Pre-Prescribed Burn Monitoring of Red and White Pine Stands In Quetico Provincial Park

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Quetico Provincial Park acknowledges that
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Executive Summary

Attitudes towards forest fires have changed drastically though the 1900s. Originally viewed as the enemy of old growth pine stands in northwestern Ontario and Northern Minnesota, resource managers now recognize fire as an essential component of dynamic boreal forest ecosystems. Not only do fire-adapted red and white pine require fires to produce the conditions favourable to germination and seedling growth, frequent fires also reduce fuel loads (preventing large, intense fires) and increase the spatial, temporal, structural, and biological diversity in boreal forests.

During the winter of 2016-17 Quetico Provincial Park's Fire Effects Monitoring Protocol (Jackson and Racey 2017) was updated to address questions asked by the Quetico Provincial Park Management Plan. Namely, how does the pre-fire vegetation community influence post-fire vegetation, red (Pr) and white pine (Pw) regeneration, red and white pine survival, and the health of traditional sacred plant species? Also, how do environmental variables such as slope influence these effects?

In the summer of 2017, 57 vegetation plots were monitored on four islands that are identified for potential prescribed burns between 2017 and 2019. These plots were selected based on canopy type: Pr/Pw plots contained at least 50-80% white or red pine canopy cover, Coniferous Pr/Pw plots contained 50-80% coniferous canopy cover and red and white pine, and Deciduous Pr/Pw plots contained 50-80% deciduous canopy cover and red and white pine. Survey methods are outlined in the 2017 Fire Effects Monitoring Protocol; data on vegetation structure and composition and fuel loading was collected. This report describes the work to-date, outlines the objectives of the fire monitoring program and, through a preliminary analysis of the data collected during 2017, assesses how effective the newest fire monitoring protocol is at answering the questions asked by the Quetico Provincial Park Management Plan. Specifically, this report aims to:

1. Characterize pre-fire vegetation community composition and structure.
Pr/Pw, Coniferous Pr/Pw and Deciduous Pr/Pw plots vary in their vegetation composition and structure. Pr/Pw plots are characterized by higher percent canopy covers of red and white pine with denser secondary canopy layers and a moderate cover of shrubs. Coniferous Pr/Pw plots have a dense coniferous canopy cover and low shrub layer. Finally, Deciduous Pr/Pw plots display the highest species diversity and also have a dense low shrub layer. High densities of balsam fir in all plots indicate a potential for large intense fires because balsam fir is highly flammable and is known to act as a ladder fuel, linking ground fires to the tree canopy.

2. Provide a pre-fire assessment of white and red pine regeneration.
Red and white pine regeneration does not appear to be occurring in any of the plot types. Though red and white pine seedlings exist in Pr/Pw plots there are very few that survive beyond the seedling stage. Red pine in particular are less common than white pine across all plots and at all ages, likely due to their dependence on fires for successful germination.

3. Locate traditional medicinal and sacred plant species.
Cedar, a scared plant to Anishinaabe people, was located in 18 of the 57 plots monitored but no correlation with canopy type or slope position was found. Cedar are thin-barked, shade tolerant and resin rich, making fire highly destructive to their survival. Preservation of this species will require careful planning of the prescribed burns.

4. Evaluate the effectiveness of *Fire Effects Monitoring Protocol – Operational Final Draft 2017* with respect to its ability to accurately and reliably assess pre-burn V-type, the regeneration of red and white pine, and the location of traditional and sacred plant species.
The 2017 *Fire Effects Monitoring Protocol – Operational Final Draft* provides an efficient assessment of pre-burn forest conditions. Some challenges include:
- determining V-type in the field. Crews should include Canopy Layers 1 (upper canopy, trees >10m), and 2 (secondary canopy, trees >10m) in this classification and distinguish on their datasheets between the most and second most common canopy covers.
- collecting red and white pine seedling data in the field. Crews should record both a percent cover of red and white pine in layer 4&5 (low woody shrubs <2m), and a count of the number of seedlings.
- analysing categorical data. Consideration of future data analysis methods and pre- and post-burn comparison methods prior to future data collection will help determine if categorical data is sufficient for addressing the goals of the Fire Management Plan.

Contents

Introduction

Quetico Provincial Park is a wilderness class park in the Fort Frances District of the Ontario Ministry of Natural Resources and Forestry in northwestern Ontario. The park protects 4,718 km^2 of Canadian Shield bedrock, numerous lakes and streams, and a forest that is a transition zone between northern boreal forest (dominated by black and white spruce (Sb, Sw), jack pine (Pj), trembling aspen (Po), white birch (Bw) and balsam fir (Bf)) and Great Lakes St. Lawrence forest (white and red pine (Pw, Pr) and balsam poplar (Pb)). These forest types persist on the landscape as a result of a continuous cycle of disturbances such as human and lightning caused fire, blow down, insect infestation, and disease.

Over the past century, the fire cycle in Quetico increased drastically from 78 years (approximately 11,735 ha burned per year) to 870 years (approximately 970 ha/yr) (Scoular *et al.* 2010). Currently, the estimated fire cycle for the period of 2005-2014 is 950 years or 390 ha/yr (Jackson 2016). Fire suppression was undertaken in Quetico and many of North America's protected areas with the intent to preserve the aesthetic value of old growth forests while protecting human life and property. However, over time, fire suppression, in conjunction with the elimination of traditional burning activities of indigenous peoples, has increased the prevalence of fire-sensitive, shade tolerant species in the forest understory; large, over mature, and dying fire resistant and resilient trees, and a layer of dry woody debris (Jackson 2017). This resulted in forests that are highly susceptible to disease, blow down, and large, intense fires. Ironically, it has also resulted in a decline in the fire-dependant, large, charismatic species, typically thought of as old growth, that fire suppression was intended to protect: red and white pine. This changing forest ecosystem with both increasing age and species composition has the potential to impact wildlife species dependent on these forests.

Beginning in the early 1990s, fire management has shifted from fire suppression to controlled reintroduction of fire to the landscape. Two fire management plans have been developed for Quetico Provincial Park (1996; 2009-2019). They outline priority actions and management goals for reintroducing fire in a way that is collaborative, instructive, and ecologically valuable. Multiple monitoring protocols (Unknown 1996/97; Solomon 2006; Solomon 2008-13) have also been used in Quetico in the past, a comprehensive summary of which is available in Adair and Jackson (2016), in an effort to better understand regeneration of fires to inform future planning. In 2017, a prescribed burn strategy was prepared which identified some knowledge gaps that would help assess how effective prescribed burn efforts were at meeting defined objectives. Finally, the *Fire Effects Monitoring Protocol – Operational Final Draft* (Jackson & Racey 2017) was developed to collect data to specifically answer questions relating to the maintenance of red and white pine communities as identified in the 2009 Fire Management Plan:

1. How does pre-fire vegetation community composition and structure including duff/litter, understory and canopy affect fire intensity, fuel consumption and future vegetation community composition?

2. How does pre-fire vegetation community composition and structure including duff/litter, understory and canopy affect red and white pine seedbed quality (what kind of seedbed is produced) and the regeneration of red and white pine.
3. How does pre-fire vegetation community composition and structure including duff/litter, understory and canopy affect survival of pre-burn red and white pine after low to medium intensity prescribed fire?
4. How much variability in fire effects is attributed to variation in slope, fuel type, direction of burn and local fuel loading?
5. How does fire affect traditional medicinal or sacred plant species?

Answering these questions will help determine how effective fire management efforts, such as prescribed burns, are in restoring red and white pine communities and meeting the goals of the Fire Management Plan.

Objectives

In anticipation of a prescribed burn, 57 vegetation plots at four potential prescribed burn sites were monitored in 2017. This report will use this pre-fire data to:

1. Characterize pre-fire vegetation community composition and structure (Question 1 and 2)
2. Provide a pre-fire assessment of white and red pine regeneration (Question 3)
3. Locate traditional medicinal and sacred plant species (Questions 5).
4. Evaluate the effectiveness of *Fire Effects Monitoring Protocol – Operational Final Draft 2017* with respect to its ability to accurately and reliably assess pre-burn V-type, the regeneration of red and white pine, and the location of traditional and sacred plant species.

Methods

Study Sites

Vegetation plots were located on four islands in Sarah, McIntyre, and Tuck Lake in Quetico Provincial Park (Figure 1). Detailed maps of each island with plot locations are available in the Appendix. These plots are located on islands that are proposed for prescribed burns between 2017 and 2019.

Plot locations on the islands were selected to describe different conditions of red pine and white pine stands in Quetico. Plots were first selected using three canopy classes that contained Pr or Pw in the canopy: Pr/Pw plots had a canopy consisting of 50-80% red and white pine, Coniferous Pr/Pw plots had a canopy consisting of 50-80% conifer and less than 20% red and white pine, and Deciduous Pr/Pw plots had a canopy consisting of 50-80% deciduous and less than 20% red and white pine. They were also selected based on shrub density (high or low), and elevation (upper or lower slope). This selection was not intended to provide a unbiased representation of the forest as a whole, but instead to capture a range of forest conditions associated with red and white pine to specifically answer the identified questions. 61

plots were selected on four islands in Tuck, McIntyre and Sarah Lakes based on aerial photo interpretation of canopy composition and slope position. Crews verified this selection and selected for shrub density in the field (Figure 2). 57 plots were monitored. Plot location maps are available in the Appendix 1.

