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Effects of Wildfire Severity on Early Successional Dynamics in Boreal Peatland Complexes

Elizabeth Ernst
Michigan Technological University, ejernst@mtu.edu

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EFFECTS OF WILDFIRE SEVERITY ON EARLY SUCCESSIONAL DYNAMICS IN BOREAL PEATLAND COMPLEXES

By

Elizabeth J. Ernst

A THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

In Forestry

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This thesis has been approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE in Forestry.

School of Forest Resources and Environmental Science

Thesis Co-Advisor: *Dr. Evan S. Kane*

Thesis Co-Advisor: *Dr. Joseph W. Wagenbrenner*

Committee Member: *Dr. Laura L. Bourgeau-Chavez*

School Dean: *Dr. Terry L. Sharik*

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Preface

This thesis is submitted in partial fulfillment of a Master of Science in Forestry degree at Michigan Technological University. The field data was collected under supervision of Dr. Evan Kane (School of Forest Resources and Environmental Science; USDA Forest Service Northern Research Station) and Dr. Laura Bourgeau-Chavez (Michigan Tech Research Institute) at several burned sites in the Northwest Territories of Canada. The findings from this study will supplement NASA's Arctic Boreal Vulnerability Experiment (ABoVE), an 8-10 year study that began in 2015. The main objectives of ABoVE are to gain an understanding of the vulnerability and resilience of Arctic and boreal ecosystems to environmental change, and use scientific findings to improve decision-making to better suit societal needs on a local and global level. The original work within this thesis is in preparation for submission for publication. Additional editorial comments were provided by Dr. Joe Wagenbrenner (USDA Forest Service Pacific Southwest Research Station) during the writing process.

Acknowledgements

This work was made possible by NASA's Arctic Boreal Vulnerability Experiment (ABoVE). We were also supported by Michigan Technological University's Michigan Tech Research Institute and School of Forest Resources and Environmental Science. I thank the Principle Investigator of this study, Laura Bourgeau-Chavez, and my graduate co-advisors, Evan Kane and Joe Wagenbrenner, for their input, patience, and guidance throughout this entire process. I would also like to thank the second half of our field team, Sarah Endres and Nor Serocki for making field work fun, no matter how big the bugs. I want to acknowledge Rod Chimner for introducing me to the PC-ORD software, and thank Chris Webster and John Hribljan for helping me learn how to interpret the results. Finally, I would like to thank my family for being a constant source of support and encouragement throughout every challenge.

Abstract[1]

The Arctic-boreal region is experiencing changes in climate, trending toward warmer summers, resulting in a greater occurrence of wildfires with longer burning periods and higher intensities. Drought-like conditions dry surface fuels, leading to a higher probability of ignition, even in lowland peatlands. Previous work has been done to characterize post-fire succession rates in boreal upland sites, but much less is known of fire effects and early successional dynamics in lowland peatlands. Areas surrounding the Great Slave Lake in Canada's Northwest Territories experienced exceptional wildfire activity in 2014 and 2015. These fires burned a variety of ecotypes, including bogs, fens, other lowlands, and uplands. To relate fire severity to early succession following wildfires, we collected seedling regeneration data in 2015 and 2016; we used mixed modeling and multivariate analyses to relate patterns in post-fire succession to burn severity metrics. Our study quantified burn severity at the surface, shrub, and canopy layers at several burned sites across ecotypes. We found that the most significant indicator of early regeneration of coniferous trees were severe ground fires, with canopy severity having little influence on successional patterns. Patterns of early succession of deciduous trees, however, related more to canopy severity. This work adds much needed context for post-fire succession in boreal peatland ecosystems, as the susceptibility of these systems to burning will continue to increase with a warming climate.

[1]The written work in this thesis is in preparation for submission to *The International Journal of Wildland Fire,* by E. J. Ernst, E.S. Kane, L.L. Bourgeau-Chavez, J. W. Wagenbrenner, and S. Endres.

1. Introduction

1.1 Background

Changes in climate in the Arctic-boreal region (ABR) are trending toward warmer, longer summers. In the past, wildfire frequency in the ABR was roughly every 100-150 years; however, climate models show that the length of fire seasons and frequency of fires are likely to increase in response to warmer and drier conditions (Wotton & Flannigan 1993; Stocks et al. 1998; Flannigan et al. 2000; Wotton et al. 2010; Schiks et al. 2016). The projected long-term effects of increased evapotranspiration rates will dry fuels, giving them a higher probability of ignition and more foliage consumption in higher intensity fires (Flannigan 2009). We know that increased fire frequency has direct impacts on vegetation cover, shifting toward younger forests (Kurz & Apps 1999; Kasischke & Turetsky 2006), however, little is known about the patterns of early secondary succession in this region, particularly as it adapts to climate change.

The number one disturbance factor in Canada's Northwest Territories (NWT) is wildfire, which plays an important role in the health and productivity of ecosystems. The second largest disturbance factor is permafrost thaw, which is also mostly climate-driven (Heilbig 2016), and can accelerate when wildfires remove insulating organic layers (Yoshikawa et al. 2003). There are immediate and long-term impacts on surface energy, water balance, and underlying permafrost after a wildfire takes place. As both the size and number of fires have increased over the last four decades (Kasiscke & Turetsky 2006), fire regimes have extended and directly affected ground layer combustion and severity (Turetsky et al. 2011), even in lowland wetlands. For these reasons, it is important to identify and assess fire's many alterations to surface water extent, soil moisture, and vegetation function.

