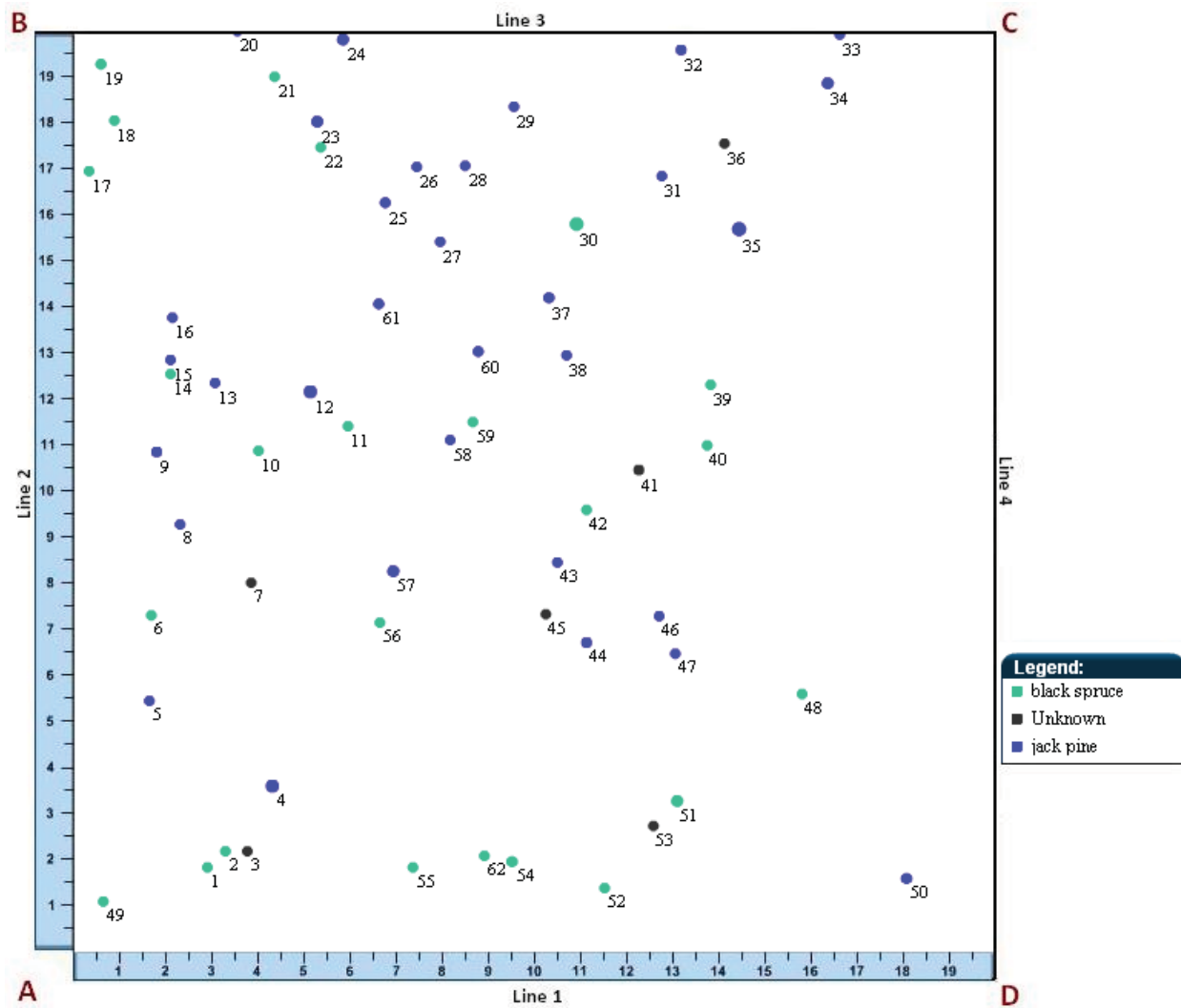
Metcaf Lake Riparian Blow-Down Plot 2



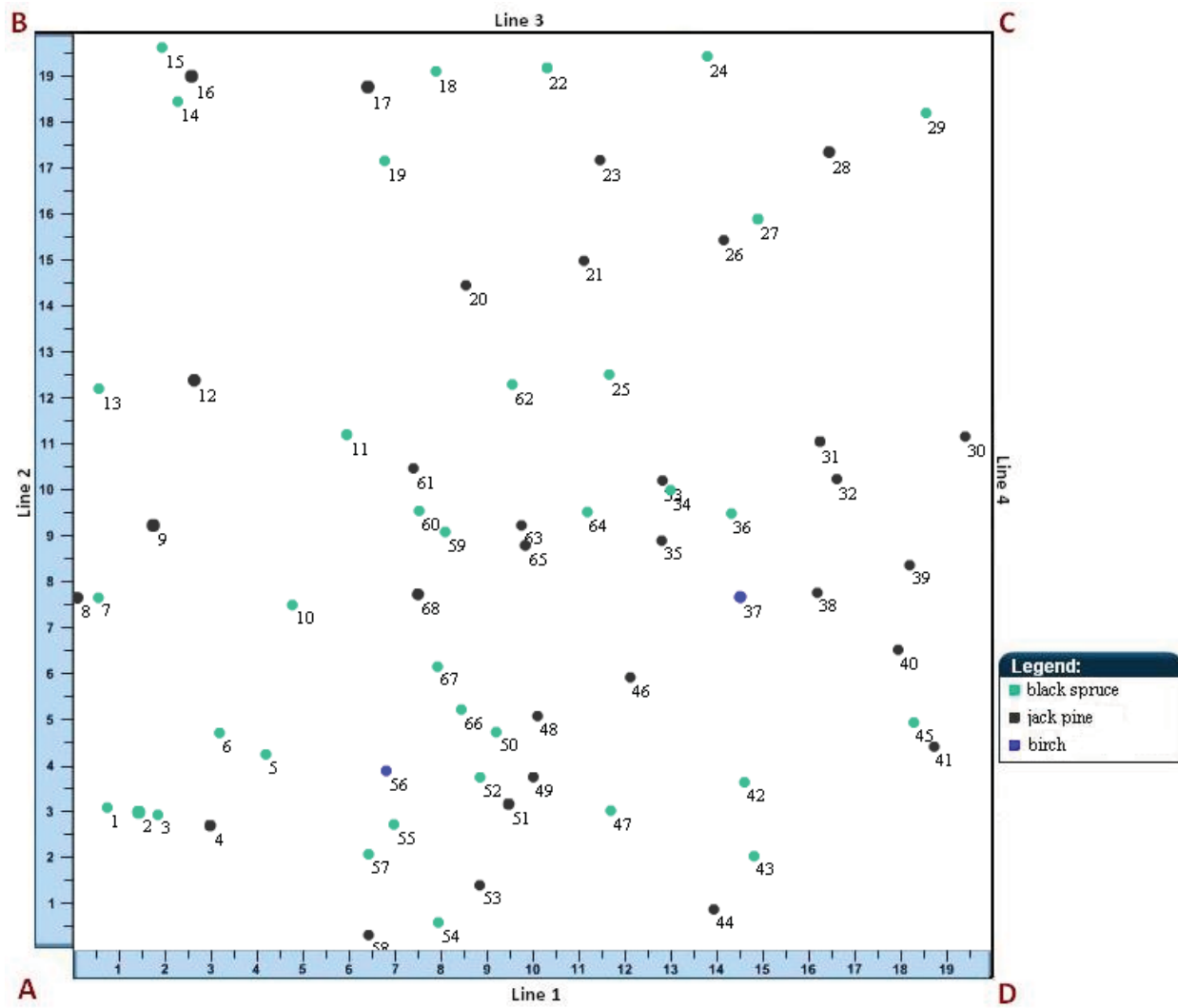
Metcaf Lake Riparian Blow-Down Plot 3



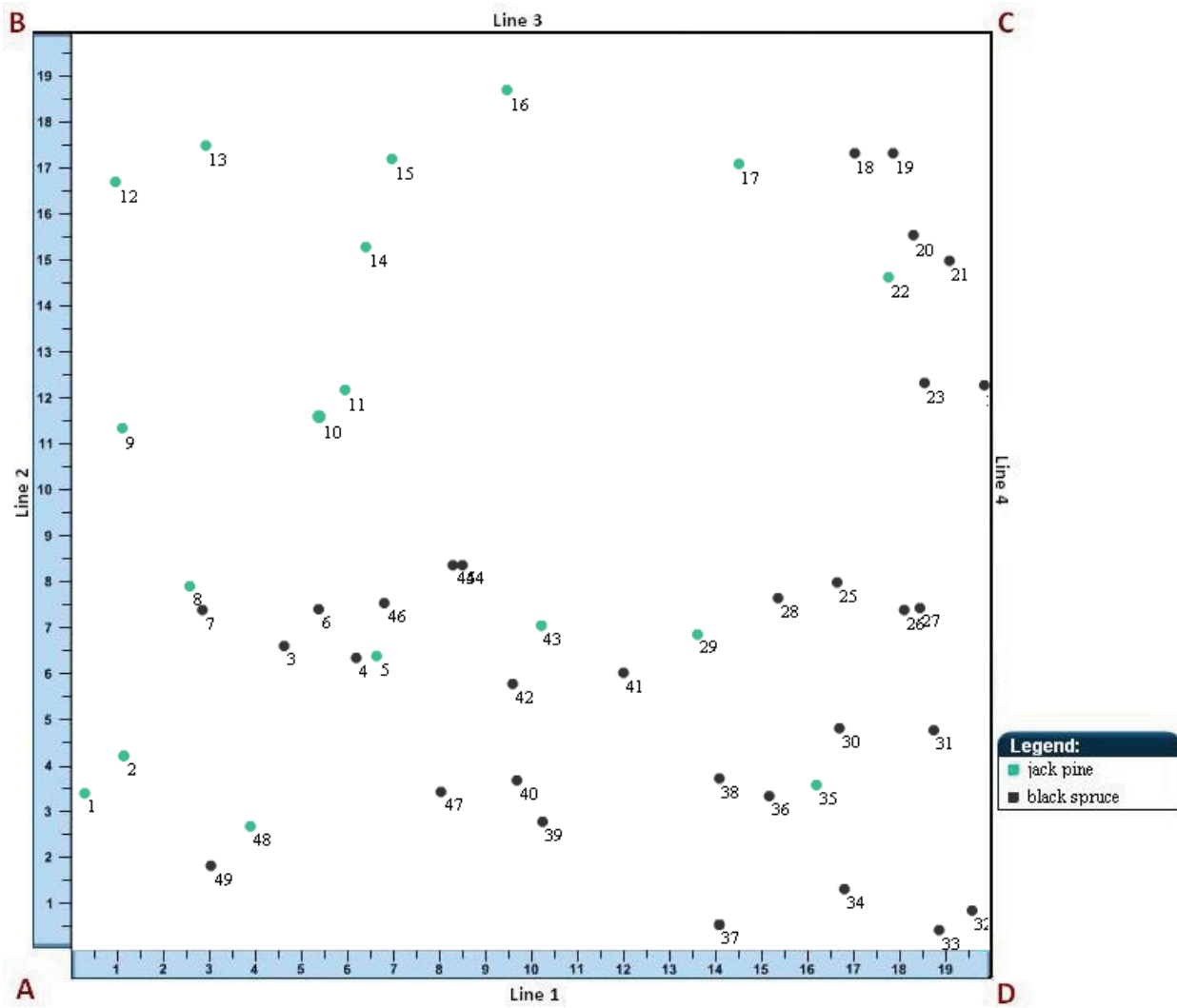
Metcaf Lake Riparian Blow-Down Plot 4



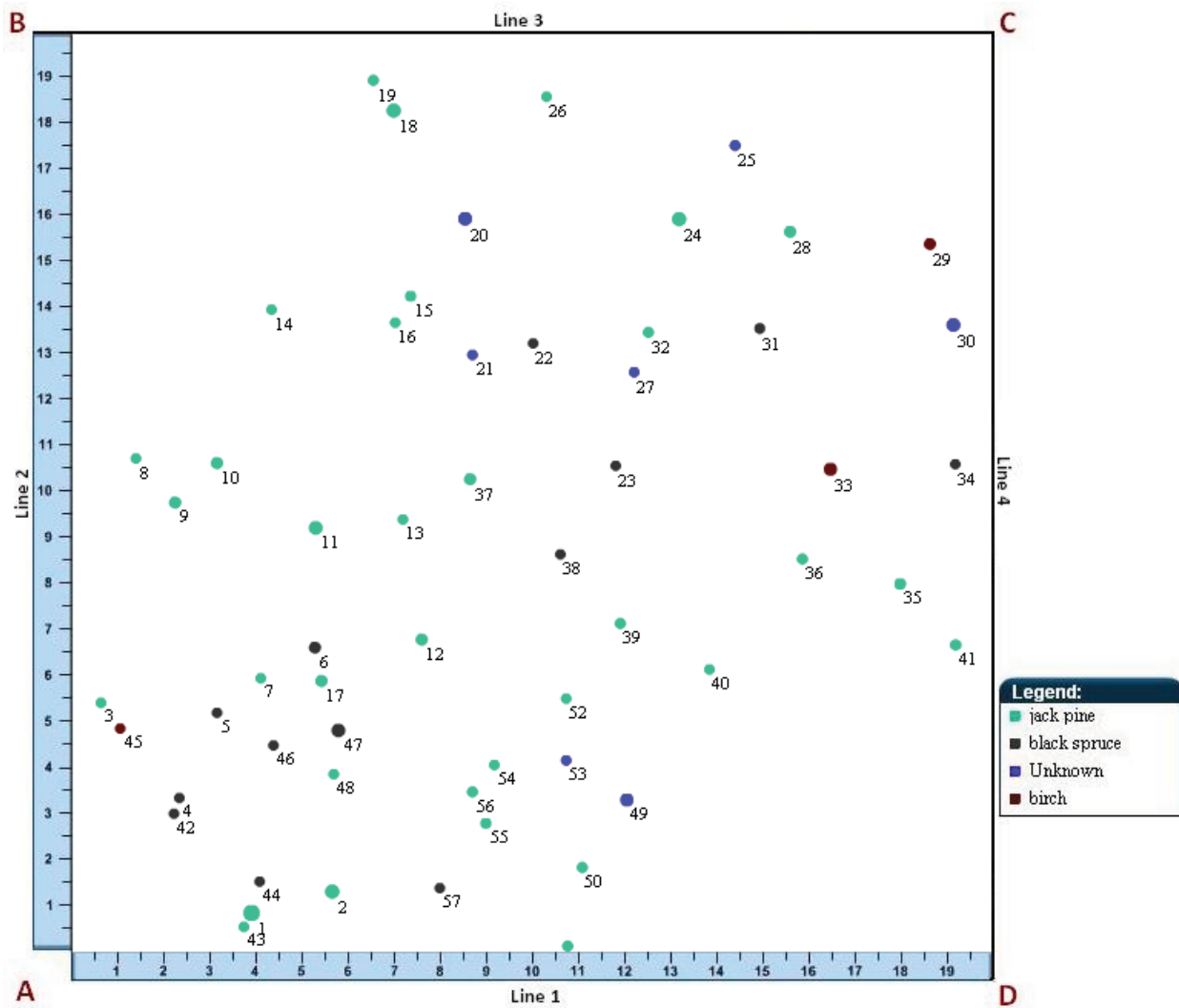
Metcaf Lake Riparian Blow-Down Plot 5



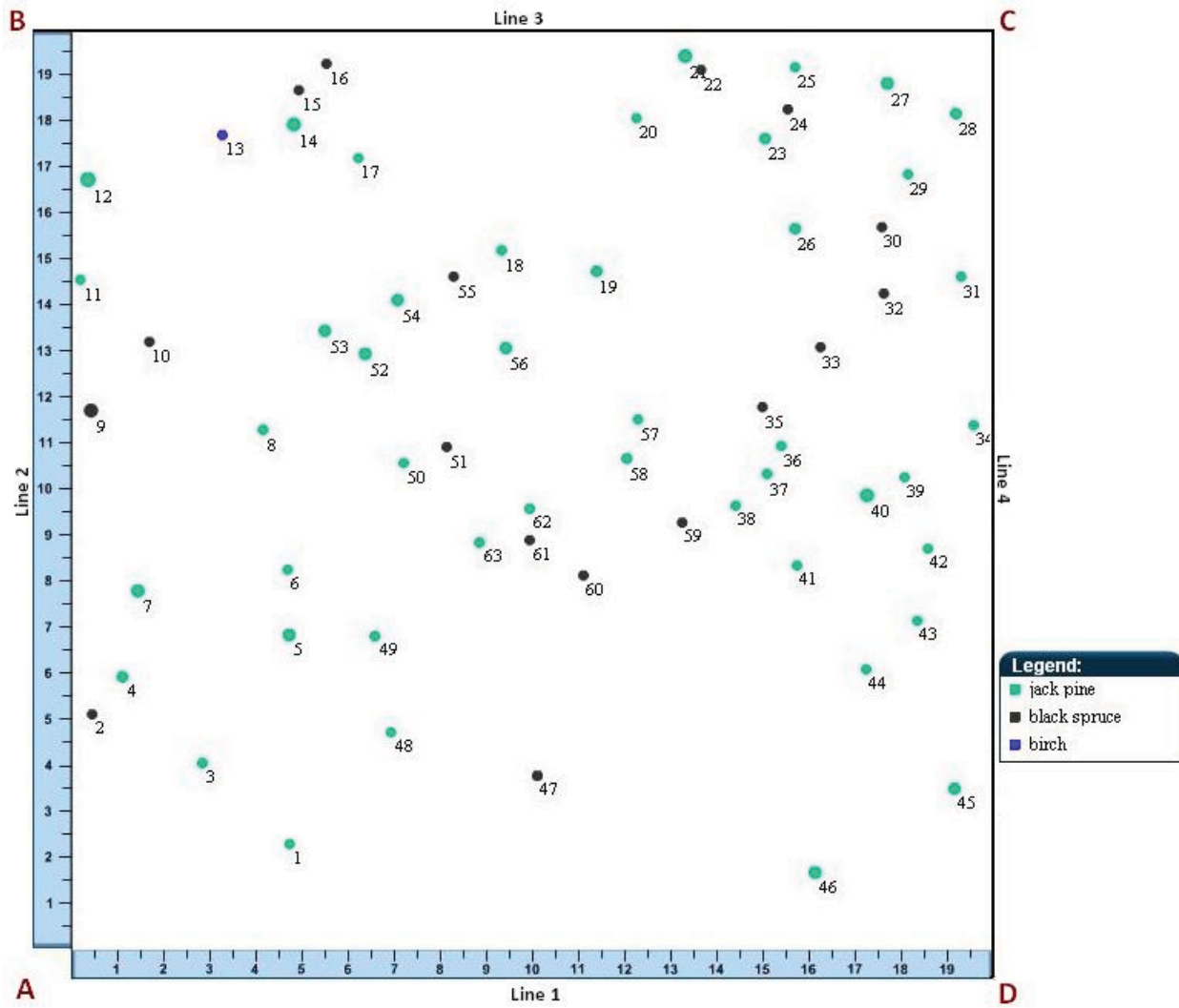
Metcaf Lake Riparian Live Standing Plot 1



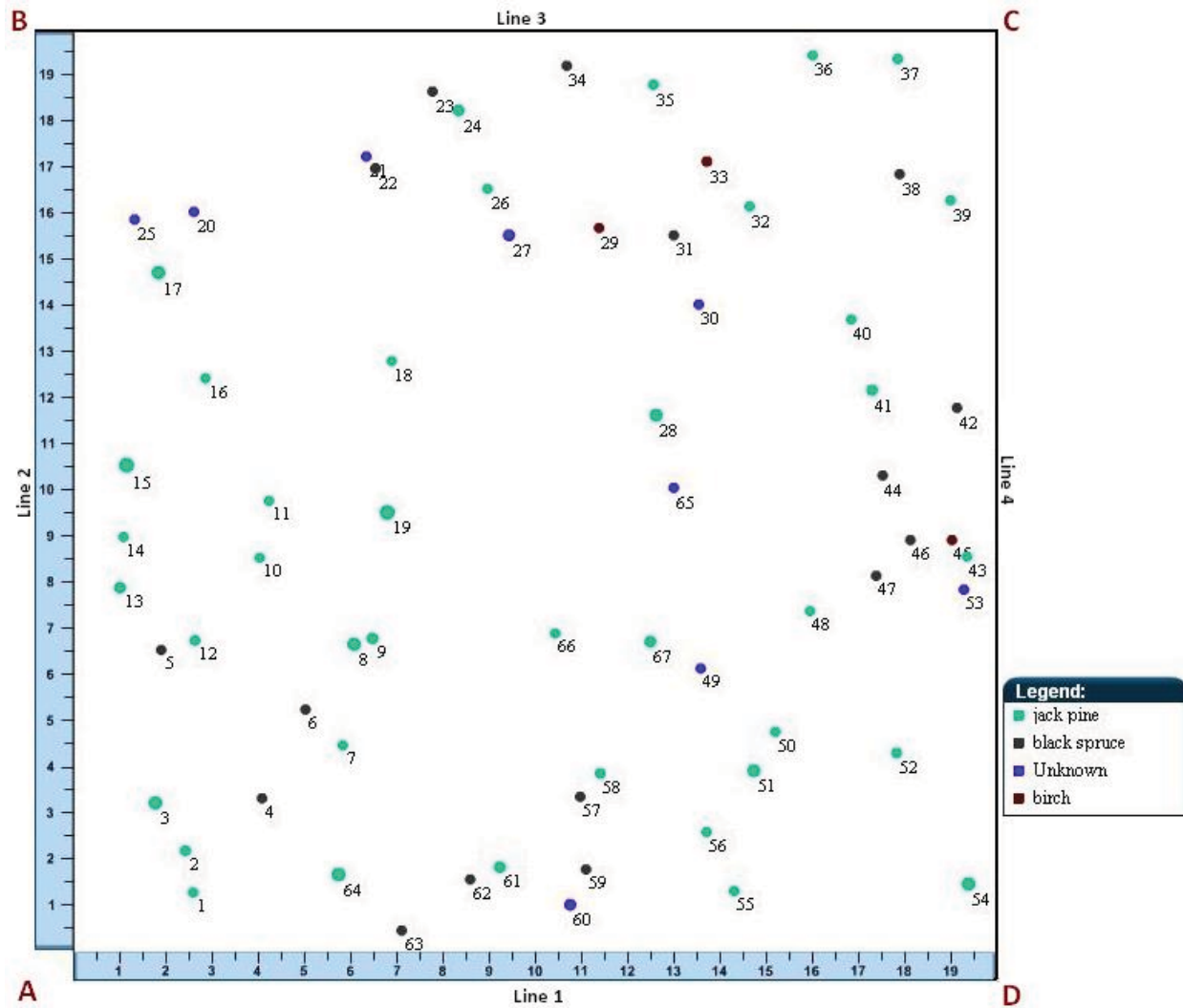
