Community Monitoring at the Boreal Ecology Centre: Aspen, White Spruce - Mixed Forest

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Prepared by:

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Photo credit to Graham Peters.

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Abstract

This study aims to establish a consistent methodology for ongoing monitoring of plant biodiversity at the Boreal Ecology Centre (BEC). Through semi-annual observations of pre-defined forest subtypes, changes in species composition will be tracked, enhancing understanding of forest health and succession. If a decline in biodiversity or overall populations is detected over time forest management interventions that mimic natural disturbance regimes may be necessary to support natural cycling. Importance Values for each tree species were determined to track and compare ecological dynamics between quadrats and years.

Adopting ecosystem monitoring protocols from A Rocha Brooksdale, the study incorporates permanent monitoring plots to observe plant populations and diversity over time (Bunnell et al. 2018), giving a sense of ecosystem health. We can assess how forest regions are changing overtime, evaluating whether they promote a healthy ecosystem or if the forest is becoming susceptible to intense fires and loss of biodiversity.

Our findings show that species composition of the observed ecounit is more in line with the expected species in Ecounit 7 - Labrador Tea, Jack Pine, Black Spruce, than to its previously defined Ecounit 6 - Aspen, White Spruce - Mixed Forest. This was determined from relative abundances for expected species trembling aspen (8.22%), jack pine (16.44%), and ash (1.37%) being relatively low and average diameter breast height being relatively high, suggesting those that remain are older. The tree layer showed black spruce (24.66%) and balsam fir (21.92%) in greater relative abundances. This and the shrub and herb layer observations will serve as our baseline understanding of the species diversity and with continued monitoring we can track fluctuations in relative abundances and overall species diversity.

1. General Introduction

The BEC can be understood as a mosaic of forest types, defined in 2006 as part of an environmental inventory, which was designed to identify potential conservation initiatives in line with A Rocha's mission to live out God's calling to care for creation and equip others to do likewise. The ecological diversity of the centre made it valuable for its potential for education and the wide array of initiatives that could take place over the different ecouints[1]. These areas can be characterized as mapped regions identified by consistent sets of vegetation and other ecological elements including growth patterns and serve reporting purposes in management planning (Scuralli & Mielhausen 2018). This diversity lent itself to recommendations for potential management and further study in fire risk management and succession among other areas of interest (Kistamo & Carlson 2006).

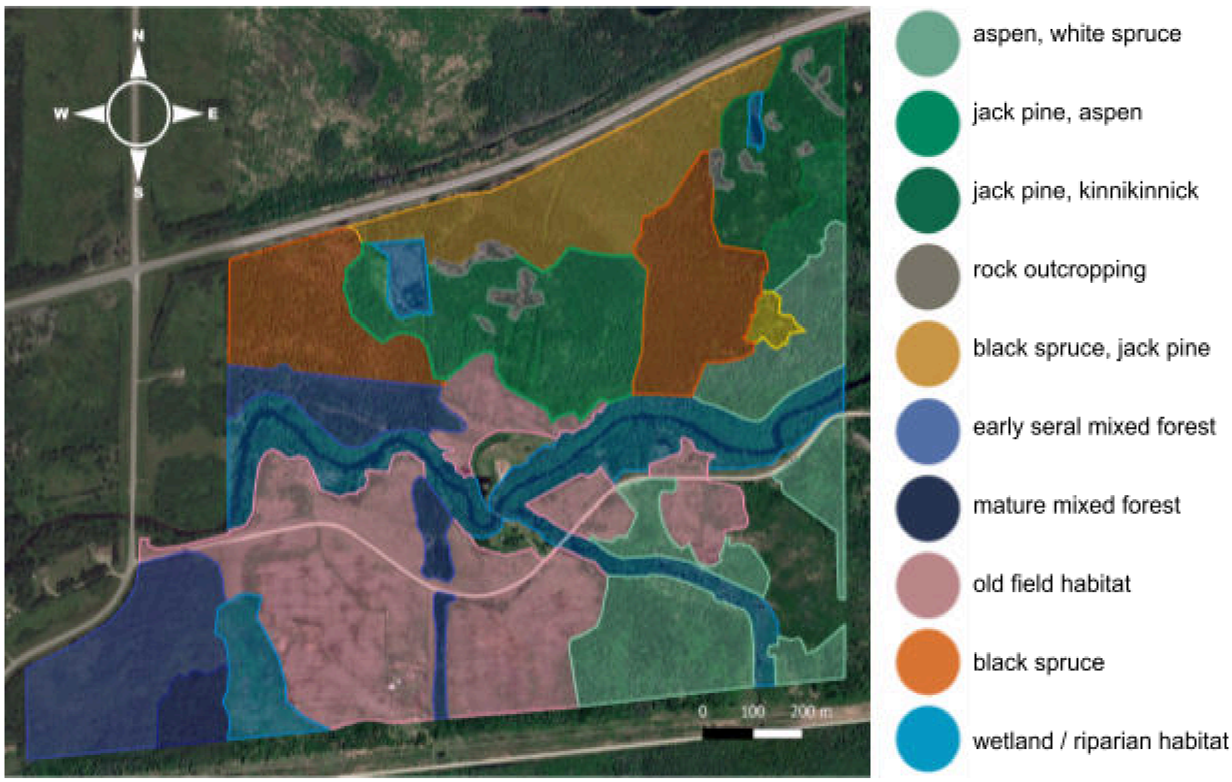

Figure 1. Ecosystem Map of the Boreal Ecology Centre 2022 potential ecounit update.

In the summer of 2020 this initial inventory was referenced as part of a site map update that would approximate changes to ecounit ranges as shown in Figure 1. Our preliminary findings after ground truthing suggested several of our defined ecounits now occupied different ranges, possibly indicating succession. Quantitative estimates for the portions of stands that are in the process of transitioning to a different ecounit and those that remain unaltered can be calculated (Longpre & Morris 2012). Photo sequencing and survival analysis can potentially be used to measure forest succession and plan appropriate management. Succession has been

[1] Ecounit is a term referring to areas containing similar physical characteristics and vegetation communities used by Kistamo & Carlson 2006. This appears to be unique to this inventory; other sources use terms such as forest or vegetation type.

observed most clearly in areas previously defined as old field habitat after clear cutting and mowing now succeeding into early seral mixed forest containing tamarack (*Larix laricina*), trembling aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*), white spruce (*Picea glauca*), balsam fir (*Abies balsamea*), and jack pine (*Pinus banksiana*).

Also observed in preliminary ground truthing was a large build up of downed woody material (most appear to be jack pine). 25% dead standing trees are typical to eastern North American forest stands (Prior et al. 2012). A lack of large coarse woody debris can impact insects and cavity nesting birds and fungi, therefore debris may be valuable for overall biodiversity (Patry 2013). The observation of breeding birds or other fauna may be important to identifying the potential benefits of woody debris. In British Columbia abundant coarse woody debris of western redcedar (*Thuja plicata*) does not represent a pulse of recent mortality, the synchronous death of an overstory cohort, or a mortality rate that is disproportionate to the number of trees (Daniels 2003). Our preliminary understanding may represent a gradual buildup of woody debris, therefore mortality rate will be important to monitor.

However, fire origins are also a requirement for the natural reproduction of boreal forest and have played a key role in the mosaics of distinct vegetation types (Girardin & Mudelsee 2008). Various factors including light, moisture, temperature, and soil nutrients, contribute to vegetation development and distribution, all of which can be altered by fire (Ahlgren 1960). The last recorded wildfire in the area was the Richer fires in the 1950's when 38,000ha of pine, spruce, and poplar forest was burned. Stand-replacing disturbances could occur in as little as 20 years in jack pine forests in Ontario or as long as 500 years in black spruce (*Picea mariana*) forests in Labrador (McRae et al. 2001). A buildup of dead woody material could impact on the ability of future vegetation to establish themselves. Forest management can be used to emulate natural disturbances to recreate natural variability native species would have adapted to. This requires knowledge of natural variability therefore land history is required (Patry et al. 2013).

Biodiversity as a critical element of a forest's ability to maintain resilience has become increasingly obvious with the changing climate. Data for the Whiteshell area, located ~35.5km away from East Braintree, shows that average annual temperature is likely to increase by between 5.1°C and 9.4°C by the end of the century, compared to the average from 1981-2010. Current development patterns suggest a rise in temperature between 2.9°C to 5.6°C, while a shift towards sustainable development could limit the increase to 1.6°C to 4.3°C. Precipitation projections vary considerably across scenarios: under high-emission conditions, precipitation could increase by 20% or decrease by 10%; medium-emission scenarios suggest a potential increase of 15% or decrease of 4%; and low-emission scenarios predict either a 10% increase or a 3% decrease in precipitation (Shiab et al. 2024). These changes may impact forest health, as well as susceptibility to fire in the coming years.