Peatlands are wetlands with low evapotranspiration rates and slow decomposition rates that accumulate thick layers of decomposed or decomposing organics over time. Though peatlands populate roughly 25-30% of boreal forest floors (Gorham 1991; Wieder et al. 2006), they are currently poorly represented in fire behavior prediction models (Schiks et al. 2016), despite recent studies showing that these systems are vulnerable to burn under warmer and drier conditions (Bourgeau-Chavez et al. 2015). There has been little research on fire effects in boreal peatlands, with most of the focus on upland forests in the boreal region (Schiks et al. 2016). A study by Schiks et al. in 2016 showed that there is similar fuel loading at the ground level across fen types (Schiks et al. 2016), but treed peatlands are more susceptible to severe burning than those that lack drier woody fuels, such as open or shrubby fens (Turetsky et al. 2002; Schiks et al. 2016).

A study in Alberta, Canada from 2009-2014 showed that boggy lowlands burned more severely than the uplands during three out of four wildfires (Bourgeau-Chavez et al. 2015). In the earliest of these fires (May 2011), 67% of bog sites burned, while only 30% of the uplands burned, opposing previous assumptions that wetter peatlands with high water tables are less likely to burn than upland sites (Bourgeau-Chavez et al. 2015). This study gave us an idea of how susceptible bogs are to severe burning, but our understanding of the vulnerability of other lowland and peatland systems, such as fens, is still incomplete.

Relative to bogs, fens are more common, making up roughly 60% of Canada's peatlands (Vitt et al. 2000; Schiks et al. 2016). Fens have water tables that fluctuate from just below, to just above the ground surface (Rydin & Jeglum 2015). As compared to bogs, fens are less acidic, and chemical properties within fens vary, with poor fens relating closely in acidity to bogs (pH~4), and rich fens having lower acidity (pH~7).

Peatland fires characteristically smolder in the ground layers (Zoltai et al. 1998; Benscoter and Wieder 2003; Rein et al. 2008; Schiks et al. 2016), but can also consume some fuels above the surface layer, such as shrubs and trees. Downed woody debris on the surface or buried beneath mosses can add to smoldering time (Brown et al. 2003; Schiks et al. 2016). Mosses, litter, and other ground fuels available for burning may vary greatly by season, depending on thaw depth and surface conditions (Turetsky et al. 2011). Combustion of ground layer fuels is heavily influenced by organic soil moisture at the time of burning, which can fluctuate considerably throughout a fire season as the water table rises and falls (Benscoter et al. 2011; Huang et al. 2015; Schiks et al. 2016), however, the depth of burns typically increase later into the fire season (Turetsky et al. 2011). The depth of organic layer burns influence tree recruitment and recovery in boreal uplands (Landhaeusser & Wein 1993; Kasischke & Turetsky 2006), and ground moisture may also play a role in the survival of new seedlings, especially black spruce (*Picea mariana*), which were found to be more successful in wetter sites as opposed to dry ones (Brown et al. 2015). There is a gap in knowledge on the effects of ground layer severity as it relates to revegetation in peatlands, which could help improve future land management in these lowland systems as they adapt to more frequent and severe wildfires.

Today's fire ecologists face the challenge of predicting post-fire successional trajectories in a changing climate, with increasing fire extent and severity. In the past, evidence of historical disturbance was used to help determine succession based on an ecosystem's previous response; however, increased burn severity adds new conditions and nonlinear responses (Johnstone et al. 2010). Furthermore, plant community composition after major disturbance is variable and often hard to predict by influences of the surrounding environment alone. For example, *P. mariana* and tamarack (*Larix laricina*) are dominant tree species in peatlands, but more frequent wildfires and permafrost thaw may increase the saturation of soils, creating unfavorable conditions for one or both species. Shifts to more severe and frequent fires can interrupt stable cycles of *P. mariana* regeneration after wildfires (Johnstone et al. 2010), giving deciduous species new potential to dominate these boreal systems. Due to the difficulty of predicting ecological response to more frequent and severe wildfires, it is necessary to implement observational studies as a way to map early succession, because patterns of seedling composition a few years after wildfires are good indicators of successional trajectories of these systems (Johnstone et al. 2010).

The NWT experienced particularly active wildfire seasons during the summers of 2014 and 2015, burning throughout a variety of ecozones, including the Taiga Plains, Taiga Shield, and Boreal Plains. Fire regimes have shifted in these ecozones (Kasiscke & Turetsky 2006), revealing gaps in our understanding of the effects of more frequent wildfires. In 2014, a record 3.4 million ha burned in the NWT (Gabbert 2014), as compared to all of Canada's yearly average of 2.1 million ha. The yearly average burned in NWT alone is nearly 500,000 ha, which was exceeded again in 2015, when 654,302 ha burned (Matt Coyle, Government of NWT, affiliation, personal communication, March 13, 2017). These fire seasons started earlier and ended later than average, burning throughout a variety of boreal ecosystems, or ecotypes, including bogs, fens, lowlands, and uplands.