Metcaf Lake Riparian Live Standing Plot 2



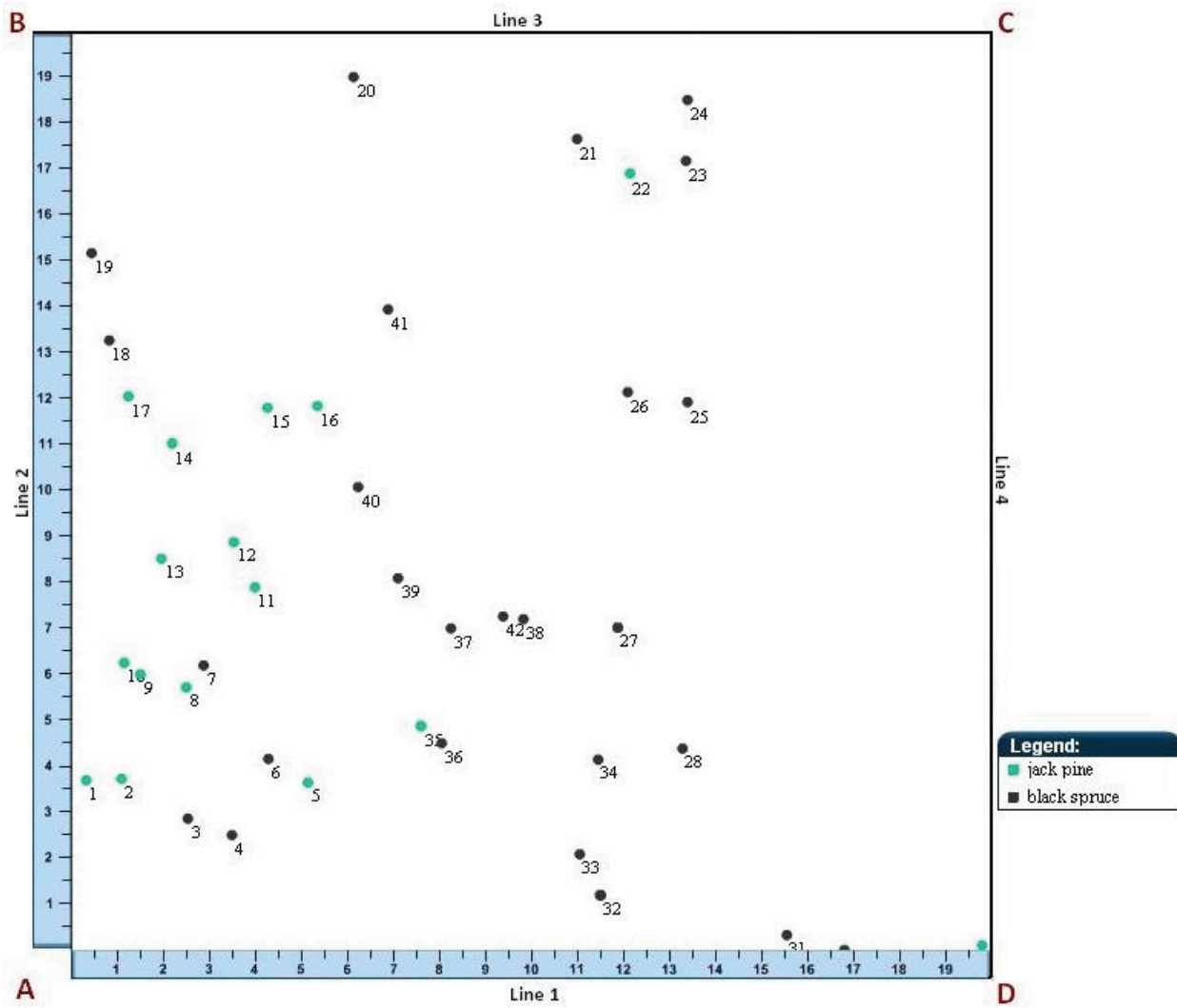
Metcaf Lake Riparian Live Standing Plot 3



Metcaf Lake Riparian Live Standing Plot 4



Metcaf Lake Riparian Live Standing Plot 5



Appendix III: Species list

Trees		
Common Name	Scientific Name	Notes
Black Spruce (BS)	<i>Picea mariana</i>	
Jack Pine (JP)	<i>Pinus banksiana</i>	
White Birch (WB)	<i>Betula papyrifera</i>	