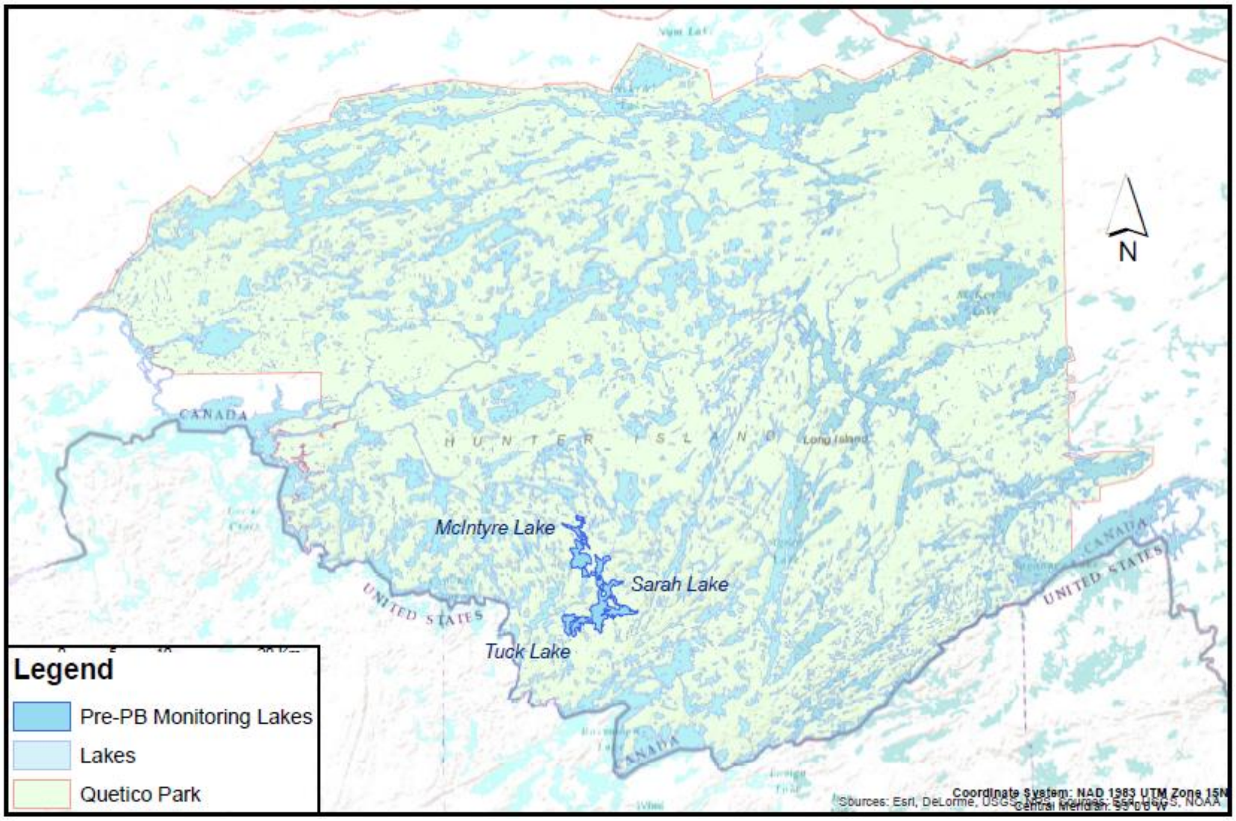

Figure 1: Map of the locations of pre-prescribed burn monitoring lakes in 2017

Field Methodology

At each plot, crews established 10x 10m plots to describe forest vegetation and physiognomic layers, conducted counts of coarse woody debris, describe humusform and classified the plots according to the Fire Fuel Type and the Northwestern Ontario Vegetation Community Type (V-type). A detailed description of monitoring methods is described in Jackson and Racey (2017) (link below).

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Park Fire Effects Mo

Data Analysis

Data analysis focused on detecting differences, if they exist, between Pr/Pw, Coniferous Pr/Pw, and Deciduous Pr/Pw plots. This was achieved through visual comparisons of graphed data, counts of the number of plots in defined categories, and ANOVA tests followed by Tukey-Kramer post-hoc tests where applicable.

Special attention was given to identification of Pr and Pw trees in all canopy layers in order to provide an assessment of pine regeneration, if any is occurring, in the absence of fire.

Additionally, cedar is one of the four sacred plants to Anishinaabe people and has been identified as a species of concern to members of the Lac La Croix First Nation. Cedar presence and location was recorded and summarized to provide a picture of its current distribution.

Finally, to evaluate the *Quetico Provincial Park Fire Effects Monitoring Protocol – Operational Final Draft 2017* results from this analysis were compared to the questions identified in the protocol. The canopy class designations and their associated V-types are also discussed. Challenges that arose during data collection and preliminary data analysis are identified in order to provide recommendations for future monitoring.

Results

Review of data collected indicated that the plots did not always match their intended canopy type. Furthermore, the V-type (based on the Forest Ecosystem Classification for Northwestern Ontario) assigned to each plot in the field did not always match the data collected, possibly due to omission of the secondary canopy layer when determining V-type in the field. If V-type in the field matched the V-type from the data, this was used as the canopy class, regardless of the original intended canopy type for the plot. If the field and data V-types did not match, the descriptions of both V-types were read and compared to data collected and photos to determine the best match. Canopy class was determined based on the new V-types, not the intended class. After these adjustments were made, 24 plots were in canopy class Pr/Pw, 16 plots in Coniferous Pr/Pw, and 17 plots in Deciduous Pr/Pw. A revised list of V-types and canopy classes is available in Table 1.

V-type was variable within Coniferous Pr/Pw (12 V-types) and Deciduous Pr/Pw (5 V-types) canopy classes while the Pr/Pw canopy class only contained V-type 26 and 27 (Table 2). The most common V-types were 27 (17 plots), 26 (7 plots), 12 (6 plots), and 4 (5 plots).

Plot ID	Slope Position	Fire Fuel Type	NW V-Type		Canopy Type (C/D/P)	
			Field Call	From Data	Intended	From Data
MCI-17/01	U	C5	3.1	3.1	D	D
MCI-17/02	U	M2 25/75	12	12	D	D
MCI-17/03	U	M2 25/75	4	4	D	D
MCI-17/04	U	M2 25/75	4	12	D	D
MCI-17/05	U	C5	26	26	P	P
MCI-17/06	U	C5	26	12	P	D
MCI-17/07	U	C5	26	26	P	P
MCI-17/08	U	C5	26	26	P	P
MCI-17/09	L	C2	34	34	C	C
MCI-17/10	U	M2 75/25	32	32	C	C
MCI-17/11	L	M4 100	24	24	C	C
MCI-17/12	U	M2 75/25	20	20	C	C
MCI-17/13	L	C5	27	26	P	P
MCI-17/14	U	M2 75/25	18	18	C	C
MCI-17/15	L	C5	26	26	P	P
MCI-17/16	U	M2 75/25	29	31	C	C
MCI-17/17	U	M2 75/25	17	17	C	C
SAR1-17/01	L	C5	27	27	P	P
SAR1-17/02	L	C5	26	26	P	P
SAR1-17/03	L	C5	27	27	P	P
SAR1-17/04	L	M2 50/50	27	12	P	D
SAR1-17/05	L	M2 75/25	21	21	C	C
SAR1-17/06	L	M2 75/25	26	26	C	P
SAR1-17/07	U	M2 75/25	12	8	D	D
SAR1-17/08	U	M2 25/75	4	4	D	D
SAR1-17/09	U	M2 25/75	5	5	D	D
SAR1-17/10	L	M2 50/50	4	4	C	D
SAR1-17/11	U	C2	26	26	P	P
SAR1-17/12	U	C5	27	27	P	P
SAR1-17/13	U	C5	26	12	P	D
SAR1-17/14	U	C5	27	27	P	P
SAR1-17/15	U	M2 25/75	4	3.1	D	D
SAR1-17/16	U	C5	26	26	P	P
SAR1-17/17	U	C5	26	26	P	P
SAR2-17/01	L	C5	26	26	P	P
SAR2-17/02	L	C5	26	26	P	P
SAR2-17/03	L	C5	26	26	P	P
SAR2-17/04	L	C5	26	26	P	P
SAR2-17/05	L	C5	26	26	P	P
SAR2-17/06	L	M2 75/25	26	27	D	P
SAR2-17/07	L	C5	26	26	P	P
SAR2-17/08	L	M2 75/25	21	21	D	C
TUC-17/01	L	M4 30	4	4	D	D
TUC-17/02	L	M2 75/25	19	19	C	C
TUC-17/03	L	M2 25/75	5	5	D	D
TUC-17/04	L	M2 75/25	22	22	C	C
TUC-17/05	L	C5	26	12	P	D
TUC-17/06	U	M2 75/25	30	30	P	C
TUC-17/07	L	C5	26	27	P	P
TUC-17/08	U	M2 75/25	20	20	P	C
TUC-17/09	L	C2	31	31	C	C
TUC-17/10	U	M2 75/25	30	30	P	C
TUC-17/11	L	C2	33	33	C	C
TUC-17/12	U	M2 75/25	27	27	P	P
TUC-17/13	U	C5	4	4	D	D
TUC-17/14	U	C5	26	26	P	P
TUC-17/15	U	M2 50/50	3.1	3.1	D	D

Table 1: Classification of each vegetation plot. Slope Position is the intended location of the plot on the slope. U = Upper Slope, L = Lower Slope. Fire Fuel Type is based on the FBP Fuel Type Descriptions (http://cwfis.cfs.nrcan.gc.ca/background/fueltypes/c1). NW V-Type Classifications are based on the Field Guide to the Forest Ecosystem Classification for Northwestern Ontario (Sims et al 1997). Coloured values indicate that the field call did not match the data. The **blue** values were used for analysis. V-type and Canopy Type is determined by the percent cover of species in the tree layer (Layer 1 and 2).
C = Coniferous Pr/Pw Plots,
D = Deciduous Pr/Pw Plots,
P = Pr/Pw Plots.

Table 2: Vegetation-types and the number of plots in each canopy type. (Sims et al 1997)

Canopy Type	# Plots	V-Type		# Plots
Pr/Pw	24	26	White Pine Conifer	17
		27	Red Pine Conifer	7
Coniferous Pr/Pw	16	17	Jack Pine Mixwood, Shrub Rich	1
		18	Jack Pine Mixwood, feathermoss	1
		19	Black Spruce Mixwood, Herb Rich	1
		20	Black Spruce Mixwood, feathermoss	2
		21	Cedar (inc. mixwood) – Mountain Maple	2
		22	Cedar (inc. mixwood), speckled alder, sphagnum	1
		24	White Spruce – Balsam Fir, shrub rich	1
		30	Jack Pine – Black Spruce, blueberry, lichen	2
		31	Black Spruce – Jack Pine, tall shrub, feathermoss	2
		32	Jack Pine – Black Spruce, ericaceous shrub, feathermoss	1
		33	Black Spruce, feathermoss	1
		34	Black Spruce, Labrador tea, feathermoss	1
Deciduous Pr/Pw	17	3.1	Maple (Yellow Birch) Hardwood and Mixwood	3
		4	White Birch Hardwood and Mixwood	5
		5	Aspen Hardwood	2
		8	Trembling Aspen (White Birch) – Mountain Maple	1
		12	White Pine Mixwood	6

Humusform

The five litter depth and total depth measurements were averaged for each plot (Figure 4). If depth was recorded as <1 cm then 0.5 cm was used for analysis purposes. If depth was recorded as BEDROCK, then 0 cm was used for analysis. Pr/Pw plots (mean average total depth = 6.9 cm, litter depth = 2.0 cm) did not have a significantly different average total depth or litter depth from Coniferous Pr/Pw plots (mean average total depth for each plot = 10.0 cm, litter depth = 2.5 cm) or Deciduous Pr/Pw plots (mean average total depth = 6.8 cm, litter depth = 1.3).