1.2 Objectives

Our study relates burn severity to early recruitment of seedlings and sprouting plants after several NWT wildfires. Burn severity can be defined as ecological changes as the result of a wildfire (French et al. 2008). We rated burn severity by the amount of consumption of biomass at the ground, surface, and canopy level, and related severities to early successional patterns. We sampled in burned areas from wildfires that started in various ecotypes and ecozones at different months in two above average wildfire years. We aimed to answer the questions:

1. Does burn severity vary by ecozone?
2. How do fire effects differ in early or late season fires?
3. How does the early succession vegetation compare among peatlands, lowlands, and uplands in boreal systems?
4. Does the ground, shrub, or canopy burn severity relate to early successional patterns of coniferous and deciduous species?

2. Methods

2.1 Sampling Methods

2.1.1 Study Area & Climate Information

All study sites were selected using satellite imagery of burned areas surrounding the Great Slave Lake in the NWT (Figure 1). Field sites represent a variety of burned ecozone types in the ABR, including the Boreal Plains, Taiga Plains, and Taiga Shield. The Boreal Plains make up the northern boundary of the American Great Plains and the southern boundary of the area used in this study. Extending 6.5 million ha, the boreal plains act as a transition zone between farmland and northern boreal forests (Smith et al. 1998). Soils in the ecozone vary from loamy to clayey glacial till, with limestone bedrock outcroppings throughout the region. Forests in this ecozone are made up of mixed stands of *P. mariana*, trembling aspen (*Populus tremuloides*), and balsam poplar (*Populus balsamifera*). We sampled at one site on the Boreal Plains (fire name: SS-28, Figure 2), which was a fen site.

The Taiga plains cover a 222,500 ha expanse of black spruce lowlands, and mixed-wood forests (Heilbig et al. 2016). Most of the sites used in this study were located on the Taiga plains, the majority of which were bog and fen sites. All sites on the Boreal and Taiga Plains were located along the road system, and we accessed them on foot (Figure 2). A number of our fen sites had standing water, and were shrubby or open, lacking a tree canopy layer. Areas sampled south of 62° were located on either the Taiga Plains or Boreal Plains.

The Taiga Shield covers ~130 million ha and is dominated by mixed conifer and conifer-deciduous forests, with sporadic floating fens and peat plateaus (Houben et al. 2016). Lowlands, which make up the majority of our Taiga Shield sites, are characterized by the presence of permafrost, which may limit the interaction between surface water and deeper organic soils. Bedrock and discontinuous till/lacustrine deposits, overlain by *P.*

mariana and jack pine (*Pinus banksiana*) forests, are representative of upland sites in the Taiga Shield. Bedrock in these systems may be volcanic, sedimentary, or granodiorite. Our sites in this ecozone were located north of the Great Slave Lake and east of Yellowknife; we accessed them by boat via Hearne Lake (Figure 2). Their location on the Taiga Shield made them generally rockier with shallower peat. All plots sampled north of 62° latitude were located in the Taiga Shield ecozone.

The landscape in the NWT varies in permafrost continuity, spanning areas of either continuous, discontinuous, or sporadic conditions (Figure 1), which can vary depending on the degree of latitude and drainage patterns in the area. The majority of our sites were located within the discontinuous permafrost boundary, with some sporadic sites and none characterized by a continuous permafrost condition. The NWT experiences low solar elevation (~28°) above the horizon at midday, and short growing seasons in cold soils, with thick organic layers (French et al. 2008). Yellowknife, the capital of the NWT, is located at the northernmost point of the Great Slave Lake. Yellowknife experiences short, dry summers with an average high of 21 degrees Celsius. The average low temperature in the winter is -29 degrees Celsius. Median cloud cover in the area ranges from 68 to 96%, with the cloudier months beginning on July 28th and moving into clearer months on January 9th. Winds in the region typically prevail from the east, with the exception of the summer months, where the winds are predominately southern (Houben et al. 2016). The mean daylight time is 17:51 in May, 19:42 in June, 18:50 in July, and 16:05 in August (Cedar Lake Ventures, Inc. 2017). Fire season here is relatively short, beginning after spring melt and ending when the snow returns in late fall.

We took in situ measurements at several burned sites surrounding the Great Slave Lake, NWT (Figure 2). Our sites were selected from 10 wildfires, 5 large fires in 2014, and 5 smaller fires in 2015 (Figure 2). The 2014 fires burned between June and September, and the 2015 fires burned between May and August (Figure 1). Ground sampling took place in early June and mid-July in 2015 and mid-July and early August in 2016. The sites varied spatially from north (62.56579) to south (60.74811) and east (-113.07375) to west (-119.09621).

To estimate climatic conditions at the times the fires burned, we obtained daily data from a weather station in Yellowknife (62.450000, -114.38333) (Government of Canada 2017). We estimated the monthly average snow pack during the winters leading up to the 2014 and 2015 fire seasons. Though the maximum snow pack was comparable in both years, the 2014 season had the maximum snow pack (~45cm) later in March while the maximum 2015 snowpack (~44cm) occurred February (Table 1). The snowpack in April 2014 (~33cm) was roughly 2 times the amount of the April 2015 value (~16cm), suggesting that there was earlier melt in 2015 (Table 1).

The 2014 fire season experienced warmer conditions later into the summer (end of July) than 2015 (Table 1). The two years had the same maximum temperature (28 degrees Celsius), but the maximum occurred on July 25 and July 29 in 2014 and nearly one month earlier in 2015 (June 28) (Table 1). The 2014 fire season experienced low total precipitation in June (5mm), and the 2015 fire season received the lowest precipitation one month earlier in May (2.2mm) (Table 1) (Government of Canada 2017).