With greater species diversity there is also increased flexibility when responding to disturbances, meaning that the ecosystem will be able to adjust and recover more easily. This would also impact new genetic variability in replacement stands after a disturbance (McRae et al. 2001). Trembling aspen is thin-barked and highly sensitive to fire even at low-intensity burns while bur oak (*quercus macrocarpa*) have thick insulating bark that allows them to survive such fires. Conifer and mixed forests can regenerate directly after fire, while boreal aspen-dominated forests can persist for extended periods without the encroachment of conifers into the canopy (Macdonald et al 2010). A resilient forest depends on the protection of biodiversity (Patry et al. 2013), therefore it is important to develop an understanding of forest biodiversity before prescribing management practices. This will help determine if natural cycling, unaffected by direct management practices, is promoting healthy succession or if management should be considered as a substitute for the burn cycles that would otherwise be part of this process.

Monitoring ground cover is important for the understanding of habitat stability. Shrubs and ground vegetation are important food sources for animals in the forest. Many species of birds will feed on dogwood or serviceberry fruits, the insects that are attracted to willows or goldenrods, or seeds from black-eyed Susans or asters (Kranking 2021). Small mammals often respond to predation risk by favoring foraging activity in areas with more shrub cover (Hinkelman 2012). Saplings are a good indicator of health of the forest and are key to determining what the future of the forest will be when the current, mature trees begin to die off (Scuralli & Mielhausen 2018).

1.1 Aspen, White Spruce - Mixed Forest

The classification of different forest types allows researchers to determine the developmental stage of a forest and track succession (Scuralli & Mielhausen 2018). With the variable ecounits throughout the BEC, it is valuable to track changes in these different forest types in order to understand the health of the system. Where to begin was dependent on our understanding of these predefined ecounits and prioritizing areas that were successionally new. We began observation in EU6, otherwise known as Aspen White Spruce - Mixed Forest which is characterized by the following plant species:

> Split between the north and south side of the Boggy River. This multi-storied mixed forest stand is composed of aspen, jack pine, green ash, and white spruce, growing on sandy, well-drained soils. The stand also includes occasional large balsam poplar wildlife trees, veteran white spruce, and veteran jack pine. The understory includes: young aspen and balsam fir, nannyberry, red-osier dogwood, green alder, and beaked hazelnut. Understory herbaceous plants include: bracken ferns, wild sarsaparilla, bunchberry, palmate and arrow-leaved coltsfoot, wild strawberry, and tall grass species and rush.

This definition provided by Kistamo & Carlson (2006) formed the basis for accepting survey locations. Vegetation types from the *Forest Ecosystem Classification for Manitoba* (Zoladeski et al. 2000) were consulted to enhance our understanding of the species composition. These guides shared similarities including canopy-dominant species and matching our expectations of successional patterns. This would bring into question the narrow scope of our defined forest types. While Zoladeski et al. (2000) grouped forest types in Manitoba into more categories than those cataloged at the BEC, they categorized them broadly into mixedwood, conifer, and hardwood forests. These simplified definitions may be valuable for future understandings of the forest.

Longpre & Morris (2012) found jack pine-trembling aspen mixtures were rare, and most stands were quickly observed to experience ingress by additional species in Ontario's boreal forest region. This pattern aligns with our anticipated species composition. This shift is characterized by the gradual decrease in jack pine and trembling aspen, while black spruce and other concurrently established and invasive species start to dominate, eventually resulting in black spruce dominance.

Through ground truthing there was also an observed continuity in the undergrowth. Many species were found throughout the changing landscape regardless of defined ranges, which may point to a greater homogeneity of forest types. As we observe additional forest types over time we will be able to more clearly determine the level of sameness in ground cover between ecounits. However, as noted by Longpre (2008), there is potential for researcher bias in expecting a trajectory of succession and observing candidates that support that understanding.

2. Overall Methods

This project was influenced by the *Community Monitoring of Forest Biodiversity* (Bunnell et al. 2018) in order to build A Rocha Manitoba's foundations for forest monitoring with connected and pre established work. As with the Brooksdale forest monitoring project, ours based its methodology on the *Ecological Monitoring and Assessment Network: Terrestrial Vegetation Monitoring Protocol* bolstered by *Forest Vegetation Monitoring Protocol for National Parks in the North Coast and Cascades Network* (EMAN). It is important to note that dynamics of Canada's forests vary greatly among and within biophysical regions (McRae et al. 2001), which influenced changes made to better fit our context. Our methods also took elements from the *Forest Vegetation Monitoring Protocol: Terrestrial Long-term Fixed Plot Monitoring Program*, due to its prior association with EMAN and usefulness for nesting quadrat methods.

The EMAN program was developed in order to put protocols in place that were specifically tailored to Canadian conditions and questions, such as decay rates and downed woody debris. However, Canada has not maintained its federal data requirements for forest health and biodiversity. This would result in the discontinuation of EMAN monitoring protocols in 2010. In spite of changes in federal policy, the need for information to assist forest conservation practices intended to sustain biodiversity is still critical (Bunnell et al. 2018). We are continuing to use this protocol in order to effectively set a baseline for our understanding of forest health and biodiversity and capitalize on EMAN's connections to other forest monitoring methodologies, such as the ORMCP Monitoring in Toronto, Ontario (Prior et al. 2012).

2.1 Reach Choice and Plot Establishment

To determine where quadrats should be established the property was subdivided into ecounits defined in the 2006 baseline report (see Figure 1). Aspen, White Spruce - Mixed Forest (EU. 6) was selected for this project because it was identified as successionally new (Zoladeski et al. 2000). Our purpose was to observe the species diversity of a hypothesized new grown area of forest before analyzing older growth forest. This would also provide an opportunity to see what species continue to succeed others in the future, if our defined ranges of mature and early forests from the baseline report are accurate.

A 20m×20m grid was overlaid on EU. 6 and sites were randomly selected from this grid and centroids of these quadrats were delineated to provide base points for locating and establishing quadrats during site visits[2]. Figure 2 shows the relocation of quadrat 6.1, where the whited out quadrat was not selected due to being too close to a gradient based proximity to gradients (trails) based on EMAN requirements. Zoladeski et al. (2000) would also recommend completing observations in sites that are representative and homogenous, which would mean sites (typically around gradients) would be rejected if they lacked target species. Table 5 in the appendix shows the target GPS and actual points that are used for the projects.

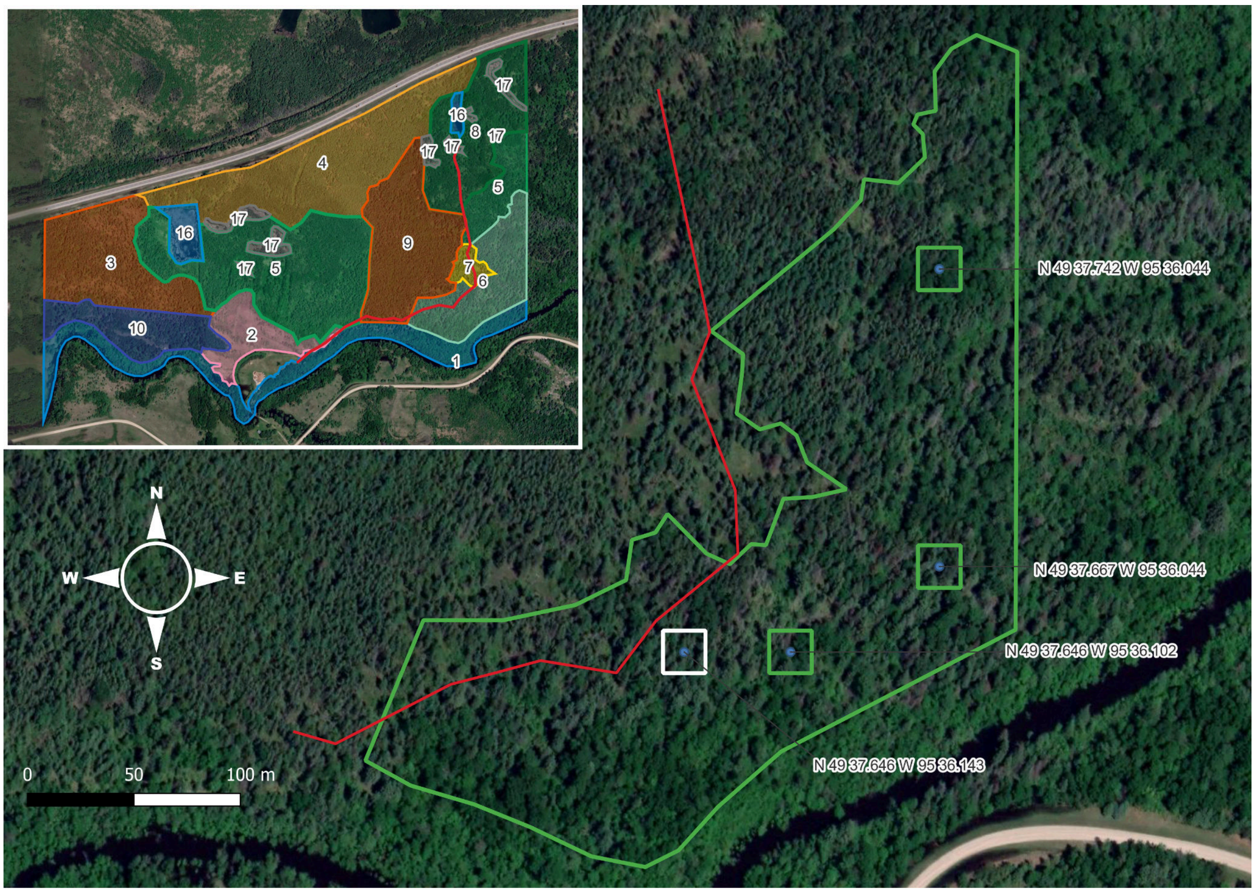

Figure 2. Randomized Aspen, White Spruce - Mixed Forest quadrats. Labels on the map correspond to ecounit numbers assigned in 2006.