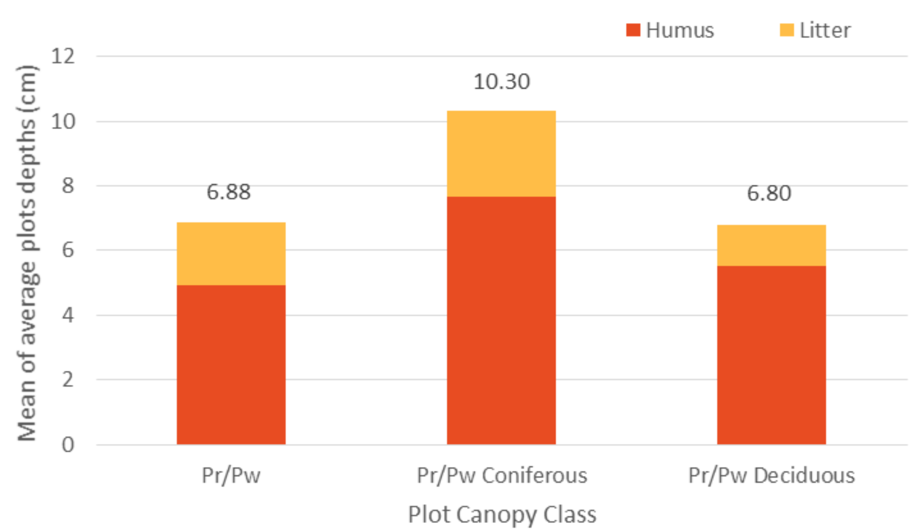

Figure 2: Average litter depth and total depth for plots in each canopy type. Data labels indicate the average total depth.

Forest Floor

Across all canopy types the most common forest floor covers were Conifer Litter, Broadleaf Litter, Moss, Grounded Wood, and Lichen (Figure 3). ANOVA comparisons between each canopy type did not yield significant results for Conifer Litter, Grounded Wood, and Lichen. Post-hoc tests show that there was also no significant difference in Moss cover between canopy types, however Broadleaf Litter had a higher percent cover in Deciduous Pr/Pw Plots compared to both Pr/Pw and Coniferous Pr/Pw plots. It should be noted though that there was a large effect size for both of these comparisons (Table 3).

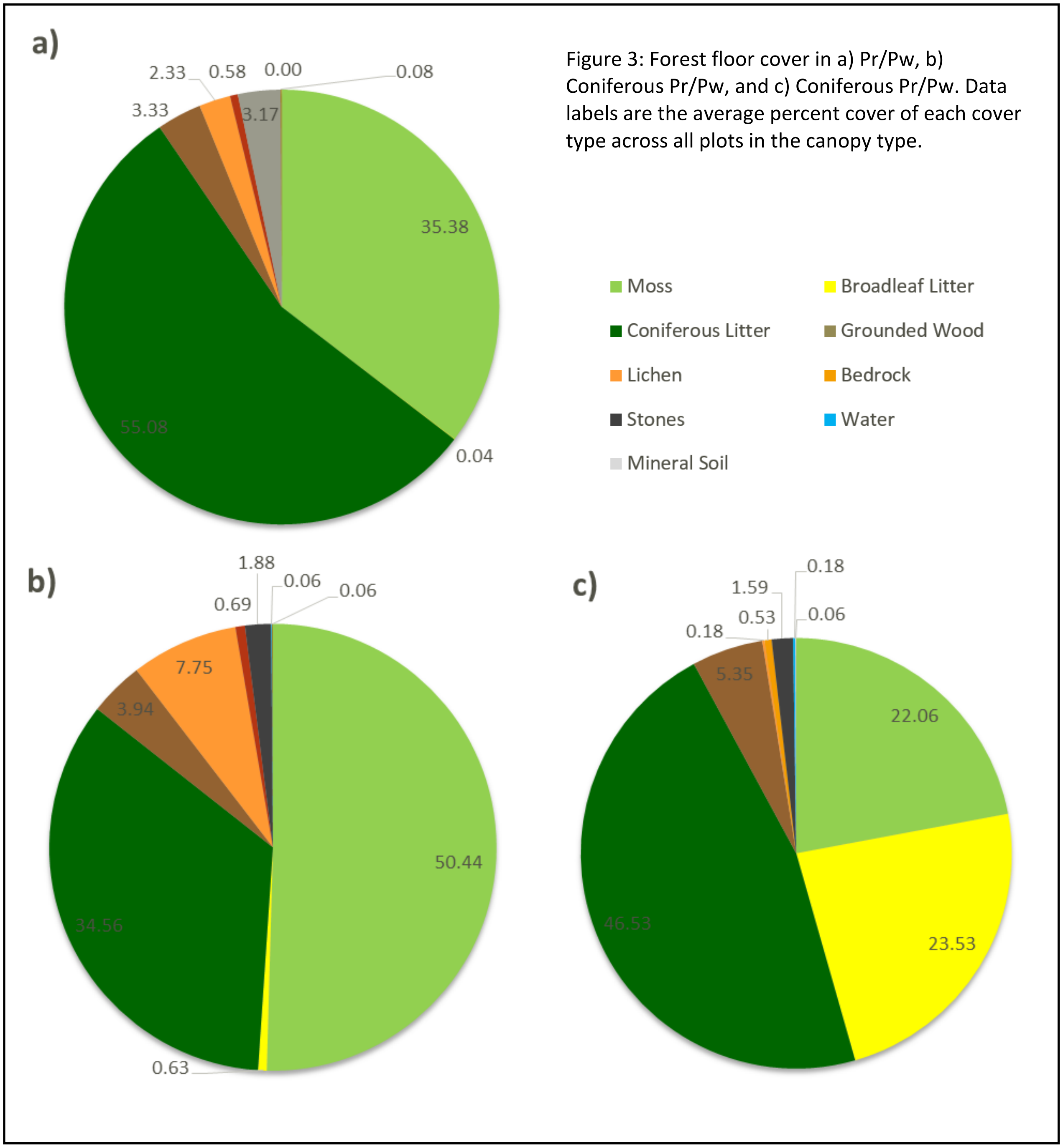

Figure 3: Forest floor cover in a) Pr/Pw, b) Coniferous Pr/Pw, and c) Coniferous Pr/Pw. Data labels are the average percent cover of each cover type across all plots in the canopy type.

Table 3: Significance values for Tukey-Kramer pairwise comparisons between moss and broadleaf litter forest floor cover. Values in brackets are average percent cover of each cover type across all plots in the canopy type.

$Q_{test}(3,51) = 3.4$

Moss	**Pr/Pw C**	**Pr/Pw D**	**Pr/Pw**
Pr/Pw C (50.4)	-		
Pr/Pw D (22.05)	3.102 (d = 1.27)	-	
Pr/Pw (35.3)	1.777 (d = 0.51)	1.599 (d = 0.53)	-

Broadleaf Litter	**Pr/Pw C**	**Pr/Pw D**	**Pr/Pw**
Pr/Pw C (3.9)	-		
Pr/Pw D (5.4)	**3.456 (d = 0.92)**	-	
Pr/Pw (3.6)	0.095 (d = 0.32)	**3.894 (d = 0.95)**	-

Coarse Woody Debris

Across all plots, the larger the CWD size (Classes C [2.5-7.6 cm] and D [>7.6 cm]), the fewer pieces are present (higher percent of CWD lines in tally classes 0 and 1-5).

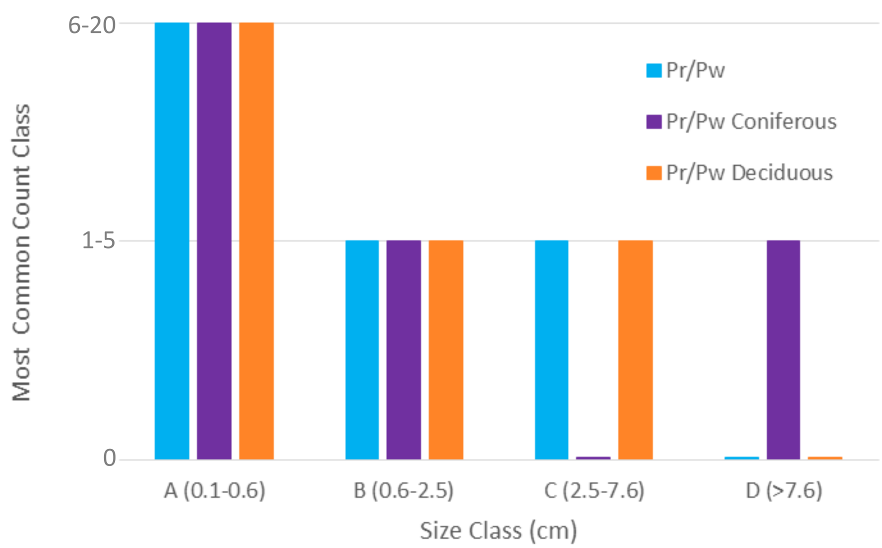

Figure 4: Most common Count Class in each CWD size class for three canopy types

Physiognomic Layers

In Layer 1 (Trees > 10 m) the recorded percent cover reflected the intended canopy characteristics of each plot. In Pr/Pw plots the majority of plots have canopy covers that were >20 or >50 % Pr or Pw. Coniferous Pr/Pw plots contain almost entirely coniferous canopy cover while Deciduous Pr/Pw plots have a much more even distribution of species with the majority of > 20 and >50 % canopy cover plots containing White Birch (Bw) and Red Maple (Mr) (Figure 5). Not all plots had a Layer 2 (Secondary Canopy, trees > 10m). The majority of those that did have a second canopy layer were in Pr/Pw plots and were a mix of coniferous and deciduous species (Figure 6). In Layer 3 (Tall Shrubs, >2m <10m), Balsam Fir (Bf) was found in the most plots and at the highest densities in both Deciduous Pr/Pw and Pr/Pw plots. Bf was also found in high densities in Coniferous Pr/Pw plots however Black Spruce (Sb) was found in a slightly higher number of plots (Figure 7). Layer 4&5 (Low Woody Shrub < 2m) shows that across all plots low shrubs rarely reach high densities (>50% canopy cover) except for Juniper and American Yew in mainly Pr/Pw plots (Figure 8). Species in Layer 6 (Herbaceous) rarely reached >20% canopy cover under any of the canopy types (Figure 9). Finally, in Layer 7 (Mosses and Lichens) feather mosses occur in the most plots and with the highest percent covers across all canopy layers (Figure 10).