Unknown (Ukn)	<i>Unidentifiable Species</i>	Species too old or decayed to identify

Saplings, Seedlings, and Shrubs		
Common Name	Scientific Name	Notes
Blueberry	<i>Vaccinium myrtilloides</i>	
Chokecherry	<i>Prunus virginiana</i>	
Gooseberry	<i>Ribes oxycanthoides</i>	
Juniper	<i>Juniperus communis</i>	
Labrador Tea	<i>Ledum groenlandicum</i>	
Lowbush Cranberry	<i>Viburnum edule</i>	
Narrow-leaved meadow sweet	<i>Spiraea alba</i>	
Raspberry	<i>Rubus idaeus</i>	
Ribes spp	<i>Ribes spp.</i>	
Rose	<i>Rosa acicularis</i>	
Saskatoon	<i>Amelanchier alnifolia</i>	
Willow	<i>Salix spp.</i>	

Also Found in Plots		
Common Name	Scientific Name	Notes
Blue bead Lily	<i>Clintonia borealis</i>	
Indian Pipe	<i>Monotropa uniflora</i>	
Sedge (carex)	<i>Carex spp.</i>	
Sweet Scented Bedstraw	<i>Galium triflorum</i>	
Hookers Orchid	<i>Platanthera hookeri</i>	
Lesser Rattlesnake Plantain	<i>Goodyera repens</i>	
One-sided wintergreen	<i>Pyrola secunda</i>	