The NWT uses the Canadian Wildland Fire Information System (Natural Resources Canada 2017), which calculates a fire danger rating called the Fire Weather

Index (FWI), based on wind, temperature, relative humidity, and rain. In Table 1, we included the maximum FWI rating for each month, which were all >30. The description for FWI ratings >30 is “extreme,” indicating that fire behavior has potential to reach high-intensity, with fast-spreading crown fires (Natural Resources Canada 2017). The FWI trend for 2014 fires started with the lowest rating in April (33), and increased throughout the season, reaching the peak FWI rating (69) for the year in September. The 2015 season began with a high FWI rating (67) in April, peaking in June (78), and decreasing from then until the end of the season, ending with a rating of 51 in September.

2.1.2 Experimental Design

Several burned sites were selected for ground sampling in this study. Study sites were selected to represent a variety of boreal-peatland types. Criteria for selected sites include 100 x 100 m of a flat, homogeneous ecosystem type, though there were some slight variations in ecosystem type within sites. Within each site, we measured 4-6 10 m x 10 m plots with field measuring tapes, and marked the plots with pin flags, taking a GPS point at the first corner of the first plot in each site (Figure 3). The result was two parallel lines (traverse lines) with 40 m between them, which marked the edges of up to three plots, spaced 15 m apart. The site selection at this scale was designed for the purpose of validating remotely sensed maps, however, in order to study fire effects, we used the most discrete unit, 10 m x 10 m plots, to run our analyses. In the field, we recorded the “ecosystem class” at each plot. Ecosystem classes of “true peatlands” (≥ 40cm of peat) included: bog, fen, open fen, shrubby fen, or treed fen.

For our analysis, we combined ecosystem classes into four “ecotypes,” defined as bog, fen, lowland, or upland. Recent work by Schiks, et al. (2016) showed that despite differences in structure, surface fuel load is mostly constant across fen types, so for the purpose of this study, we combined all fens, open (18%), shrubby (28%), and treed (54%) into one ecotype.

We validated true peatlands by inserting 3-4 m length rods into the duff until mineral soil or ice was reached. If mineral soil was reached, the measurement was recorded as peat depth. If ice was reached, then the measurement was recorded as the "depth to thaw," or the depth of the soil organic layer above frozen ground. We categorized the remaining plots (≤ 40 cm of peat) as either lowland conifer or upland conifer sites. In addition, we used am Ag/AgCl pH electrode (Thermo Scientific) to measure soil pH at each wetland site (Table 2). We also calculated the mean trees per ha for each ecotype (Table 2), by averaging the trees inventoried at each plot (described in section 2.1.4).

2.1.3 Burn Severity Measurements

To assess ground condition, we recorded the dominant ground cover (moss, lichen, grass) at each plot and noted the presence of ash, or burned moss, noting the depth of the burn. Organic layer profiles in peatlands typically include live moss (LM), dead moss (DM), upper duff (UD), and lower duff (LD), with mineral soil beneath (Figure 4). We dug pits with a shovel at each site and noted the thickness of every organic layer horizon up to 40cm, noting mineral soil type if present at that depth.

We used two methods to quantify burn severity: 1) the adventitious root method, which measures amount of organic matter consumed and is an indicator of ground burn severity (Veverica et al. 2012) and 2) ocular assessments of severity at the ground, shrub, and canopy levels. The adventitious root method was carried out by measuring the height of adventitious roots of black spruce trees above the ground surface in order to estimate the pre-fire moss level (Figure 4) and the amount of organic matter lost to burning (Veverica et al. 2012). We sampled up to five adventitious roots at each plot and took the mean of all adventitious root measurements to find the “absolute consumption (cm)” at each plot. Some plots (such as open fens) did not have trees, so those sites did not have values in our dataset, which we adjusted by taking ocular ground severity measurements.

The ocular method of burn severity was used at each plot at three forest levels, with each level containing its own severity index (Figure 4), a method modified after Dyrness and Norum in 1983. We recorded ground severity (moss and litter) condition by estimating the percentage of each level of severity on a scale of 1-5, where 1=moss unburned (least severe), 2=moss singed, 3=lightly burned moss, 4=moderately burned moss, and 5=severely burned moss (most severe) for a total of 100% at each plot. Similarly, the litter severity was estimated as either 1=unburned, 2=singed, 3=charred, or 4=ashed (most severe). To find shrub layer severity, we estimated the percentages of shrubs that were 1=unburned, 2=scorched, 3=burned with limbs left, and 4=limbs totally consumed (most severe). Tree canopy severity was rated by estimating severity on a scale of 1-5, where 1=live trees (least severe), 2=dead foliage intact, 3=dead foliage burned, 4=minor primary branches present, 5=major primary branches present, and 6=charred poles (most severe).

2.1.4 Vegetation Recruitment and Tree Inventory

We estimated the percent live canopy cover, the percent medium shrub cover, the dominant cover and the wetness of the ground at the time of sampling. In addition, we collected biophysical information at each plot to quantify early succession and assess vegetation recovery patterns. The number of seeding and sprouting species were counted in a 1 m x 1 m section of each plot, marked by "Flag Locations" in Figure 3. We classified seedbed types in each 1 m x 1 m subplot as either unburned, burned thin (singed moss), burned thick (deeply burned moss), or burned to mineral soil (all moss consumed). We combined the total number of seedlings and sprouting of each species to get a regrowth estimate at each plot.