Once each 20m×20m quadrat was established, 5m×5m were placed following the Forest Vegetation Monitoring Protocol; placing quadrants in pre-arranged locations (see Figure 3). For specific quadrat layouts see Figures 11a and 11b in the appendix. Quadrats were established in

[2] Updated ecounits were built in QGIS based on Maxar imagery from August 2014, and has since been updated with images from June 2020.

May and June of 2022, and then monitoring took place through August. The northernmost quadrat (6.3) was established, but not observed due to time constraints. To avoid this in the future we will aim to start monitoring work in July.

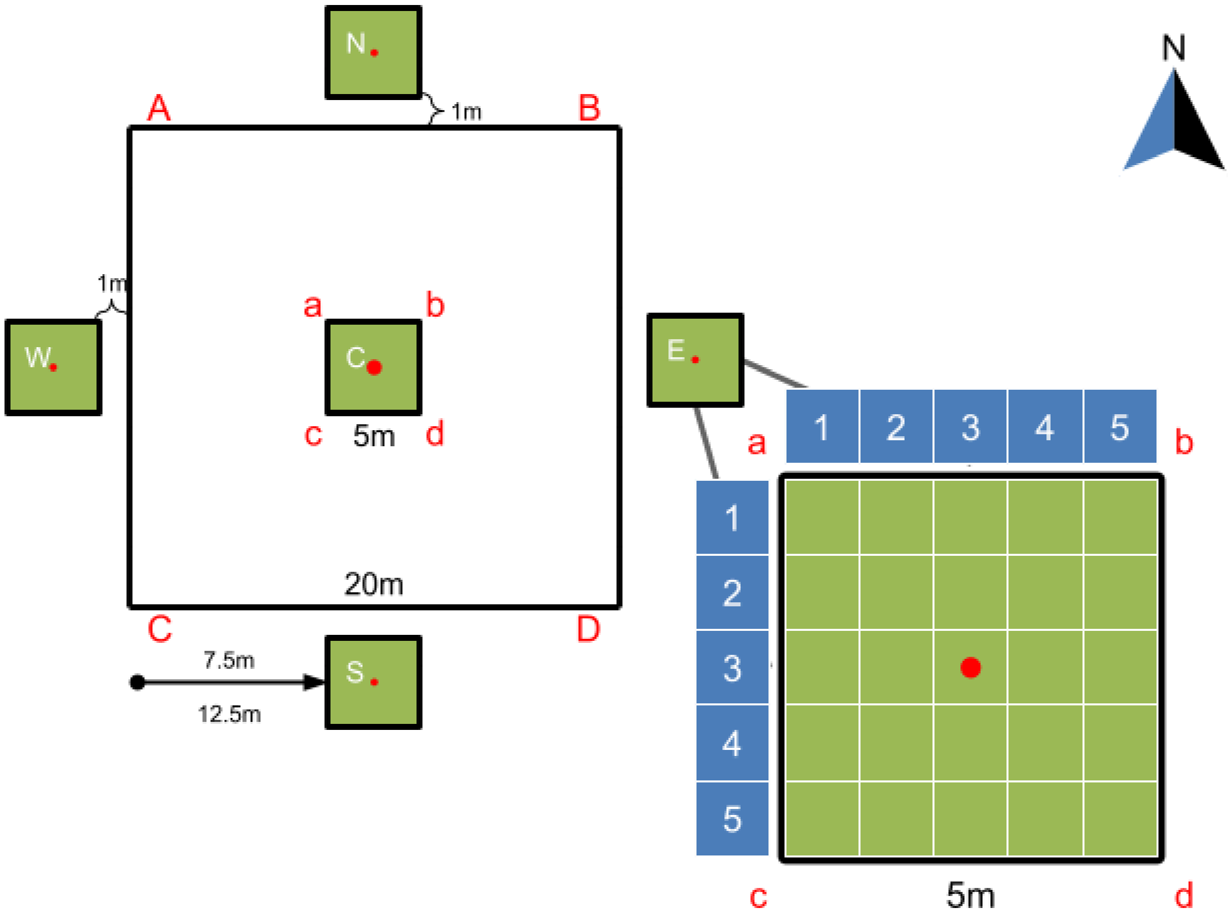

Figure 3. Forest Vegetation Monitoring Protocol quadrat measurements and example nested quadrat highlighting herbaceous quadrat random selection methodology.

2.2 Tree-layer plots

The species represented in the EU. 6 quadrats were identified ahead of time and 5 specimens of each were taken in the surrounding area for age determination. Core samples were collected and analyzed at a later date to approximately correlate diameter breast height (dbh) to the number of rings. Additional or alternative samples can be taken in the future if it is determined that they are needed in order to draw clearer conclusions about stand age.

Dbh was collected using EMAN requirements, as shown in Figure 4 and each tree with a dbh ≥3cm was labeled. We observed a smaller minimum dbh than the studies we based our work on. In Manitoba, a tree is typically characterized as a woody plant featuring a distinct trunk and visible crown. It must attain a minimum height of 4.5m when fully grown and possess a dbh of at least 5cm (Field Guide Trees of Manitoba). Adopting a smaller dbh threshold allowed us to account for the unique ecological characteristics of our region. This inclusion can provide a more comprehensive understanding of the biodiversity and species composition within the forest, capturing a wider range of species and age classes. Any irregularities with the number of stems or angles were recorded during the observation process. Trees with lower dbh are associated with earlier succession states (Scuralli & Mielhausen 2018).

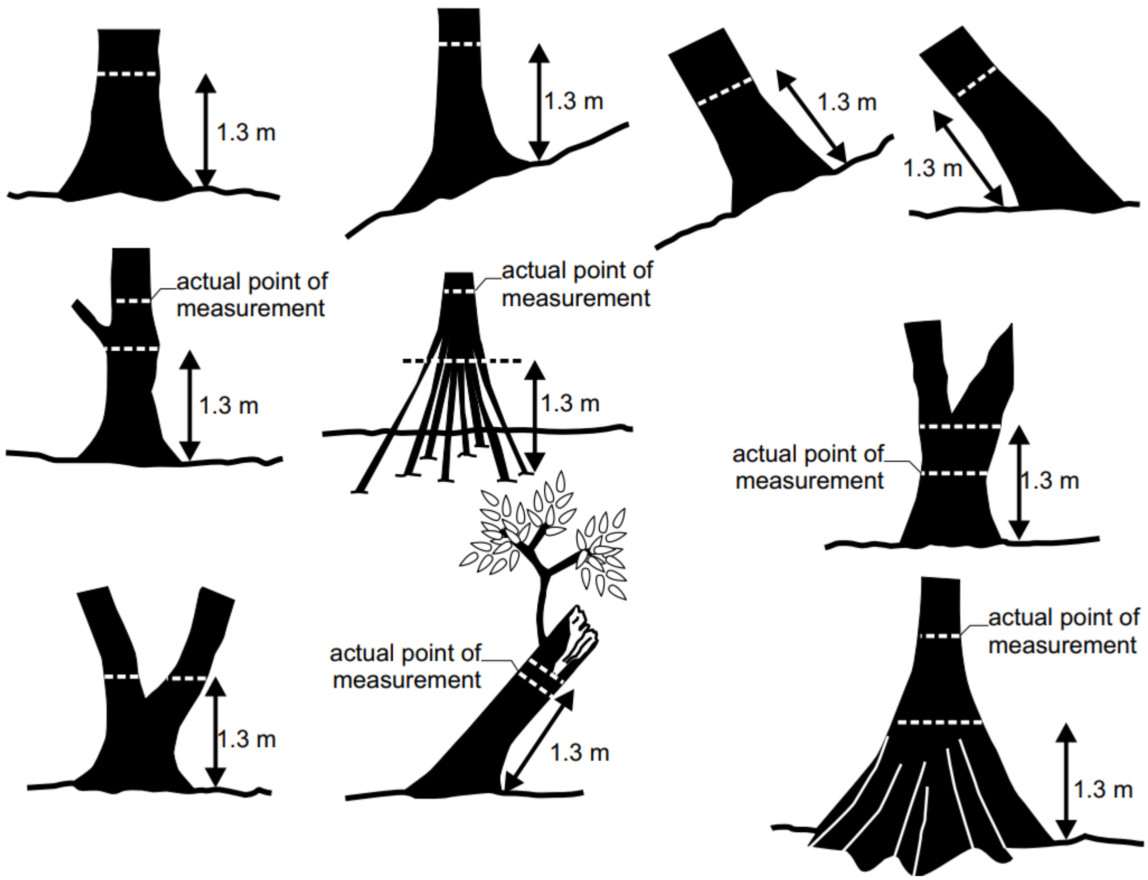

Figure 4. Measuring positions of dbh from EMAN. Single dotted line shows the measurement position - if because of a fault two dotted lines are shown, the correct position is labeled.