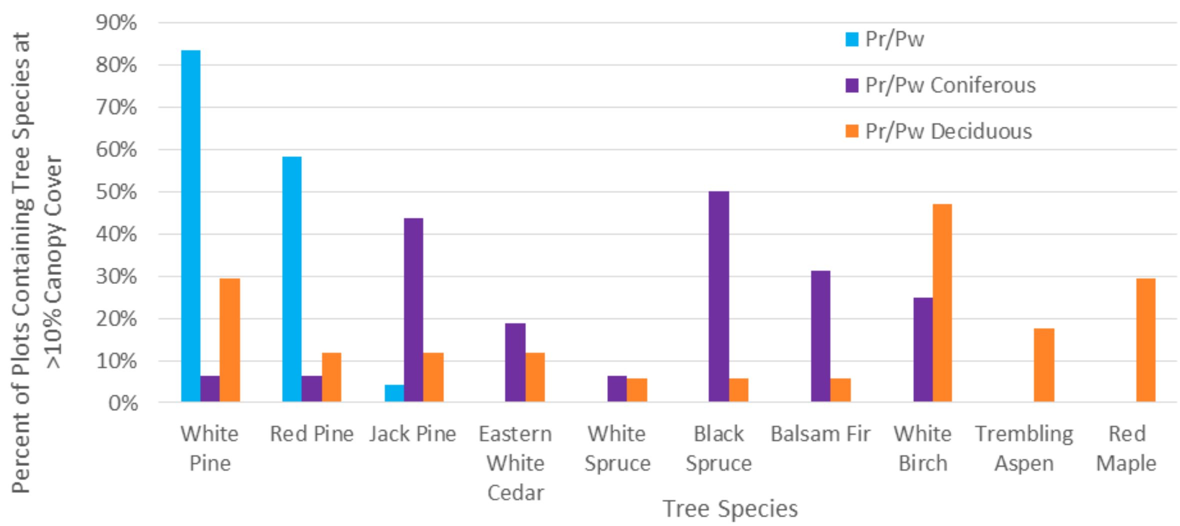

Figure 5: Tree species composition in Layer 1 by canopy type (Canopy Layer, >10m)

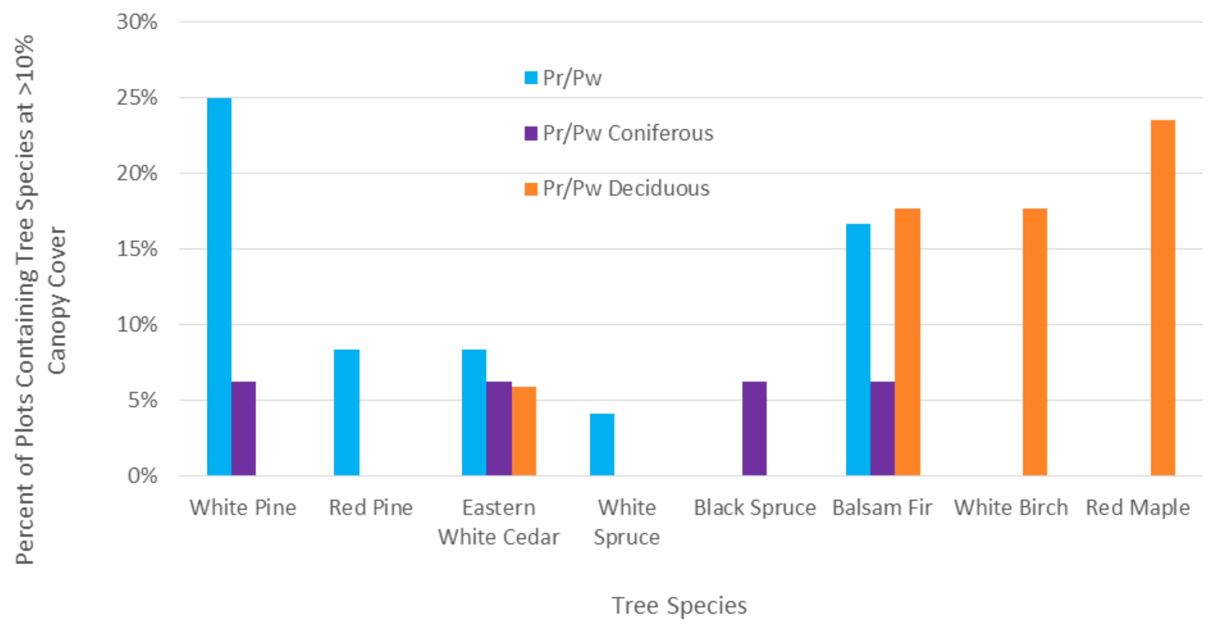

Figure 6: Tree species composition in Layer 2 by canopy type (Secondary Canopy Layer, >10m)

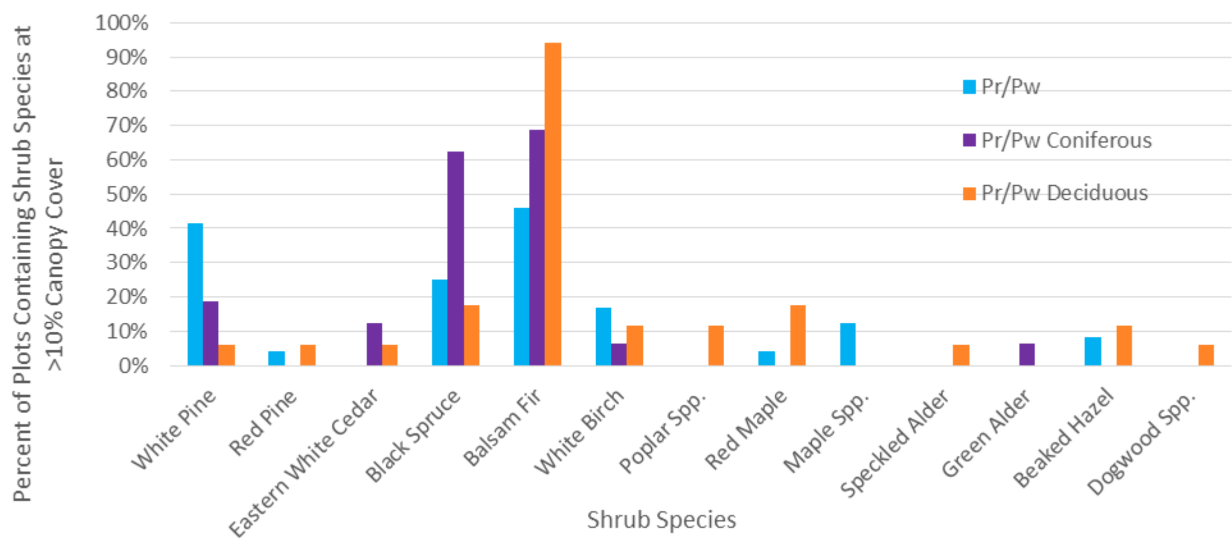

Figure 7: Shrub species composition in Layer 3 by canopy type (Tall Shrub 2-10m)

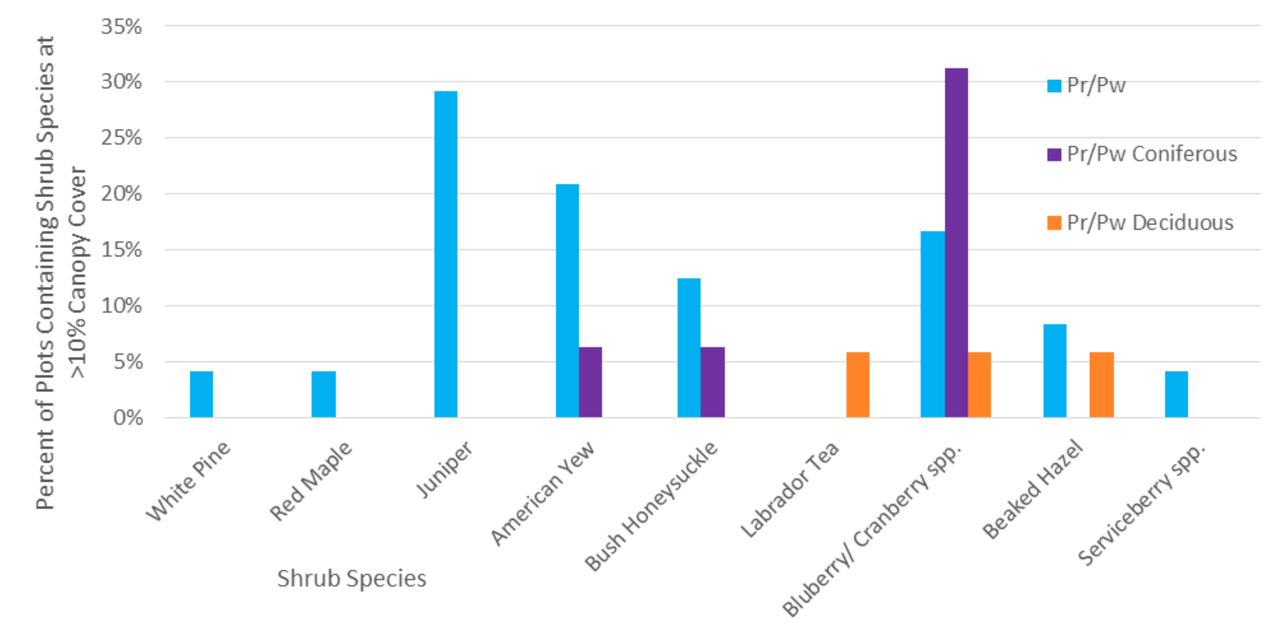

Figure 8: Shrub species composition in Layer 4&5 by canopy type (0.5-2m)