Pink Wintergreen	<i>Pyrola asarifolia</i>	
Common Snowberry	<i>Symphoricarpos albus</i>	
Wild Strawberry	<i>Fragaria virginiana</i>	

Ground Vegetation Layer		
Common Name	Scientific Name	Notes
Ash	(Green) <i>Fraxinus pennsylvanica</i> (Black) <i>Fraxinus nigra</i>	Distinction could not be made between Green and Black species
Aster spp	<i>Aster spp.</i>	
Bearberry	<i>Arctostaphylos uva-ursi</i>	
Bluebell	<i>Campanula rotundifolia</i>	
Bunchberry	<i>Cornus canadensis</i>	
Cedar Club-moss	<i>Lycopodium digitatum</i>	
Checkered Rattlesnake Plantain	<i>Goodyera tessellata</i>	
Cow Wheat	<i>Melampyrum lineare</i>	
Dwarf Scouring-rush	<i>Equisetum scirpoides</i>	
Fireweed	<i>Epilobium angustifolium</i>	
Fringed Black Bindweed	<i>Polygonum ciliinode</i>	

Ground Vegetation Layer		
Common Name	Scientific Name	Notes
Fungi	<i>Fungi spp.</i>	Unidentified mushrooms
Grass spp	<i>Poaceae spp.</i>	
Lichen	<i>Lichen spp.</i>	
Meadow Horsetail	<i>Equisetum pratense</i>	
Moccasin Flower	<i>Cypripedium acaule</i>	
Moss	<i>Moss spp.</i>	
Peavine spp	<i>Lathyrus spp.</i>	
Pine tree club-moss	<i>Lycopodium obscurum</i>	
Pink Corydalis	<i>Corydalis sempervirens</i>	
Prince's Pine	<i>Chimaphila umbellata</i>	
Rock Polypody Fern	<i>Polypodium virginianum</i>	
Running club-moss	<i>Lycopodium clavatum</i>	
Small Bog cranberry	<i>Oxycoccus microcarpus</i>	
Species B	<i>Unknown species</i>	
Spinulose shield fern	<i>Dryopteris austriaca</i>	
Star Flower	<i>Trientalis borealis</i>	
Stiff Club-moss	<i>Lycopodium annotinum</i>	
Three toothed cinquefoil	<i>Potentilla tridentata</i>	
Twinflower	<i>Linnaea borealis</i>	
Viola spp	<i>Viola spp.</i>	
Wild Lily of the Valley	<i>Maianthemum canadense</i>	
Wild Sarsaparilla	<i>Aralia nudicaulis</i>	
Wintergreen spp.	<i>Pyrola spp.</i>	