In each quadrat every numbered tree was mapped in relation to two adjacent corner stakes. Measurements to corner posts were recorded and data was used to determine the location of stems within the quadrat. These distances were also used for finding the height of each individual tree, which are important for observing growth rate in future site visits. From a measured distance from the base of a tagged tree the angle to the highest observable branch is observed and recorded using an inclinometer (see Figure 5).

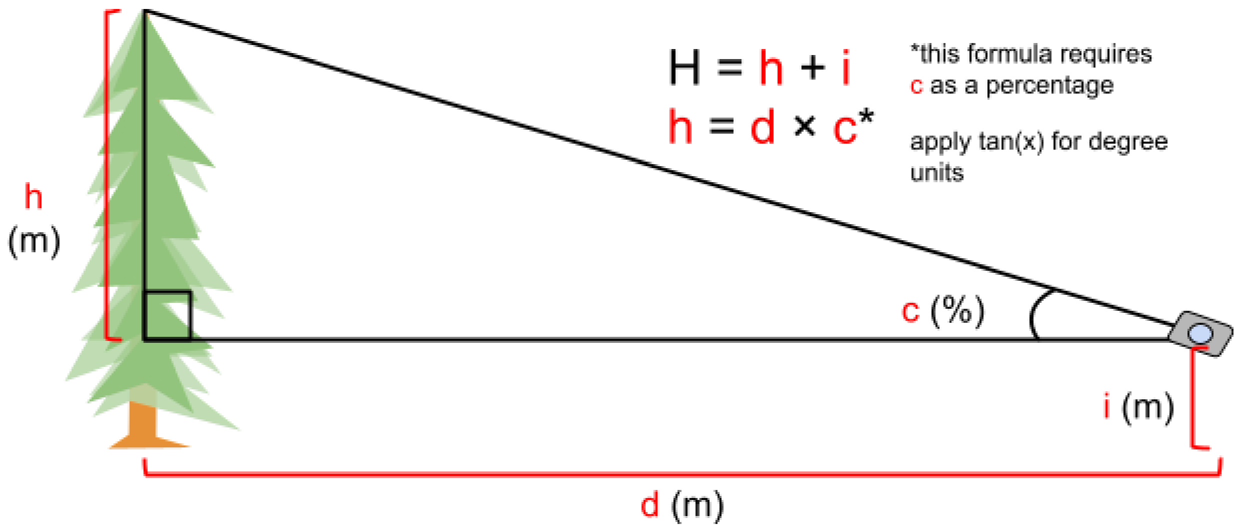

Figure 5. Clinometer methodology.

Conditions of these trees were also observed given codes from EMAN shown in Figure 6, except for 'fallen/prone dead' trees which were not recorded.

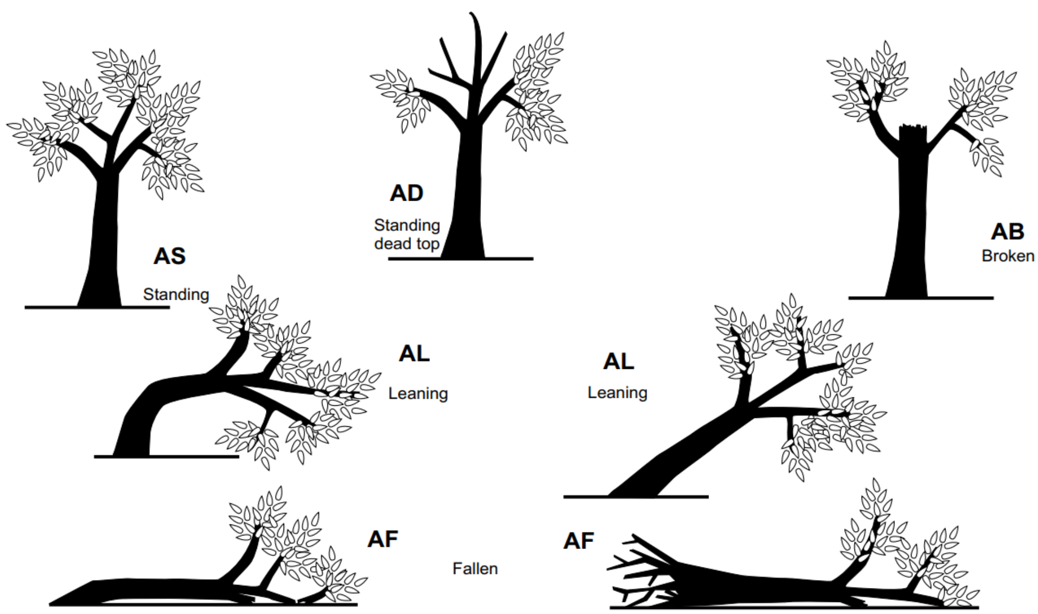

Figure 6. Tree conditions and codes from EMAN.

2.3 Shrub-layer plots

Shrubs are defined as typically multi-stemmed woody plants <4cm dbh with most of the stems originating at or near the ground. Saplings <4cm dbh were measured with the shrubs in the shrub and small tree stratum. Individuals within each species' were measured from the ground to the upper most living portion of the plant with a tape measure and recorded into the appropriate height class. For leaning plants the vertical distance from the ground to the highest part of the plant was recorded as the height. The total number of individuals in each height class was tallied by species to establish a total stem count. This procedure was repeated for all subplots.

2.4 Herb-layer plots

Within herb plots we observed all herbaceous vascular plants. Woody shrubs and saplings <1m in height, lichens, mosses and fungi were observed and recorded, but not tallied in the reported diversity counts in order to avoid incorrectly reporting greater species diversity. Once the appropriate 5m×5m quadrat was located 2 measuring tapes were used to create a cross section that intersected at the north-west corner of the randomized 1m×1m nested quadrat. Any obstructions to the 1m×1m were noted and the quadrat was shifted. The quadrat was then placed and percent cover of each herbaceous plant found within it was approximated. It is also noted if a species is solitary. Pictures were taken for each quadrat in order to refer back to, shown in Figure 12 in the appendix.

3. Results

Our study identified a total of 58 plant species across tree, shrub, and ground layers. Analysis revealed relatively low abundances of expected species such as trembling aspen (8.22%), jack pine (16.44%), and ash (1.37%), indicating a species composition more aligned with EU 7. Greater relative abundances were observed of black spruce(24.66%) and balsam fir (21.92%). Additionally, the shrub layer displayed diversity with notable species abundances including beaked hazelnut (25.67%), balsam fir (20.13%), and chokecherry (13.15%). The ground layer featured species including bunchberry (11.84%) and wild strawberry (7.89%). Some expected species were not observed, although similar ones were noted. These findings form the foundation of our understanding of biodiversity in this forest subsection moving forward.

We also calculated the Importance Values for each tree species in order to quantitatively track and compare stands in reference to species composition (Roberts-Pichette & Gillespie

1999). For this study we had the limitation that individual shrubs were not counted, therefore Relative Density could not be determined for the shrub layer. The ground layer as well may present this limitation given that individuals are estimated by percent coverage but not tallied.

3.1 Tree layer-plots

In total, 9 species were recorded in the tree layer from these plots, shown in Table 1 summarizing the mean heights and dbh of each of these species distributed across the two observed quadrats. Black ash, green ash, balsam fir, trembling aspen, and balsam poplar were observed in the shrub layer as well, as well as additional tree species Manitoba and dwarf maple.

Table 1. Attributes of live trees summarized by quadrat.