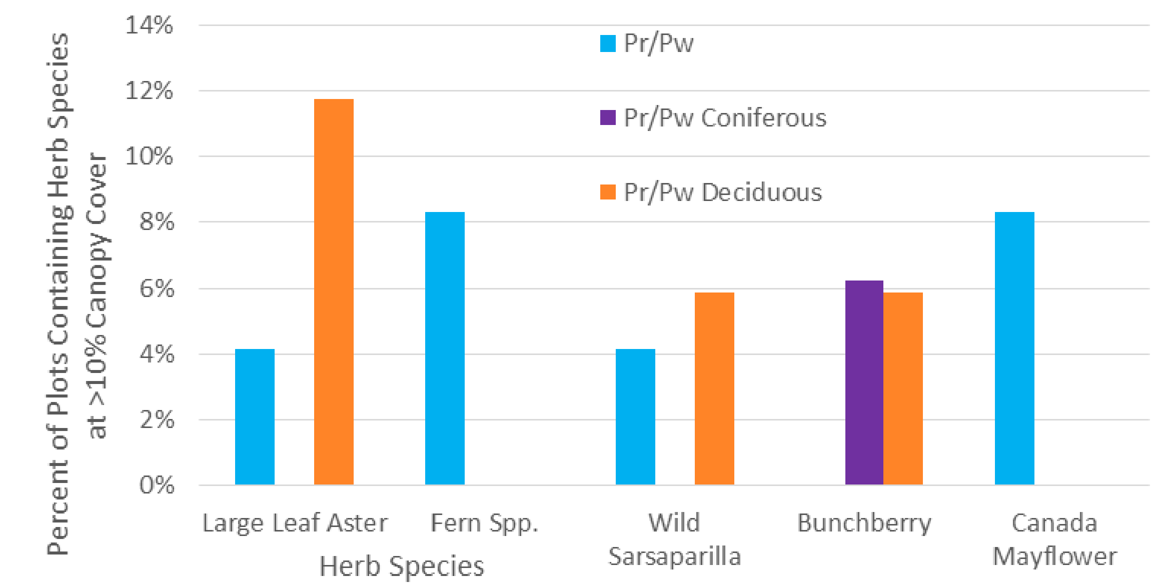

Figure 9: Herb species composition in Layer 6 by canopy type

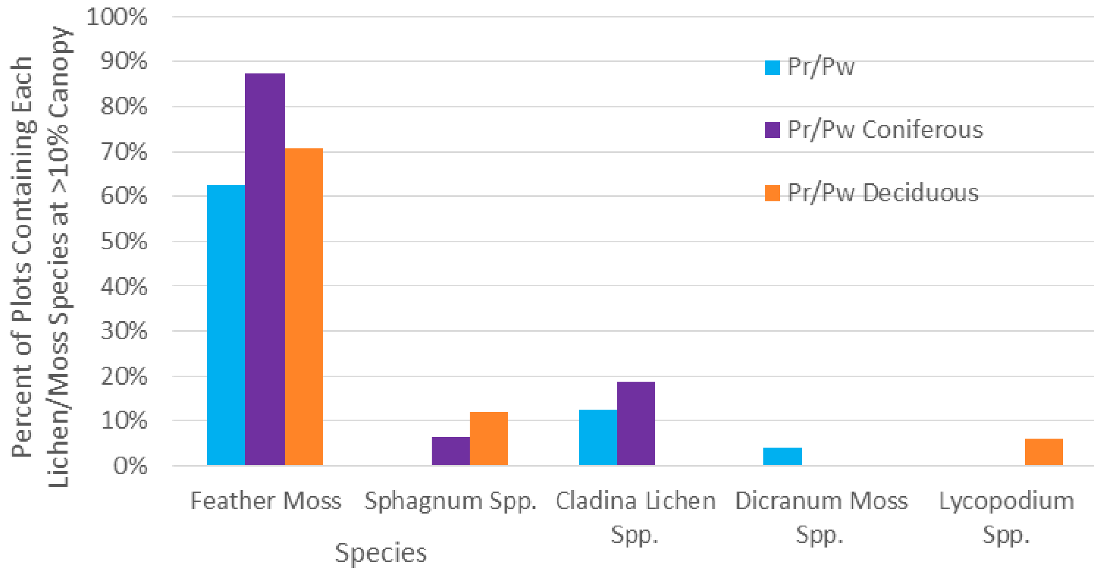

Figure 10: Moss and lichen species composition in Layer 7 by canopy type

Percent Canopy cover of combined coniferous and hardwood species was also recorded for each layer. As expected, the canopy cover of coniferous species in Layer 1 is much higher in Coniferous Pr/Pw and Pr/Pw plots compared to Deciduous Pr/Pw, which had higher deciduous percent cover. Layer two shows a similar pattern however the percent cover of all species in this layer is much lower (and in many plots this layer was not present). In Layer 3, coniferous percent cover is higher than deciduous in all plots and is the highest in Deciduous Pr/Pw plots, maily due to the presence of Bf. In Layer 4&5 coniferous and deciduous percent cover is highest in Pr/Pw plots. In Layer 6, the percent cover of herb and fern species was highest in Deciduous Pr/Pw plots while graminoids were almost completely absent from all plots. Finally, in Layer 7, feather moss is common in all plots, with the highest average percent cover in Coniferous Pr/Pw plots. Very little sphagnum moss or other cover was present.

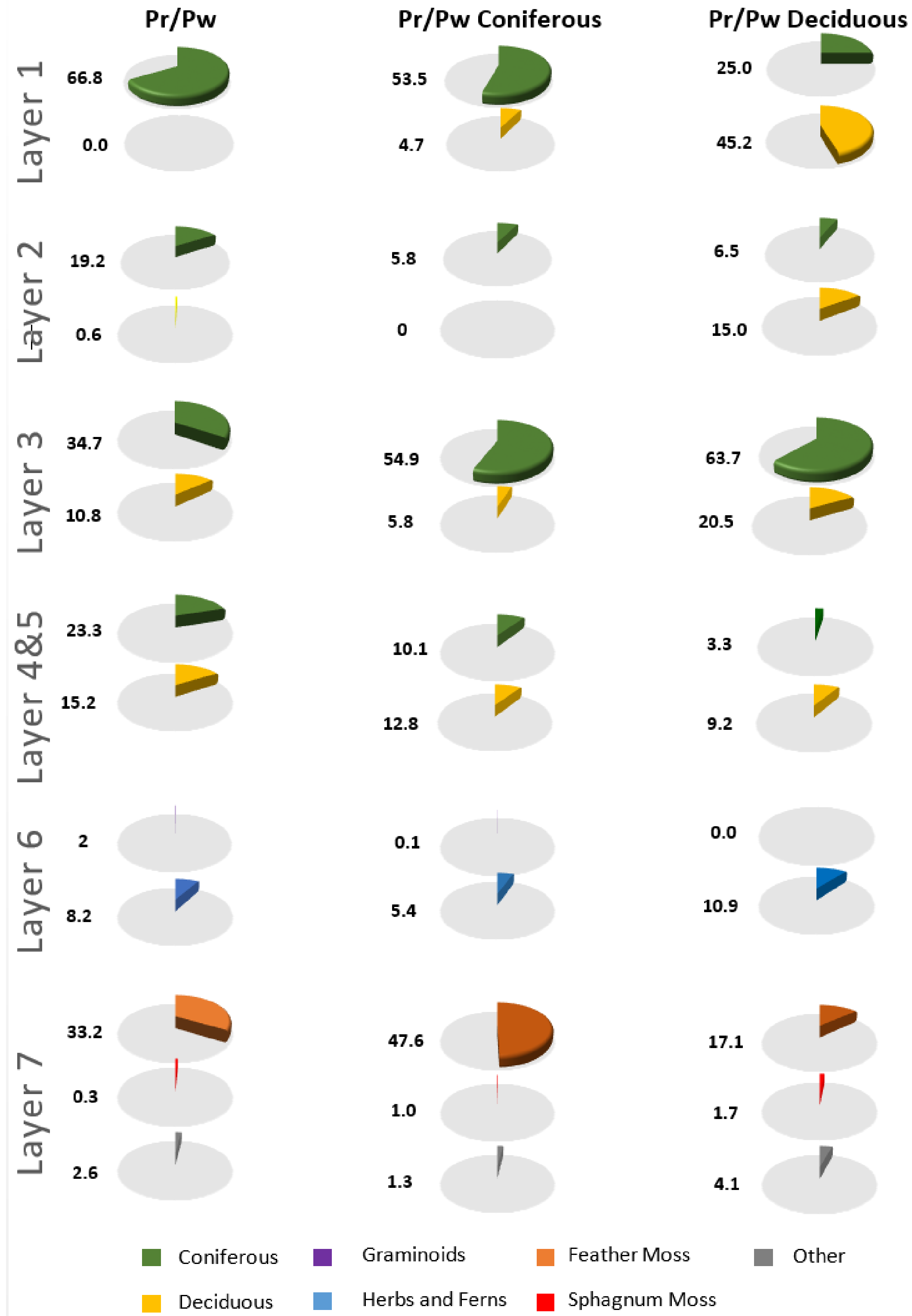

Figure 11: Percent canopy cover. Each pie chart shows the average percent cover for a given cover type (see legend) and in a given canopy layer (see rows on left) and canopy class (see columns at top). Labels beside the pie chart are the average percent cover value. Note that average percent covers do not sum to 100% because they were calculated individually for each cover type.

Pr/Pw Regeneration

Across all plots, higher densities of red and white pine are observed in the canopy (Layer 1) than in the secondary canopy (Layer 2) and shrub layer (Layer 3) (Figure 12). This is especially pronounced in Pr/Pw Plots where there are frequently plots with Pr and Pw in the >50% cover class for Layer 1 while both the number of plots and their % cover decreases in Layers 2 and 3. The average number of pine seedlings is also higher in Pr/Pw plots though their density is still not high (combined average number of Pr and Pw seedling per plot = 8.7, plot area = $100m^2$, density = 0.09 pine seedlings per m^2) (Figure 13). Pw is more abundant than Pr in all layers, though this is most pronounced for seedlings.