Since diameter at breast height (DBH) and basal diameter of trees are strong indicators of total biomass at a site (Schiks et al. 2016), we inventoried dead and live trees that survived the fire in each plot. *P. mariana* and *L. laricina* made up the majority of the canopy layer in treed sites. We created a pre-fire tree inventory by measuring the diameter of every tree >2 m in height. We used calipers to measure the basal diameter of *P. mariana* trees, and the DBH of all other species, noting the mortality and species of each tree. At particularly dense/uniform plots, we used 5 m x 5 m or 2.5 m x 2.5 m subplots instead of the full 10 m x 10 m plots. We converted our estimates from m^2 to trees per hectare (Table 2). In addition, the heights of five representative canopy trees were measured, as well as an ocular estimate of percentage of post-burn canopy closure.

We added seedling and sprouting regrowth to the number of trees that survived the fire and converted these values to get total "live" trees per hectare. Live tree estimates included any trees that survived the fire, plus any regrowth. A study by Veverica et al. (2012) showed similarities in vegetation structure of two common North American conifers, *P. mariana* and *L. laricina*, in mixed boreal stands; therefore, we combined these species with jack pine (*P. banksiana*) to represent "live conifers." We then calculated a live to dead ratio for coniferous species. For our analysis, we combined live, seedling, and sprouting paper birch (*Betula papyrifera*), bog birch (*Betula pumila*), alder (*Alnus*), and willow (*Salix spp.*), *P. balsamifera*, and *P. tremuloides* seedling/sprouting data to create an estimate of "live deciduous."

2.2 Statistical Analysis

2.2.1 Mixed Effects Model

Effects of wildfire severity on coniferous and deciduous tree regrowth were investigated using a general linear mixed model approach in SAS version 9.4 (SAS Institute, 2012). The model was used to investigate indicators of fire severity in three strata of fuel structure: 1) ground layer (moss severity), 2) shrub layer (percentage of shrubs consumed, percentage of shrubs scorched), and 3) the canopy (percentage of minor and major branches consumed, number of completely charred boles remaining), and their interactions with ecotype in explaining variation in regrowth. The distributions of the response variables were evaluated in Kolmogorov-Smirnov tests using the UNIVARIATE procedure. The appropriate data distributions satisfying assumptions of normality were assigned in the mixed effects models (PROC GLIMMIX) with either the normal or lognormal distribution and no link or a log link function, respectively. Type-3 tests of fixed effects and post-hoc comparisons of least-squared means tests across landscape positions were considered significant at alpha = 0.05. Least-squared means comparisons employed the Tukey–Kramer adjustment.

2.2.2 Multivariate Analysis

To analyze post-fire ecological communities, we used a Nonmetric Multidimensional Scaling (NMS) method with the software, PC-ORD version 6 (McCune & Mefford 2011). We chose this ordination method based on its ability to comply with a wide range of nonnormal or discontinuous data (McCune et al. 2002). We listed community data by entering the number of new plants (seedling/sprouting) in each plot (n=218), which became our "main matrix." To improve efficiency of our multivariate analysis, we removed columns from the main matrix with fewer than 2 nonzero numbers, which reduced clutter in our dataset and gave us a total of n=195 plots and 54 species (McCune et al. 2002). Our "second matrix" included several environmental conditions and burn severity classes, including the latitude, fire year, ecotype, month of ignition, permafrost condition, ecozone, depth of consumption (cm), percent consumption, ratio of live/dead trees, live deciduous, and percentage of severity at all levels (moss, litter, shrub, and canopy).

We ran ecological community analyses using the Sorensen (Bray-Curtis) ordination in PC-ORD. This is a type of NMS ordination method, which selects polar endpoints and populates other points relative to the endpoints using a distance matrix (McCune et al. 2002). This method is shows ecological gradients that are independent of linear relationships with other species (McCune et al. 2002). It can be used to analyze large datasets with hundreds of plots to describe community variation relative to specific groups.

We ran the NMS ordination in "autopilot" (input parameters are set automatically) at medium power, and graphed the results in 2D (Peck 2010). The grouping variables that we chose for our simple scatterplots were ecotype and month of fire start, and we selected "joint plot" to show environmental factors which were strongly associated with our ordination axes ($r^2>0.20$). The percentage of variation within the distance matrix explained by each axis was noted by selecting the correlations within the main matrix (∑1) and the correlations within the second matrix (∑2) (Peck 2010). We again used the Sorensen (Bray-Curtis) distance measure test (r^2) to find the percent of variation in the distance matrix. This calculated the coefficients of determination in our scatterplot, giving us the relative contribution of each axis based on ordination scores (Peck 2010).

Descriptive statistics were generated using the graphing function in PC-ORD to make simple boxplots showing the distribution of data among ecotype and the month of ignition to help supplement the ordination results. We were interested in how different levels of severity (ground, shrub and canopy) varied by ecotype and the month that the fire started, June (n=22), July (n=145), or August (n=28). We also looked at the absolute consumption (cm) from the adventitious root method to see how the depth of the burn differed among ecotypes and fire start months, validated by least squares estimates.