Species	Total	mean height (m)	mean dbh (cm)	Species	Total	mean height (m)	mean dbh (cm)
6.1				6.2			
w. spruce	8	16.40	17.51	b. spruce	15	12.84	14.09
b. fir	5	12.34	14.10	j. pine	12	17.10	24.32
t. aspen	6	19.41	27.53	b. fir	11	9.11	12.18
p. birch	3	15.66	16.55	p. birch	2	15.23	16.87
b. spruce	3	13.41	19.95	w. spruce	1	7.52	14.32
w. elm	5	12.78	11.84	a. buckthorn	1	6.63	6.05
ash spp.	1	5.48	8.28				

Over all quadrats and species, dbh ranged between 4.46cm and 36.92cm, with a mean of 17.04cm. Tree height was between 2.23m and 23m, with a mean of 13.8m, therefore our average canopy was 13.8m. Trembling aspen and black and white spruce are observed to be larger on average which is consistent with the classification of this sight in 2006 as aspen and white spruce dominant. However, jack pines in quadrat 6.2 were larger. In addition, the relative abundance of other observed species (see Table 3.) may indicate the beginning stages of succession. Overtime we will need to continue to observe the growth of these individuals, as well as die off of some of the older individuals.

Table 3. Relative abundance of tree species.

Black spruce	24.66%	Trembling aspen	8.22%
Balsam fir	21.92%	Paper birch	6.85%
Jack pine	16.44%	White elm	6.85%
White spruce	12.33%	Other[3]	2.74%

Despite the expected species dominance based on our observed range, few aspen and white spruce were observed and only one ash species in the lowest recorded diameter class (see Figure 7). This information along with the fact that aspen occurred in larger height and diameter classes may further suggest succession into something reflecting the relatively high balsam fir and black spruce, which together made up 46.58% of our observed tree species.

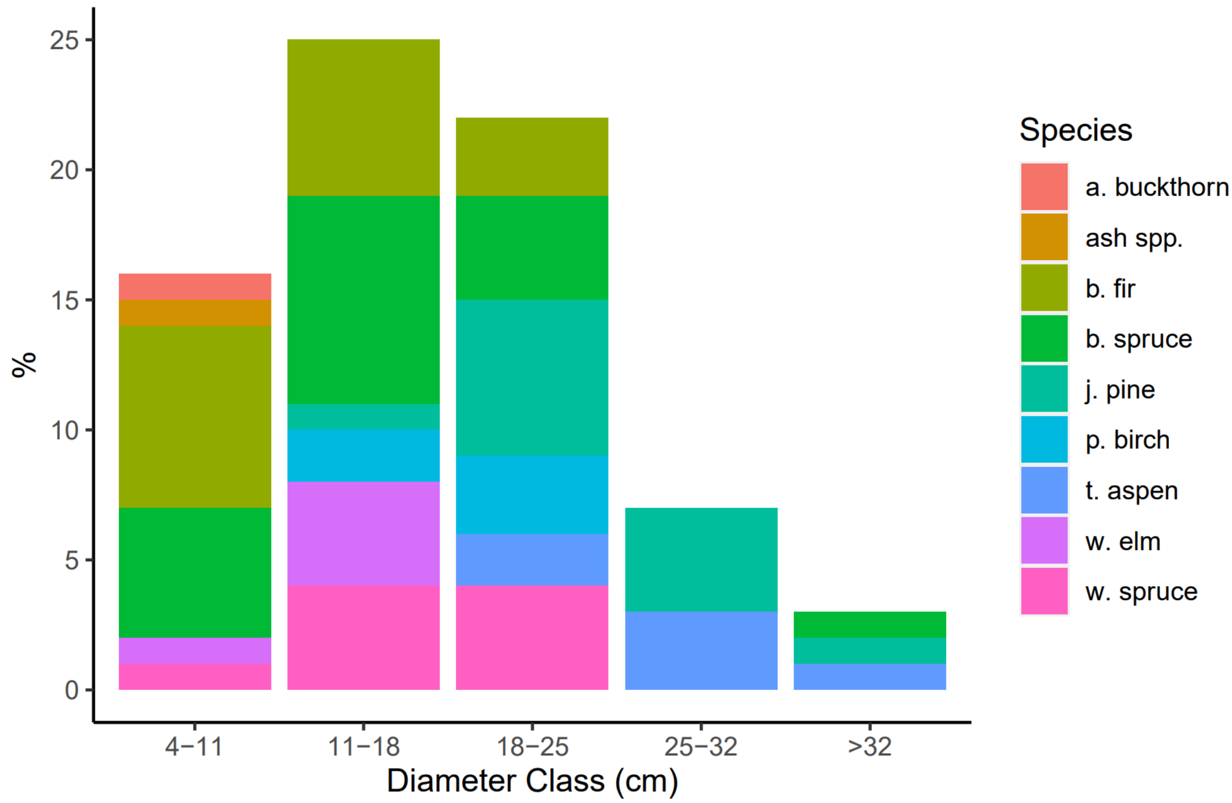

Figure 7. Diameter distribution of the tree species aggregated across both macroplots.

Our core samples presented some variability when predicting age as it relates to dbh across different species (see Table 2). These samples show an average stand age around 14 years, with jack pine stands tending to be older on average (24 years), while trembling aspen stands are relatively younger. The variability in age estimates, as indicated by the standard deviation, suggests that the accuracy of age estimation may vary, with some species estimates being

[3] Other is subdivided into single observations of alderleaf buckthorn and ash spp..

consistent than others. More samples can be taken in the future to capture all of the species we observed, which may improve the overall accuracy of our age predictions (Bunnell et al 2018).

Table 2. Average correlation between dbh and age derived from core samples for observed species.

	b. fir	b. spruce	j. pine	p. birch	t. aspen
Mean	0.702	0.848	0.971	0.709	0.484
Standard Deviation	0.078	0.325	0.280	0.316	0.026

The stem maps in Figures 8a and 8b illustrate the species diversity and distribution within the observed quadrats, along with the overall basal area. Additional details regarding the basal area are provided in Table 4. Quadrats 6.1 and 6.2 exhibit similar overall diversity, but the species composition differs. Jack pine and alderleaf buckthorn were only observed in quadrat 6.2 and trembling aspen only in 6.1.

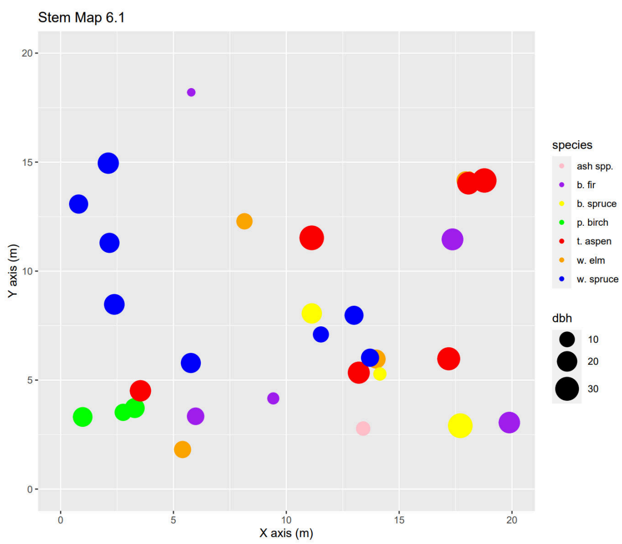

Figure 8a. Stem map depicting the density and basil area of the tree species observed in quarat 6.1.

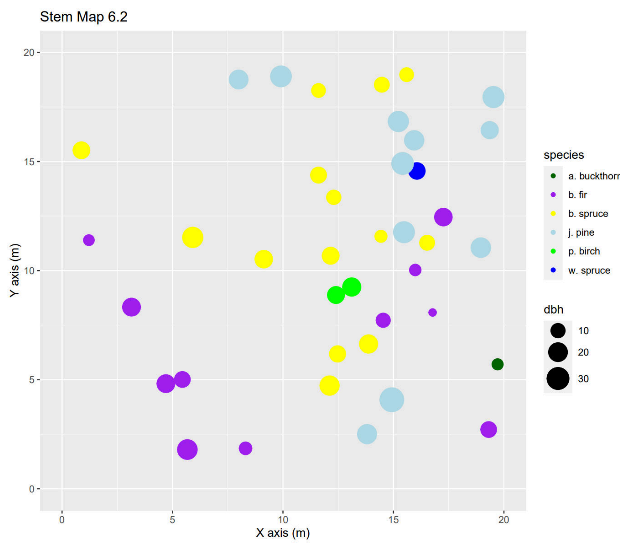

Figure 8b. Stem map depicting the density and basil area of the tree species observed in quarat 6.2.

Structural diversity within a stand can be assessed through different variables, including stem density and spatial patterns of the canopy (McRae et al. 2001). Our findings show a diverse spread of species across both quadrats. These data along with Importance Value give a base understanding for the overall tree layer diversity of the ecounit. The Importance Value is an index made up of Relative Density[4], Dominance[5], and Frequency[6]. As this value changes it will

[4] Average number of individuals of a species on a unit area basis (density) relative to the density of all species.
[5] Area a species occupies relative to the total area occupied by all species.
[6] Percentage of quadrats in the sample area in which a given species occurs (distribution) relative to the distribution of all species.

help us quantitatively track the change in species composition between stands. Table 4 shows the Importance Values calculated for the tree layer-plots. Mixed forest stands can have higher productivity because of niche differentiation, resource optimization, enhanced nutrient cycling, and nurse crop effects (Macdonald et al 2010). Overtime we may find that the diversity of species in our sites presents higher basal areas and densities.