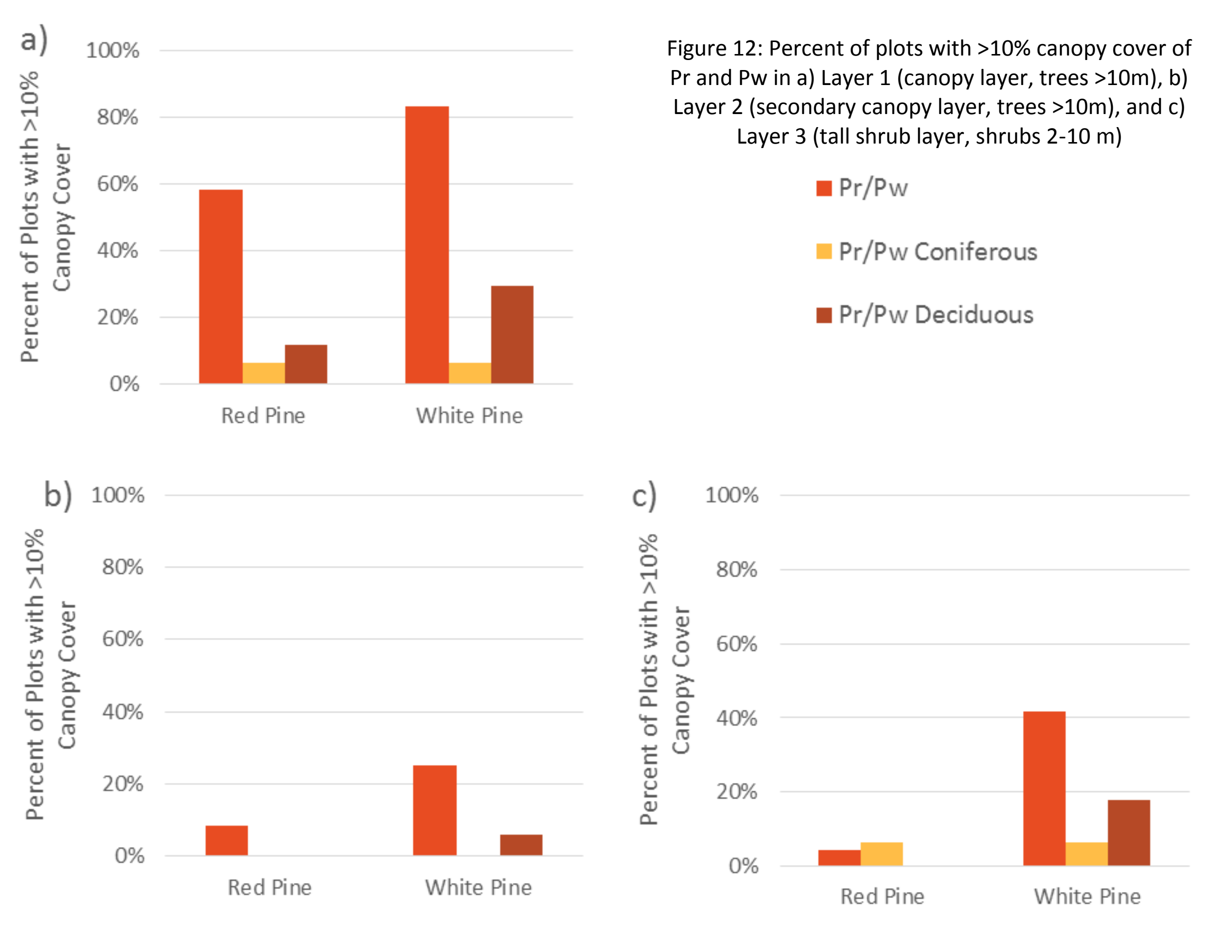

Figure 12: Percent of plots with >10% canopy cover of Pr and Pw in a) Layer 1 (canopy layer, trees >10m), b) Layer 2 (secondary canopy layer, trees >10m), and c) Layer 3 (tall shrub layer, shrubs 2-10 m)

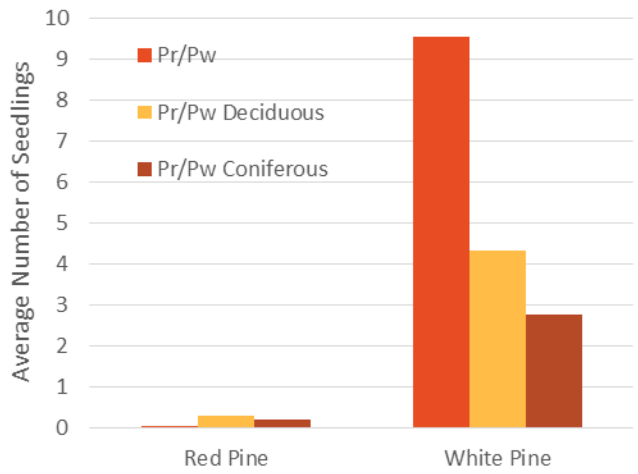

Figure 13: Average number of Pr and Pw seedlings per plot

Cedar

Eastern White Cedar trees or shrubs were found in 6 Coniferous Pr/Pw plots (35% of plots), 6 Deciduous Pr/Pw plots (46% of plots) and 6 Pr/Pw plots (22% of plots). Similar to the pine seedlings, the highest percent cover of cedar trees was found in the canopy layers. However, more plots contained cedar shrubs than cedar trees (Figure 17). Finally, of the 18 plots containing cedar, 13 were selected to represent lower slope characteristics and 5 in the upper slope.

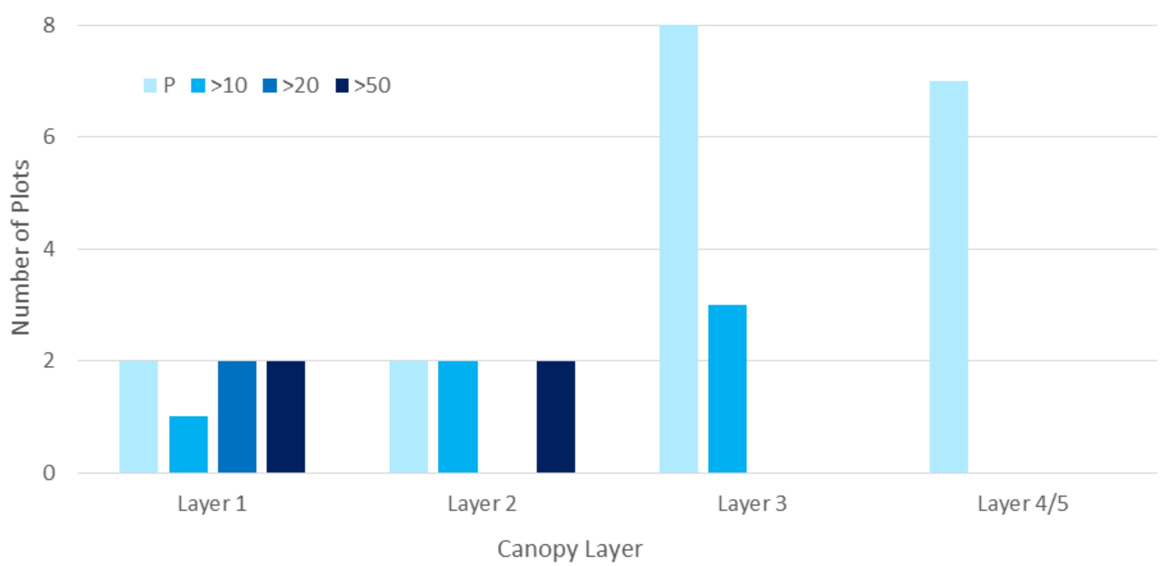

Figure 17: Number of plots containing Eastern White Cedar (18 plots) in each canopy layer. Graduated colour bars indicate the percent cover.

Discussion

1) Pre-fire Vegetation Community Composition and Structure

Forest Floor

Forest substrate in all vegetation plots depended largely on the overlying tree species. Though no significant difference was detected, Coniferous Pr/Pw plots had on average a deeper total forest floor layer compared to the other canopy types. Increased litter in Coniferous Pr/Pw plots is likely because coniferous needles are not as quickly broken down as broadleaf litter. Similarly, composition of the forest floor layer depends largely on the overlying tree species. Across all three canopy types the average percent cover of lichen, stones and water was < 5% and the percent cover of grounded wood and bedrock was <10%. Broadleaf litter and conifer litter on the other hand made up the majority of the forest floor cover. In Deciduous Pr/Pw plots, as expected, the cover of broadleaf litter was significantly greater than in Coniferous Pr/Pw and Pr/Pw plots. Similarly, conifer litter had the highest forest floor cover in Pr/Pw plots. Moss also accounted for a large portion of the forest floor cover with the highest coverage in Coniferous Pr/Pw plots followed by Pr/Pw plots and Deciduous Pr/Pw plots. Mosses are shade-tolerant, prefer wet soils and can thrive in low nutrient conditions. Conifer needles create dense shade and as they break down produce acidic, low nutrient soils (Burns and Honkala 1990). The distribution of moss cover between canopy types is consistent with this situation.

Coarse Woody Debris

Coarse woody debris does not appear to vary greatly depending on canopy type. Overall, the majority of CWD was in the A and B Size Class (between 0.1 and 2.5 cm diameter) with slightly more occurrences of these size classes at high densities in the Pw/Pr Coniferous and Pw/Pr Deciduous plots. This is likely because coniferous trees tend to be more densely branched than deciduous and more likely to fall as a large pile of small CWD.

Physiognomic Layers

Physiognomic forest layers vary in their composition and structure between canopy classes. ***Pr/Pw plots*** had a clear dominance of Pr and Pw in the canopy layer with all plots containing at least >20% cover of one of these species. Pw is present in more plots and at higher percent covers. Pr/Pw plots also had a more diverse secondary layer with a higher percent cover compared to both other plot types. Both deciduous and coniferous trees are present with Bf and Pw being the most common followed by Bw. Tall shrub species composition is similar to the other plot types with Bf and Sb in the majority of plots and at high percent covers. Pw however is also present in about a third of Pr/Pw plots. The low shrub layer has a higher percent cover in Pr/Pw plots compared to other canopy types with blueberry spp., beaked hazel, American yew, and juniper reaching >20% cover. Herbaceous cover on the other hand is uniformly sparse between all canopy types and feather moss is the most common in the moss layer.

Coniferous Pr/Pw plots have a mix of coniferous tree species in the canopy with Sb and Pj the most common. Bw is the only deciduous tree species present. These plots had very little secondary canopy. The tall shrub layer consisted mostly of Bf and Sb (often in high densities) with some Pw and Ce. Low shrubs were sparse except for a handful plots that had a higher percent cover of blueberry spp and one with >50% American Yew cover. Herbaceous cover showed a similar trend as the low shrub with the majority of species only present in a few plots. Finally, feather moss was present in all plots, frequently at high densities.