2.2.3 Simple Linear Regression

To analyze differences in ground severity across ecozones, we made a simple linear regression model using R software (R Core Team 2016) and created a plot with ggplot2 (Wickham 2009) showing the absolute consumption from the adventitious root method by latitude.

3. Results

3.1 Fire Severity Effects on Regeneration Patterns

Overall, we found that the fen sites sampled burned less severely in the litter layer than any other ecotype (Figure 5). The boxplot in Figure 5 was generated as "litter charred by ecotype," which shows that the bog, lowland, and upland sites had about the same median of litter charred, while fen sites had a much lower median of litter charred (Figure 5). The least squares estimate of litter charred was much lower for fen ecotypes (36.3%, σ^2=3.2%), compared to least squares estimates of the other ecotypes (67.1-73.9%, σ^2=3.2-8.8%), where σ^2 is the standard error (Appendix A).

A test of burn severity effects on the ratio of live (survived plus regrowth) to standing dead coniferous species and the interaction of burn severity in the ground layer (moss and litter), shrub layer, canopy layer showed moss severity to be significant across all ecotypes, with a significance level of α=0.05 (Table 3). Moss severity showed a positive correlation with the ratio of live to dead conifers (p=0.003, F=9.16, DF=126), while severity within the shrub and canopy layers did not show significance. The interaction between moss severity and ecotype was also significant (p=0.0209, F=3.36) (Table 3) for all ecotypes. The least squares estimates showed a large separation between the bogs, fens, and lowlands in contrast with uplands, with the live to dead ratio of bog, fen, and lowland sites ranging from 1.05-5.87 (σ^2=13.33-14.83), and the least squares estimate of uplands yielding a ratio of 192.60 (σ^2=32.04) (Appendix A).

Another model analyzed burn severity as it relates to live deciduous tree species after fire (Table 4). In this case, ecotype was the most significant predictor (p=<0.0001, F=12.61, DF=172) and none of the burn severity interactions with ecotype were significant (Table 4). The variation in deciduous regrowth across ecotypes is shown in Figure 6, where fens had the highest deciduous regrowth and bog sites had very little deciduous regrowth (Figure 6). Live deciduous was also significantly related to the most severe canopy class, charred poles (p=0.0158, F=5.94) (Table 4).

The output of our multivariate analysis using the NMS method was an ordination diagram (scatterplot), which we grouped by ecotype. We interpreted the ordination diagram to find patterns in how the main matrix (regrowth) and the second matrix (environmental factors/burn severity classes) separated by the four ecotype classes between ordination axes (Figure 7). The coefficients of determination between the two axes together explained 41% of the variability in the scatterplot; Axis 1 explained 26% and Axis 2 explained 15% of the variability (18,915 entity pairs used in correlation) (Appendix B).

The species from the main matrix that showed a strong positive correlation with Axis 1 were bog labrador tea (*Rhododendron groenlandicum*) (r^2=0.28), cloudberry (*Rubus chamaemorus*) (r^2=0.21), and cranberry (*Vaccinium oxycoccos*) (r^2=0.15) (Table 6). A negative correlation with Axis 1 was shown by willow (*Salix spp.*) (r^2=0.14) and bog birch (*B. pumila*) (r^2=0.13). Axis 2 was positively correlated with *B. pumila* (r^2=0.16), fireweed (*Chamaenerion angustifolium*) (r^2=0.10), and *R. groenlandicum* (r^2=0.09) (Table 5).

Litter charred, ecozone, and deciduous regrowth showed a high relative association (r^2>0.20) in the second matrix ordination diagram (Figure 7). Axis 1 had a high positive relative association with a ground severity class, litter charred (r^2=0.25), and a strong negative association with deciduous regrowth (r^2=0.22). Ecozone showed a positive correlation with this axis (r^2=0.20), and severity classes, including shrub consumed (r^2=0.15) and moss moderate (r^2=0.15) were also positively correlated. Axis 2 was most influenced by a positive correlation with depth to thaw (r^2=0.10), and was negatively associated with two ground severity classes, moss moderate (r^2=0.09) and litter charred (r^2=0.08) (Table 6).

3.2 Timing and Ecozone Effects on Severity

We were interested in how seasonal timing of fires related to severity across ecotypes, which is shown by the boxplot in Figure 8. This graph shows that there were very few early fires in bog and fen (peatland) ecotypes, while the lowland and uplands burned earlier in the season and did not have any fire starts in August.

We generated a second ordination diagram to study patterns between regrowth and environmental factors by the grouping variable, month of ignition (Figure 9). In this scatterplot, there were some differences in fire effects associated with fires started early in the season (June) vs later in the season (August). These differences were distributed along Axis 2, with August showing positive association and June showing a negative association to Axis 2, and July fires scattered randomly between both axes. The boxplot in Figure 10 shows a difference between absolute consumption by month, where the median consumption was less in June than in July or August. The least squares estimates of consumption by shows a similar trend, with the estimate for June (4.0cm, σ^2=1.2cm) showing lower absolute consumption than July or August (5.7-7.8cm, σ^2=0.4-0.8cm) (Appendix A) for all ecotypes.

A linear regression model of absolute consumption (cm) by latitude showed more consumption in higher latitudes (at 62° latitude or higher) (Figure 11). The regression line had an r^2 value of 0.2997, and a p value < 0.0001. All plots sampled in higher latitudes were located on the Taiga Shield ecozone. There were no early (June) fires in the Taiga Shield, where fires started in either July or August in both years.