Table 4. Importance Values for each species observed in the Tree layer-plots.

Species	6.1	6.2	Total
w. spruce	0.63	0.19	0.39
p. birch	0.32	0.24	0.28
t. aspen	0.67	0.08	0.34
w. elm	0.31	0.08	0.18
b. fir	0.43	0.56	0.50
b. spruce	0.38	0.76	0.59
ash spp.	0.12	0.08	0.09
j. pine	0.08	0.78	0.48
a. buckthorn	0.08	0.11	0.10

3.2 Shrub-layer plots

To establish an optimal sample size for our shrub layer and ground layer quadrats, we developed a species accumulation curve. The curve enables us to plot the relationship between the area surveyed (number of quadrats) and the cumulative number of species observed. The curve will typically exhibit a sharp rise, reflecting the first observation point including entirely new species, and then as more observation points are added, the rate of new species observations will decrease as species will have already been observed in previous quadrats. As increased effort yields a slower rate of new species, the cost-benefit of said data increases. Therefore we can conclude that we have taken enough samples sometime after the curve starts to flatten.

The break point can be estimated when 10% increase in area yields less than 10% new species. To find this point, a line is drawn between point 0 and the point representing 10% of the total species observed and 10% of the total area observed, then extending the line. The tangent of the species accumulation curve that bears the same slope as the 10% line intersects the curve at the break point; the minimum number of quadrats needed to gain an effective sample size.

Our species accumulation curve, shown in Figure 9 shows the breakpoint at x = 3.27, therefore suggesting that we are taking an effective sample at ~4 quadrats. While with additional observed area we see a gradual decrease in the number of new species observed, even after the breakpoint the rate never drops lower than 1 therefore we may need to observe more area in order to get a more accurate picture of biodiversity in this ecounit type. This can easily be achieved in future monitoring by monitoring the third quadrat that was set up and not monitored due to time constraints.

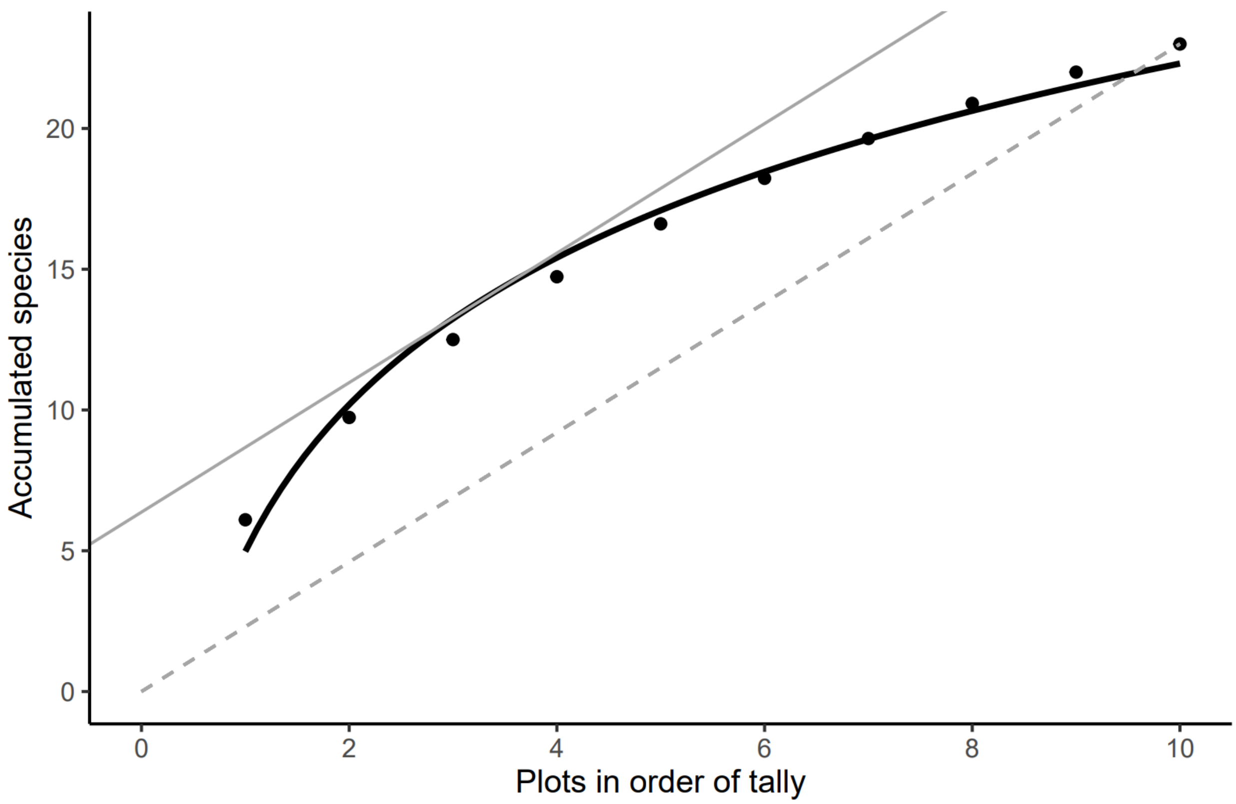

Figure 9. Species accumulation curve plotted versus plots by order of tally.

We observed a total of 23 individual species between both observed quadrats. 2 species of *ribes* were observed in the ground layer but not reported in the shrub layer. This overall shrub layer diversity included a relative abundance of the following target inclusions: beaked hazelnut (25.67%), balsam fir (20.13%), chokecherry (13.15%), black ash (10.46%), prickly rose (8.24%), and trembling aspen (5.86%). These target inclusions made up a total of 83.52% of our total shrub species observed, all others occurred in frequencies less than 5% and can be found in Table 6 in the appendix. There were fewer stems of any shrub species recorded in quadrat 6.2.

3.3 Herb-layer plots

Our species accumulation curve, shown in Figure 10 shows the breakpoint at x = 6.75, therefore suggesting that we are taking an effective sample at ~7 quadrats. After this point the rate of observed new species per unit area is less than 1. This would suggest that we observed enough area in order to effectively sample the ground layer of this ecounit, however additional plots will be added regardless due to the future monitoring of quadrat 6.3.

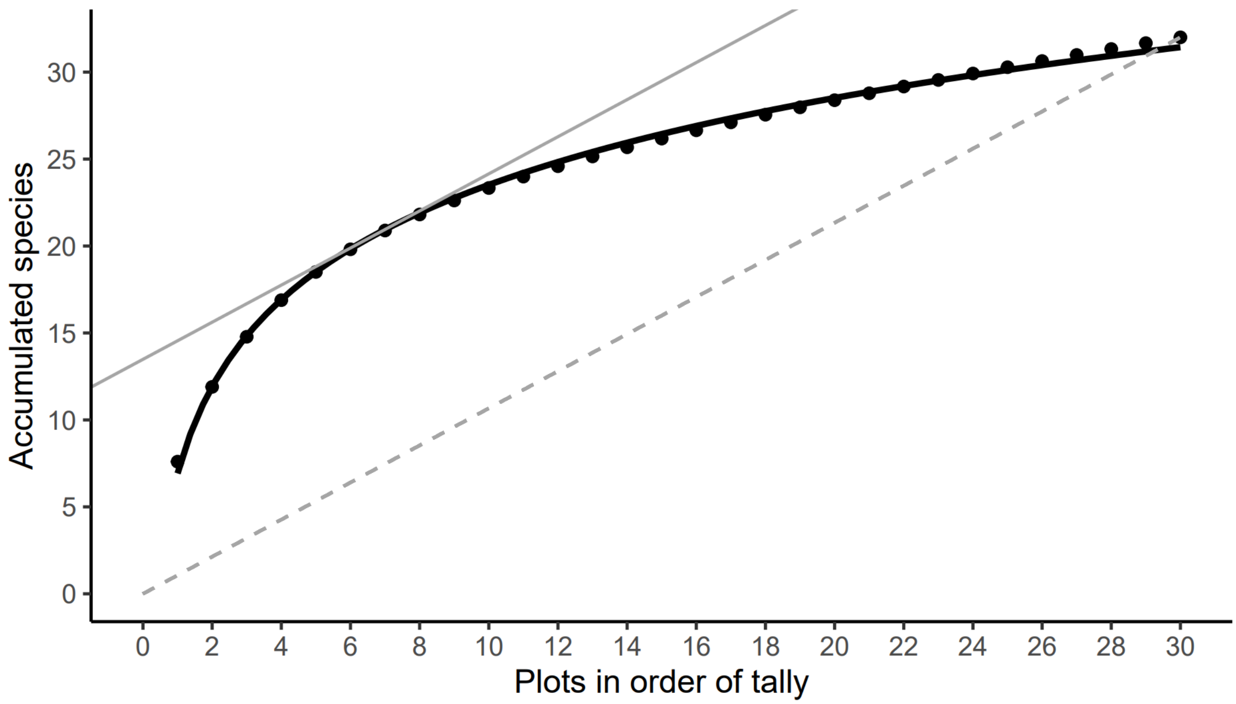

Figure 10. Species accumulation curve plotted versus plots by order of tally.