Deciduous Pr/Pw plots contained a mix of coniferous and deciduous species in the canopy though only deciduous Bw, Mr, and Pot reached percent coverages >50%. There was a sparse or absent secondary canopy in these plots. The tall shrub layer contained a greater number of species compared to Coniferous Pr/Pw Plots however Bf was more dominate. All but one plot contained Bf at either >20 or >50% cover. Low shrubs and the herbaceous layer on the other hand were very sparse. Finally, similar to Coniferous Pr/Pw plots, feather moss was the most common in the moss layer.

It is possible that the large difference in lower forest canopy layers between Pr/Pw, Coniferous Pr/Pw and Deciduous Pr/Pw plots is due to the canopy structure of Pr and Pw trees. Both are large, well branched trees that typically grow above the canopy of other species (Burns and Honkala 1990). Therefore, they allow more light down into the lower canopy layers compared to a spruce, fir, or deciduous canopy cover. This additional light likely allows for the secondary canopy layer and denser tall shrub layer observed in Pr/Pw plots.

Potential Influence of Forest Structure on Fire

Heinselman (1973) indicates that fire suppression in the Boundary Waters Canoe Area (which adjoins Quetico in northern Minnesota) began around 1910. Between 1912 and 1916 Stallard and Bergman (Bergman and Stallard 1916; Stallard 1929) conducted a detailed inventory of the forest communities in northern Minnesota. They described red pine stands as a "beautiful and clear forest whose trees are straight with high naturally trimmed trunks but with overlapping crowns in whose shade only the seedlings of white and red pine and certain shrubs of the forest floor can persist indefinitely" (Stallard 1929 p. 480). The Pw dominate stands occurred less frequently and contained alders, dogwoods and maples in the understorey.

The forest structure observed during this study indicates that fuels are building in all plots. Coniferous Pr/Pw and Deciduous Pr/Pw plots have the highest percent cover of tall shrubs and all plots have secondary canopy layers that can facilitate ignition of crown fires. This contrasts starkly to the 'clear forest' described by Stallard. Balsam fir is present at high densities in the tall and low shrub layers of all plots. This accumulation may create high intensity fire in the study site when these areas burn. Balsam fir and other understory conifers have very resinous bark and foliage that is highly flammable (Heinselman 1973). Heinselman (1973) and Scheller et al (2005) note that a buildup of 'ladder fuels', which carry fire into tree crowns, are capable of creating fires that are more intense and likely to kill older pines, compared to fires that burnt over 100 years ago.

2) Pre-fire Assessment of Red and White Pine Regeneration

In 1989, Pringle conducted a survey of the status of red and white pine in Quetico to determine if active management was required to keep these species on a landscape threatened by logging, fire suppression and white pine blister rust (Pringle 1989). It was found that though 80% of Pw trees were <30 years old, 90% were also <1m tall indicating a very high mortality rate between seedling and sapling stage. It was thought that a combination of white pine blister rust infection and competition (shade) from other tree species was preventing Pw regeneration in areas where seedlings had not established post-fire or forest clearing. Numbers of Pr seedlings were even lower because they only germinated well after a fire.

The vegetation plots monitored this year exhibit similar trends to that observed by Pringle. In Pr/Pw plots there is a clear decrease in number of plots containing Pr and Pw as well as the percent canopy cover of these species between the upper canopy and lower tree and shrub layers. It does not appear that there are large numbers of Pr and Pw waiting in the understory to replace mature Pr and Pw as they die. It is difficult to determine the status of Pr and Pw regeneration in Coniferous Pr/Pw and Deciduous Pr/Pw plots due to the overall low numbers of Pr and Pw in these plots. However, the high density of shrubs in these plots are likely reducing seedling survival by creating dense shade.

Furthermore, across all plots and layers, Pw is more common than Pr. Pr is highly dependent on low intensity fire for germination, requiring a thin ash layer, reduced tree and shrub competition, an open overstory canopy, and reduced cone-eating insect populations (Burns and Honkala 1990). Pw on the other hand can germinate in disturbed and undisturbed litter layers and are more shade tolerant than Pr (Burns and Honkala 1990). The decreased fire cycle (fewer hectares burned per year) in Quetico would therefore reduce the area and frequency of suitable habitat for Pr germination. This is observed in all plots: there are very few Pr seedlings per plot and in the Coniferous Pr/Pw and Deciduous Pr/Pw plots where there are very few Pr in the tall and low shrub layers.

3) Location of Traditional Sacred Plant Species: Eastern White Cedar

Eastern White Cedar is a sacred species to the Anishinaabe people. Members of Lac La Croix First Nation (Zhingwaako Zaaga'Iganing) have expressed concern about damage to cedar trees and shrubs in their traditional territory in Quetico Provincial Park as a result of prescribed fire. Unlike Pr and Pw, Ce is not dependant on fire for germination or light availability, and older trees are highly susceptible to damage from even low intensity fires due to their thin bark with high oil content (Burns and Honkala 1990). Unlike pines, shade-tolerant cedar is likely benefiting from fire suppression. Ce trees were present in 18 of the 57 plots monitored. They reached higher percent coverages in the Canopy and Secondary Canopy Layers and were present sparsely in the Tall and Low Shrub Layers. Ce shrubs, unlike pine, can persist in the understory due to their shade tolerance. There does not appear to be a strong relationship between the presence of cedar with canopy type, slope position, aspect, or canopy layer although they tended to be more predominant in lower slopes. Therefore preservation of these individuals might require on-the-ground searches for Ce trees and shrubs prior to the prescribed burn.

4) Review of the Fire Effects Monitoring Protocol – Operational Final Draft 2017

Quetico's *Fire Effects Monitoring Protocol – Operational Final Draft 2017* was developed to address five key questions identified by the *2009 Fire Management Plan*. The preliminary analysis of pre-fire vegetation plots presented here shows that this protocol facilitates the collection of summary data regarding stand composition and structure that is comparable across plots. Furthermore, field crews from the 2017 season report that each plot could be surveyed in approximately 1 hour, highlighting the efficiency of the methods outlined in the protocol.

A few challenges and recommendations that have arisen through this first summary of the data include:

A) Intended canopy types differed from the actual tree cover in 7 plots.
Furthermore, 13 of the 16 Coniferous Pr/Pw plots and 11 of the 17 Deciduous Pr/Pw plots did not contain pine in Layer 1 or 2. 19 of these plots did contain pine in Layer 3 or 4&5 indicating that (consistent with the definition), there were likely pine trees within 10m of the plot boundary. 5 plots contained no pine. This indicates that it might not always be possible to predict on the ground canopy type based on aerial photographs or that it was challenging in the field to predict canopy class prior to completing the survey. This year a good representation of each canopy class was obtained despite these difficulties. In the future, crews could adjust in the field to ensure that the required plot stratification is reached, or keep track of the number of each canopy type surveyed to ensure that despite on-the-ground differences in canopy type, the surveyed plots are allocated between canopy types similarly to what was planned.

B) V-type Field Call differed from the recorded data in 11 plots.
In some cases this difference is explained by including the secondary canopy when keying out the V-type (i.e. many plots were classed as V-type 26 or 27 in the field but upon inspection of the secondary canopy layer were re-classed as V-type 12). In other cases, a more precise measure of percent canopy cover in the field is required to determine the V-type based on the data (i.e. to distinguish between V-type 26 and 27 when both Pr and Pw are classed as having >50% cover). In the future, the protocol could specify the use of both Layer 1 (Upper Canopy, trees >10m) and Layer 2 (Secondary Canopy, trees >10m) for V-type determination. Crews should also rank tree species from the highest percent canopy cover to the lowest percent canopy cover within Layers 1 and 2.

C) V-type variability within canopy classes
Pr/Pw plots contained 2 V-types, Coniferous Pr/Pw plots contained 12 V-types and Deciduous Pr/Pw plots contained 5 V-types. This variability is to be expected based on the definitions of the canopy classes. (i.e. Pr/Pw plots must contain one of two tree species at >80% canopy cover while the other two plots focus on coniferous vs deciduous trees).

While not necessarily an issue with the protocol, high variability in V-type within Coniferous Pr/Pw and Deciduous Pr/Pw plots may make predicting fire behaviour and post-fire regeneration more challenging because of the variability in species composition, fuel loading, fuel type, forest structure and seed source.

D) Categorical data collection.
The use of categories (i.e. Decay Class, Percent Cover Class) allows for efficient and accurate data collection. However, these categories also make between plot comparisons challenging because data cannot be averaged or added. Though visual inspection of graphed data is possible, it is not straightforward. The importance of this limitation however depends on the use of the data collected going forward and how comparisons between pre and post fire monitoring will be made.

E) Pr and Pw seedlings were not reliably counted in Layer 4&5.
Field sheets provided a location for crews to record the percent cover of Pr and Pw seedlings in Layer 4&5. This appeared to cause confusion because on some field sheets a percent cover (P, >10, >20, >50) was recorded and on other sheets the seedlings were counted individually. This inconsistency makes it challenging to assess Pr and Pw regeneration, one of the key questions this protocol intends to address. Therefore, it is suggested that field sheets are updated to include spaces for both a percent cover and seedling count, and that crews record both of these variables.