4. Discussion

Our results indicated that ground level burn severity is a significant indicator of coniferous regrowth in boreal peatland systems. Severe burning within surface moss fuels in particular was an important control on *P. mariana*, *L. laricina* and *P. banksiana* regeneration in the first two years following wildfires, with canopy severity showing no significance. It is surprising that canopy severity did not have a significant influence on the live/dead ratio of coniferous trees, because *P. mariana* and *P. banksiana* trees store seeds in semiserotinous cones, and rely on fire to open their cones and release seeds (Greene & Johnson 1999; Brown & Johnstone 2012). Therefore, we expected severity in the canopy level to be more influential on seed dispersal and early success of seedlings. Instead, the importance of a moderate ground layer burn was showcased in our results. Our findings emphasize that these conifer species require specific seedbeds and surface conditions for regeneration, typically germinating on mineral soil or burned humus, with little success on burned duff (Greene et al. 1999).

There was variation across ecotypes as they related to coniferous regeneration, with uplands showing a considerably large ratio of live (survived plus regrowth) to dead conifers as compared to all three of the lowland systems. This could be attributed to differences in ground surface and seedbeds between ecotypes, with uplands characteristically having more mineral soil exposed as opposed to the thick mosses and organic layers found in peatlands. Only 6 out of 195 of our plots were classified as having a “mineral soil” seedbed, and all 6 of these plots were upland ecotypes. Fens and bogs generally have smaller fuel loads than upland sites (Schiks et al. 2016), which may have also contributed distinctions among ecotypes found in our study.

It is important to note that 1-2 years after fire is potentially too soon to get a fair estimate of coniferous regeneration, because these species typically recruit 3-6 years after fire (Peters et al. 2005; Johnstone et al. 2010). In our future work, we will continue to survey for these species at established plots to note if there is a significant increase in seedling regeneration as the 3-6 year window after fire approaches.

The presence of deciduous tree species after fire was less dependent on ground layer severity and more heavily influenced by canopy layer severity. Deciduous species rely heavily on resprouting asexually after fire (Greene & Johnson 1999; Johnstone et al. 2010), and do not require such specific ground layer conditions as conifers; our finding that the ground layer severity had little influence over deciduous regeneration helped support this. Ecotype played a significant role in regeneration of deciduous trees, emphasizing the variation between bogs, fens, lowlands and uplands. Our results showed fens had a high success in deciduous regeneration after fire, and bog sites had little to no deciduous regrowth.

Severity of burning within the ground (litter) layer had the highest relative association with regrowth in our multivariate analysis. Litter charred, which we classified as an indicator of moderate severity ground fire, was the most significant environmental factor in our ordination diagrams (Figures 7 and 9), showing a strong positive correlation with ground layer severity (Axis 1) and a slightly negative association with Axis 2. Other fire effects that had a strong correlation with this Axis 1 were moderate to severe burns in the ground and shrub layers (shrub consumed and moss moderate). Bog sites had a strong positive correlation with Axis 1, suggesting that regrowth in boggy peatlands are more associated with ground layer severity and coniferous regrowth than deciduous regrowth.

Patterns of coniferous regrowth in response to ground layer severity were different in uplands, as shown in our mixed effects model. This separation between ecotypes was also observed by the polarization of uplands along Axis 2 in the ordination plots (Figure 7). The upland ecotype was accompanied by *P. mariana*, representative of coniferous species, which also had a strong negative association with Axis 2. The deciduous regrowth condition had a strong negative correlation with Axis 1 and a slight positive correlation with Axis 2, responding exactly opposite of the litter charred condition (Figures 7 and 9). In addition, individual deciduous species, such as *B. pumila* and *P. tremuloides* were positively correlated with Axis 2, supporting our model that shows little significance in ground severity for succession of these broad-leaf species.

The month that the fire started showed variation between early season and late season fires. This variability is partially driven by conditions being most suitable for fires in boreal forests during the late season, when fuels are cured and there is lower moisture on the surface (Schiks et al. 2016), which is represented by the general trend of increasing FWI ratings later in the season. Our multivariate analysis showed a visible separation between fires started in June (negatively correlated with Axis 2) and those that started in August (positively correlated with Axis 2). The environmental condition, depth to thaw (cm), had a strong association with Axis 2, which corresponds with previous knowledge that the depth of burns into organic layers increase with seasonal ice thaw toward the end of summer (Turetsky et al. 2011). In addition, we found that the depth of absolute consumption at the ground layer was much lower for fires started in June as compared to those started in the middle and end of the fire seasons. We recognize that snowpack during the winter leading up to the fire season may have an influence on the frequency of early season fires. The snowpack in April leading up to the 2014 fire season was about 2 times the snowpack in April, 2015, which could be a contributing factor to the 2015 fire season starting one month earlier, in May.

Regrowth in these systems was influenced by ecozone (20% of the variance), as shown by our ordination plots. Ground severity also varied by ecozone, with the Taiga Shield plots having a higher ground severity with deeper absolute consumption than plots sampled in the Taiga Plains and Boreal Plains ecozones (Figure 11). We recognize that plots in the Boreal Plains are not well-represented (covering only 6 plots), however, the contrast between consumption on the Taiga Shield and Taiga Plains was significant in our linear regression model. Taiga Shield plots had no early fires, with 60% of the fires starting in July, and the other 40% starting in August, which is likely the reason we see such severe fires in this ecozone. In order to explore the relevance of ecozone, more plots in the Boreal Plains should be added in the future.