We observed a total of 32 individual species. It should be noted that this includes asters and grasses which were not identified to species. Among the observed species were the following target inclusions, each with their respective relative abundances: bunchberry (11.84%), grass (9.65%), wild strawberry (7.89%), wild sarsaparilla (3.07%), and grass (9.65%). Our expected bracken ferns were not observed in this study, however we did observe crested wood fern in one quadrat (0.43%). We also observed western sweet coltsfoot in a relative abundance of 7.46%, rather than the target arrow-leaved coltsfoot.

Non-target inclusions also observed in higher frequencies are northern bedstraw (6.87%), twinflower (5.15%), and Canada mayflower (5.15%). These with the listed target inclusions (that occur in percent frequencies greater than 5.15) make up the majority of our observed species. As was the case with the shrub layer, we observed several species that we would expect given our ecounit definitions. All other observed species occurred in frequencies less than 5% and can be found in Table 7 in the appendix. The only non-native species observed in both quadrats was a solitary common dandelion (*Taraxacum officinale*).

4. Overall Discussion

This baseline will guide future monitoring, if we observe stems from the tree layer dying off more than stems from shrub layer coming into the tree layer we may find that management is necessary in order to maintain a healthy forest. Over time, changes in plant abundances can be used to communicate changes in biodiversity, and therefore forest health. Species mortality and recruitment rates can be qualitatively measured over long-term from the proportion of tagged stems that have died and been recruited (McNutt 2012). This work also clarifies our understanding of the expected species composition of this area. As with our initial questions regarding the comparisons between ecounit definitions developed by Kistamo & Carlson (2006) and Zoladeski (2000) we may be able to draw more similarities between different defined eounits, or simplify tree layers into broader categories.

4.1 Succession

The distribution we observed may suggest that our site has succeeded to be more in line with EU7 and therefore shifted away from EU6. While the dominance of labrador tea in the ground layer is not as prevalent, the tree species that are present in the greatest abundance shares more in common with those expected in EU7 than EU6, which would expect more aspen and white spruce. The consistency of this transition across randomized sites further supports the notion of succession-driven change rather than an inaccurate sampling range. Alternatively this may suggest that our definitions for the different forest types observed are too narrow, and the specific targeted tree species are not necessarily only present within target ranges. We may instead be observing a gradient or a more homogenous ecosystem distribution, where there is a greater range of potential overstory species.

Daniels (2003) found uneven-age structures of western redcedar suggest that regeneration following catastrophic disturbance is not necessarily the dominant mode of regeneration in these forests. Either gap-phase or continuous modes of regeneration of western redcedar may be more common than previously thought under the pretext of the traditional successional paradigm. Based on the wide range of diameters it is possible that this stand did not originate all at once, pointing again to the potential occurrence of succession.

Contemporary successional theory suggests vegetation change is the outcome of populations interacting with one another within a fluctuating environment. This means systems are not working toward the most stable version of themselves, therefore we are investigating processes rather than outcomes (Daniels 2003). Ahlgren (1960) previously observed no evidence of reaching a stable condition after five years – vegetation continues changing and giving indications of succession. The continued monitoring of forests will track changes overtime, rather than anticipating successional direction towards a climax community.

4.2 Fire

Many of the species we observed are either considered pioneer species, in that they will be the first to populate a space after a natural disturbance (including trembling aspen and labrador tea). Further, many also depend on fires to establish future generations both by the burn creating space space and their seeds being particularly resilient to heat, allowing their establishment after a burn (jack pine, black spruce, bearberry). Should the populations of these species decrease and no other species increase we may be observing that the area is in need of a natural disturbance like a fire. Possible management strategies could require focus on reducing the negative effects of wildfire, particularly by increasing fire suppression efforts and promoting regeneration (Girardian & Mudelsee 2008).

For this baseline forest monitoring dead standing and fallen material was not cataloged, this will be in future monitoring to track the mortality of our labeled individuals. Such a buildup of dead material could lend itself to natural burn off.

5. Recommendations

Currently we do not have overarching management recommendations. However, we propose continued monitoring of the forest to gain deeper insights into its dynamics. The purpose of permanent quadrat monitoring is an improved ability to detect change in the structure and composition of vegetation communities (McNutt 2012). Through ongoing studies, we aim to better understand the forest dynamics which will inform targeted management strategies in the future. Once trends begin to become clear, they may influence other areas of study in restoration or forest management designed to replicate natural cycles.

5.1 Future Monitoring

The purpose of this project is to detect change, requiring a minimum of 5 years to have a large enough data set to conduct analysis and identify trends (Prior et al. 2012). With this as our baseline, we can continue to observe how species diversity and composition shifts over time. These quadrats should be returned to in the future in order to observe growth rate and changes in biodiversity. This will not require additional checks of the stem map but marked individuals should have their dbh and heights observed. Shrub and herbaceous monitoring would be repeated in their entirety, while referring back to species data from previous years. If with return visits we see fewer species, it may suggest that we are experiencing biodiversity loss due to some lack of natural cycling or disturbance. If we see that diversity is not decreasing, it may suggest that we are observing succession into other observed ecounits. In addition, quadrat 6.3, which was established but not monitored due to time constraints should be picked up in the next observation period. In future observations it may influence overall relative abundance of observed species.

Future quadrat priorities should be jack pine dominant ecounits in order to observe the health of the forest through different stages and types of succession (jack pine being successionally older and having fire as a critical part of their natural cycling) and to help develop a clearer picture of succession in the Boreal Shield. As other quadrats are set up in these other ecounits, relative abundances can be compared in order to clarify differences or lack thereof between forest types.

5.2 Future Studies

Any restoration work should not be considered until we are able to observe a clear trend in species composition. If this becomes a reality it might be valuable to conduct a study where the suspected cause of biodiversity loss is managed in a particular quadrat, and then overtime comparing the resulting changes in biodiversity for both sites. That could suggest effective management strategies for protecting species abundance. Such a project should not be considered until diversity drops to concerning levels or if fire risk becomes a threat to safety.

These projects may be comparable with our breeding bird surveys. In Saskatchewan, mixedwood forests were found to support higher abundances of songbirds, including Swainson's thrush, Blackburnian warbler, Red-breasted nuthatch, Black-throated Green warbler, and Bay-breasted warbler (Macdonald et al 2010), each of which have been observed in spring monitoring projects. As we improve our knowledge of the general species composition of different ecounits at the BEC we can use that information along with developing knowledge about where we are finding greatest abundances of breeding birds. We may find that different habitat types correlate more strongly with the presence of breeding birds. In this way our forest monitoring can work to inform us about the overall biodiversity of the region.

6. Conclusions

This first round of monitoring establishes a methodology effective for observing the biodiversity of the variety of ecounits found in at the BEC. This methodology presents species richness measures in different ecounits and is repeatable over long term in order to track die off of old growth and identify new growth given a base expectation for species abundances and biodiversity. The continued monitoring of the various ecounits of the BEC will be a valuable tool for communicating health of mixed forests overtime and engaging people in forest conservation through community biodiversity monitoring.

7. References

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8. Appendices

Table 5. Quadrat target and field GPS coordinates.

Quadrat	Target GPS	Field GPS
6.1	N 49 37.646 W 95 36.102	N 49 37.644 W 95 36.644
6.2	N 49 37.667 W 95 36.044	N 49 37.669 W 95 36.044
6.3	N 49 37.742 W 95 36.044	N 49 37.734 W 95 36.043

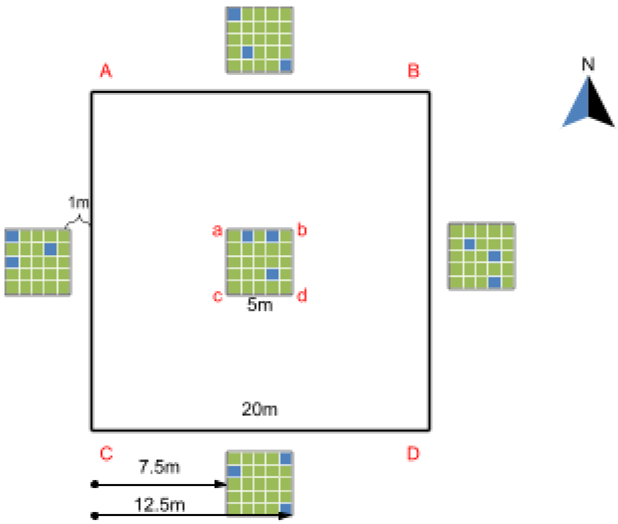

Figure 11a. The quadrat layout for quadrat 6.1.