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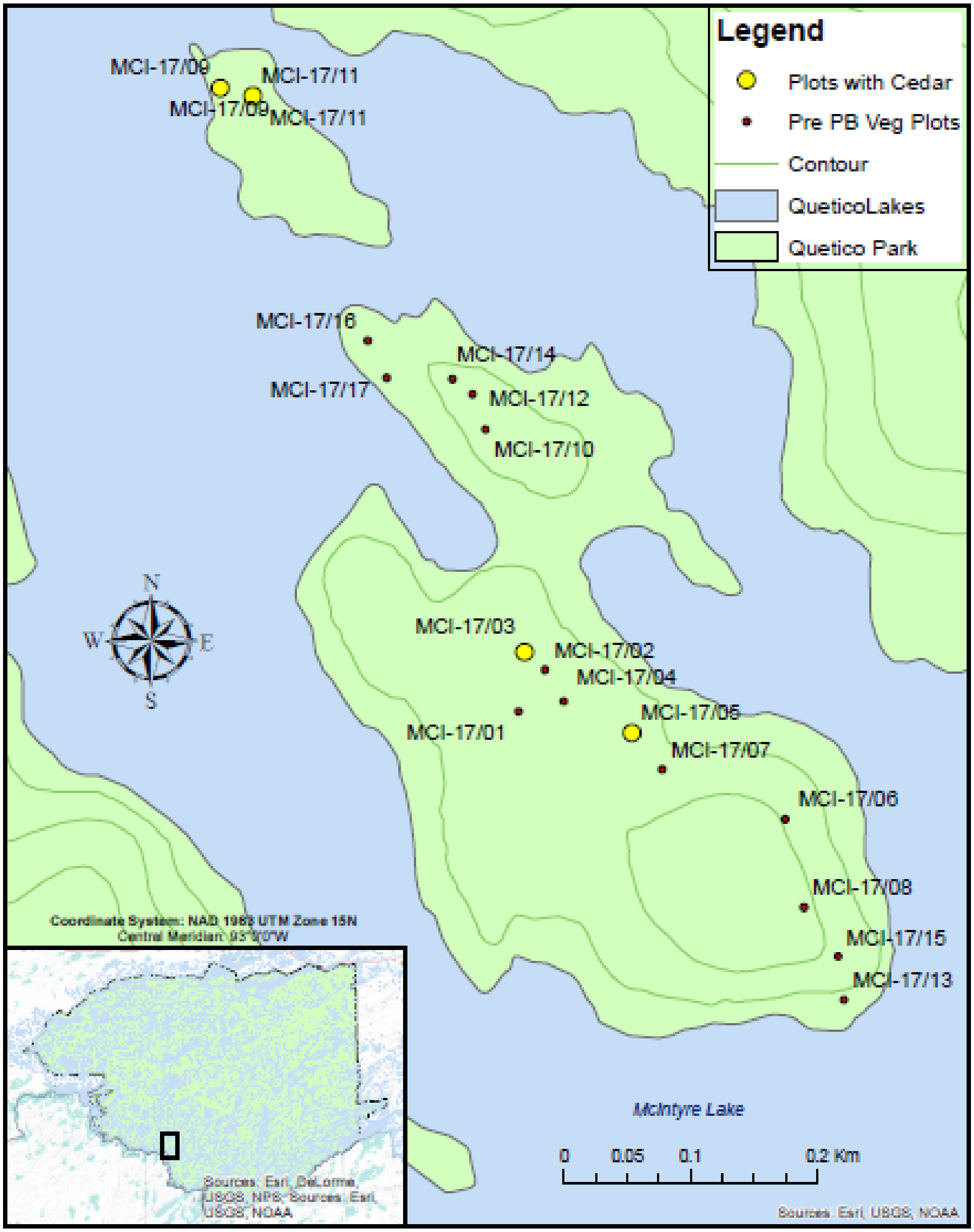
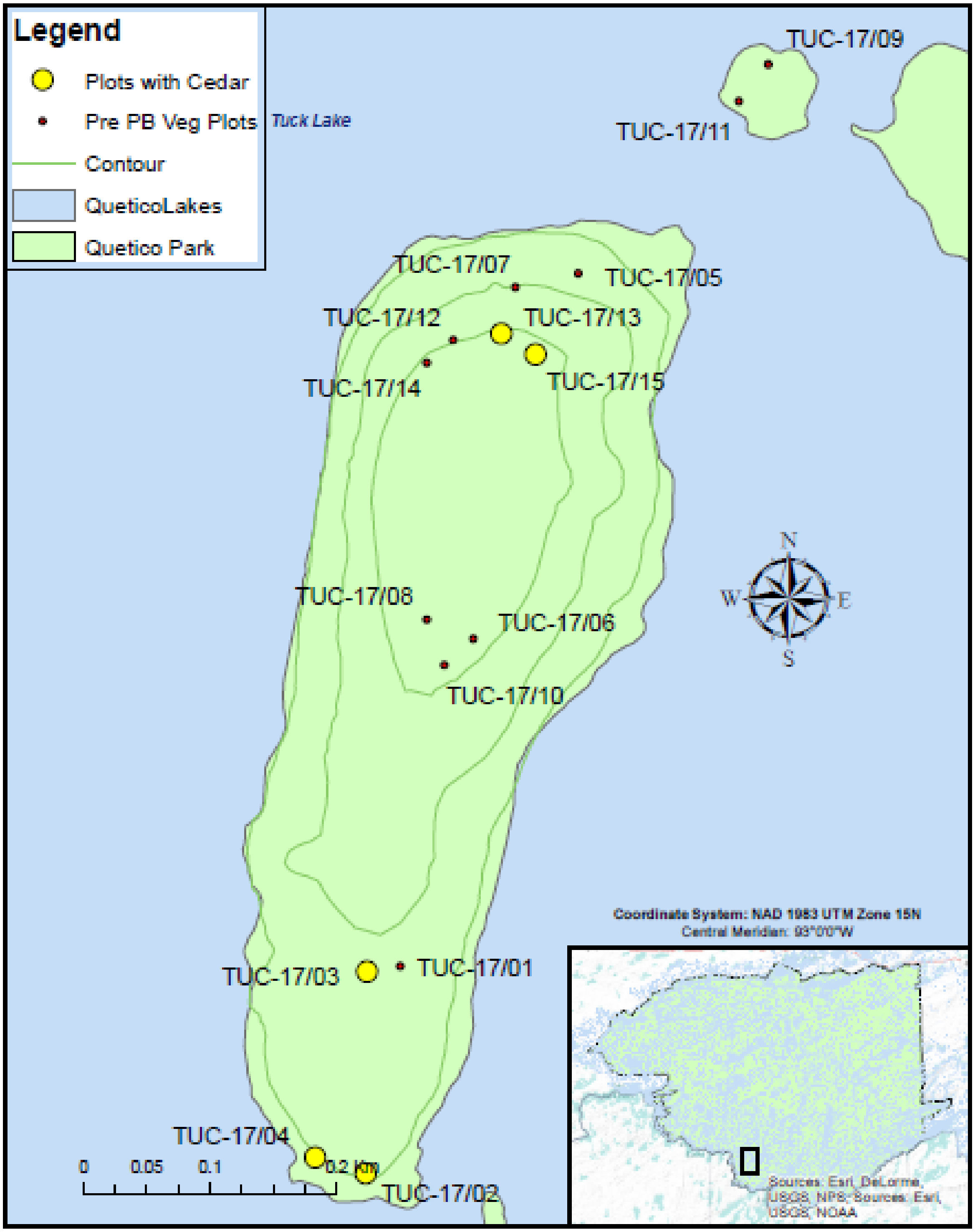
Appendix 1. Plot Locations

The following maps show the location of each vegetation plot. Plots containing cedar trees are highlighted in yellow.

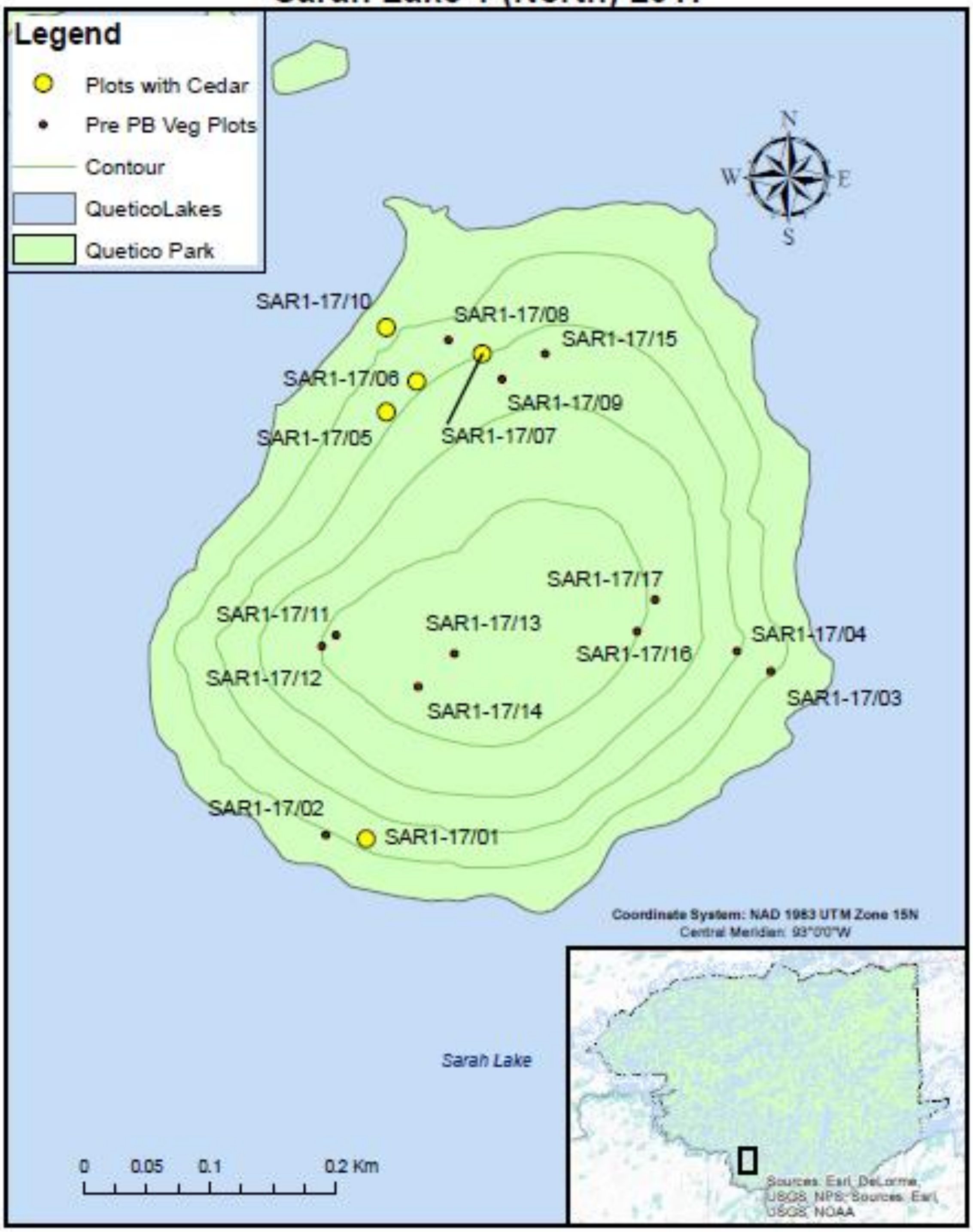
Pre Prescribed Burn Vegetation Plots McIntyre Lake 2017



Pre Prescribed Burn Vegetation Plots Tuck Lake 2017



Pre Prescribed Burn Vegetation Plots
Sarah Lake 1 (North) 2017



Pre Prescribed Burn Vegetation Plots
Sarah Lake 2 (South) 2017