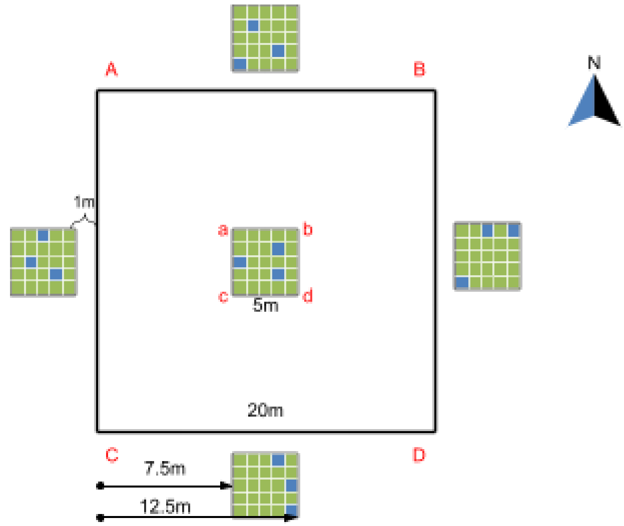

Figure 11b. The quadrat layout for quadrat 6.2.

Table 6. Shrub layer plants and overall percentage of individuals relative to total individuals observed.

Beaked hazelnut	*Corylus cornuta*	25.67%	Chestnut spp.	*Chestnut spp.*	0.95%
Balsam fir	*Abies balsamea*	20.13%	Red-osier dogwood	*Cornus stolonifera*	0.95%
Chokecherry	*Prunus virginiana*	13.15%	Saskatoon	*Amelanchier alnifolia*	0.48%
Black ash	*Fraxinus nigra*	10.46%	American bush-cranberry	*Viburnum opulus*	0.48%
Prickly Rose	*Rosa acicularis*	8.24%	Manitoba Maple	*Acer negundo*	0.16%
Trembling aspen	*Populus tremuloides*	5.86%	Mountain maple	*Acer spicatum*	0.16%
Grey alder	*Alnus incana*	3.49%	Paper birch	*Betula papyrifera*	0.16%
Lowbush blueberry	*Vaccinium angustifolium*	3.49%	Common dogwood	*Cornus sanguinea*	0.16%
Green Ash	*Fraxinus pennsylvanica*	1.74%	American hazelnut	*Corylus americana*	0.16%
Balsam Poplar	*Populus balsamifera*	1.43%	Black hawthorn	*Crataegus douglasii*	0.16%
Alder-leaved buckthorn	*Rhamnus alnifolia*	1.27%	Labrador tea (common)	*Ledum groenlandicum*	0.16%
Low bush-cranberry	*Viburnum edule*	1.11%			

Table 7. Ground layer plants and overall percentage of individuals relative to total individuals observed.

Bunchberry	*Cornus canadensis*	11.84%	Wood anemone	*Anemone quinquefolia*	1.75%
Grass spp.	*Grass spp.*	9.65%	Wild red raspberry	*Rubus idaeus*	1.75%
Wild strawberry	*Fragaria virginiana*	7.89%	Star-flowered false solomon's seal	*Maianthemum stellatum*	1.32%
Western sweet coltsfoot	*Petasites frigidus palmatus*	7.46%	Early blue violet	*Viola adunca*	1.32%
Northern bedstraw	*Galium boreale*	7.02%	Cream-coloured vetchling	*Lathyrus ochroleucus*	0.88%
Twinflower	*Linnaea borealis*	5.26%	Calico Aster	*Symphyotrichum lateriflorum*	0.88%
Canada mayflower	*Maianthemum canadense*	5.26%	Aster spp.	*Aster spp.*	0.44%
Common horsetail	*Equisetum arvense*	4.82%	Bush honeysuckle	*Diervilla lonicera*	0.44%
Lindley's aster	*Aster ciliolatus*	4.39%	Crested wood fern	*Dryopteris cristata*	0.44%
Dewberry	*Rubus pubescens*	4.39%	Purple wood aster	*Eurybia spectabilis*	0.44%
Canada anemone	*Anemone canadensis*	3.51%	Snakeroot / Black sanicle	*Sanicula marilandica*	0.44%
Threeleaf goldthread	*Coptis trifolia*	3.51%	Perennial sow thistle	*Sonchus arvensis*	0.44%
Naked bishop's cap	*Mitella nuda*	3.51%	Western snowberry	*Symphoricarpos occidentalis*	0.44%
Northern starflower	*Trientalis borealis*	3.51%	Common dandelion	*Taraxacum officinale*	0.44%
Wild sarsaparilla	*Aralia nudicaulis*	3.07%	Tall meadow rue	*Thalictrum dasycarpum*	0.44%
Canadian wild ginger	*Asarum canadense*	2.63%	Wild vetch	*Vicia americana*	0.44%

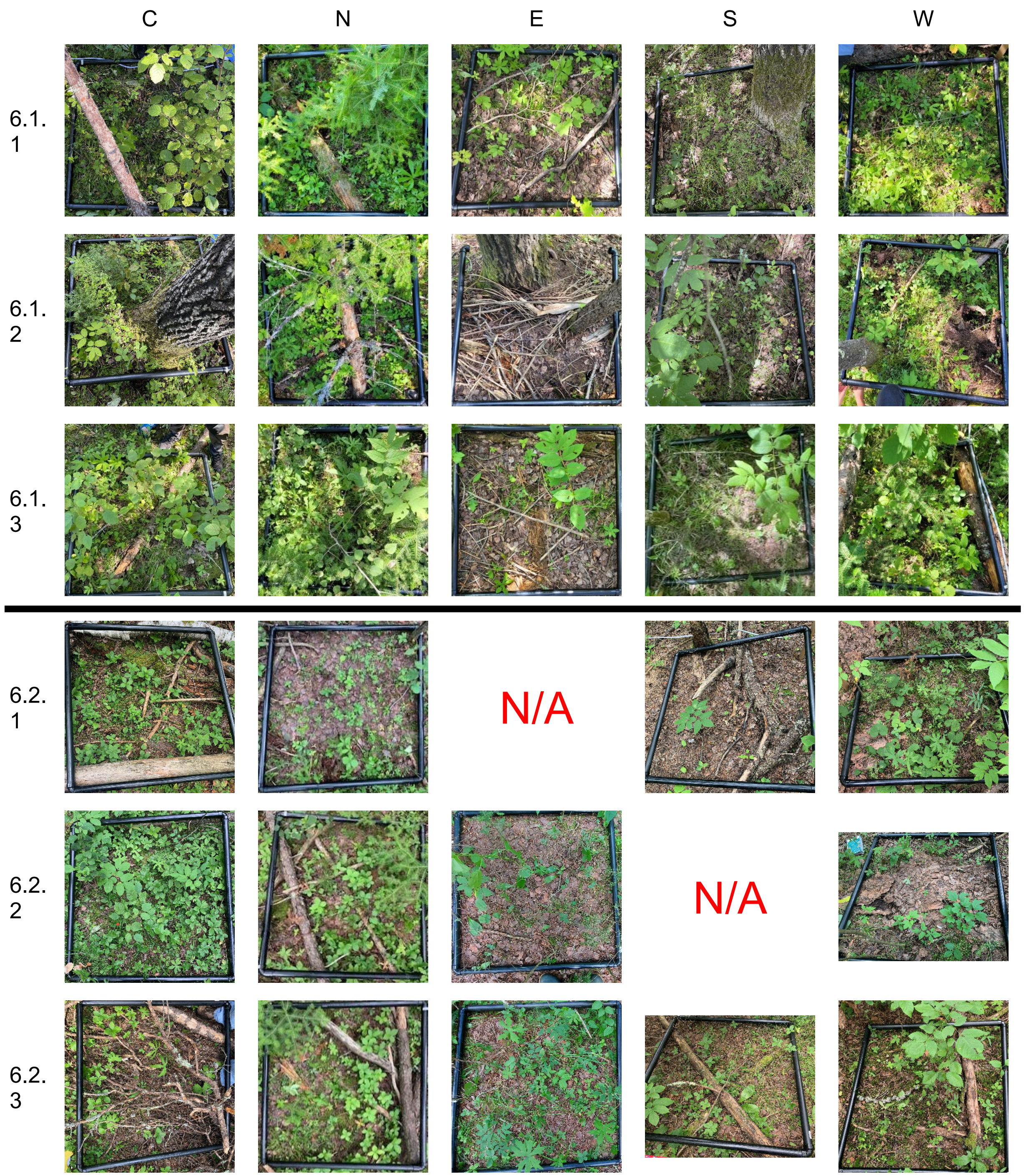

Figure 12. Herb-layer quadrat images.