5. Conclusion

We assessed severity indicators at the ground, shrub, and canopy level at several burned sites in Canada's Northwest Territories to determine whether one of these indicators could be used to predict early succession after wildfires in boreal forests. The ground (moss and litter) burn severity was a significant predictor of the presence of live conifers, and the two were positively correlated. In contrast, canopy burn severity was the strongest predictor of the presence of live deciduous trees. We found that there was a difference in ground burn severity among boreal bog, fen, lowland, and upland sites, with fen sites exhibiting the lowest ground layer severity. There was also variation in the succession of coniferous species across ecotypes, with upland sites having more live coniferous trees than any of the lowland or peatland types, and deciduous regrowth showing more success in the fen ecotypes.

In addition, we found that there was less absolute consumption at the ground layer in fires started early in the season, as compared to those started in the middle or near the end of fire season. Peatland systems did not experience any early season fire starts, as shown by bog and fen plots either starting in June or August. Upland and lowland ecotypes, however, burned earlier in the season, and did not have any fires that started in August. Finally, we found that burned areas at higher latitudes had higher ground severity. These higher latitude plots were in the Taiga Shield ecozone, which generally had more absolute consumption than the Taiga Plains or Boreal Plains plots.

6. References

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7. Tables

Table 1: Weather data in Yellowknife, NWT from October 2013 to September 2015. (Government of Canada 2017).

	Mean Temperature (°C)	Total Precipitation (mm)	Mean Snow Pack (cm)	Maximum Fire Weather Index
2013				
October	1.73	32.6	1.3	-
November	-13.06	31.4	8	-
December	-29.13	9.5	19.3	-
2014				
January	-24.7	47.5	34.1	-
February	-25.5	7.0	42.0	-
March	-20.4	8.0	45.1	-
April	-8.1	3.5	33.1	33
May	4.5	21.0	0	44
June	14.3	5.0	0	49
July	17.8	9.2	0	51
August	13.6	56.4	0	64
September	6.5	13.6	0	69
October	0.1	21.8	0.3	-
November	-15.9	18.6	8.1	-
December	-21.1	32.0	23.3	-
2015				
January	-24.6	39.3	35.9	-
February	-26.1	9.0	43.9	-
March	-15.7	15.2	35.6	-
April	-4.3	8.9	16.3	67
May	7.0	2.2	0	67
June	14.5	7.2	0	78
July	16.1	25.8	0	74
August	15.0	46.8	0	70
September	8.1	18.0	0	51

Table 2: The number of plots and mean pH, peat depth, thaw depth, and trees per unit area per ecotype. NA indicates not represented within the study sites.

Ecotype	Number of Plots	Mean pH	Mean Peat Depth (cm)	Mean Thaw Depth (cm)	Mean Trees Per Hectare
Bog	52	4.9	87.6	92.8	4070
Fen	68	6.2	81.4	89.8	3598
Lowland	66	5.3	21.5	57.3	7016
Upland	9	NA	7.3	NA	4411

Table 3: Mixed model results of the ratio of live to dead conifer trees, where F Statistic is the critical value and the Pr > F is the significance probability.

Type III Test of Fixed Effects					
Effect	**Vegetation Layer**	**Degrees of Freedom**	**Den DF**	**F Statistic**	**Pr > F**
Ecotype	-	3	126	2.02	0.1147
Seedbed	Ground	3	126	0.54	0.6555
Moss Severe	Ground	1	126	9.16	0.003
Shrub Consumed	Shrub	1	126	0.16	0.6883
Shrub Scorched	Shrub	1	126	1.5	0.2232
Minor Primary Burned	Canopy	1	126	0.08	0.7804
Major Primary Burned	Canopy	1	126	2.61	0.1088
Charred Poles	Canopy	1	126	0.02	0.8815
Moss Severe*Ecotype	Ground	3	126	3.36	0.0209
Major Primary*Ecotype	Canopy	3	126	1.16	0.3296
Moss Severe*Major Primary	Ground/ Canopy	1	126	2.83	0.0951
Moss Severe*Major Primary*Ecotype	Ground/ Canopy	3	126	0.71	0.5498

Table 4: Mixed model results of live deciduous species, where F Statistic is the critical value and the Pr > F is the significance probability.

Type III Test of Fixed Effects					
Effect	**Vegetation Layer**	**Degrees of Freedom**	**Den DF**	**F Statistic**	**Pr > F**
Ecotype	-	3	172	12.61	<.0001
Seedbed	Ground	3	172	2.37	0.0724
Moss Severe	Ground	1	172	0.29	0.5907
Shrub Consumed	Shrub	1	172	2.53	0.1136
Shrub Scorched	Shrub	1	172	0.22	0.6368
Minor Primary Burned	Canopy	1	172	1.06	0.305
Major Primary Burned	Canopy	1	172	0.11	0.743
Charred Poles	Canopy	1	172	5.94	0.0158
Moss Severe*Ecotype	Canopy	3	172	0.32	0.809
Major Primary*Ecotype	Canopy	3	172	1.13	0.3382
Moss Severe*Major Primary	Ground/ Canopy	1	172	0.23	0.6308
Moss Severe*Major Primary*Ecotype	Ground/ Canopy	3	172	0.26	0.854

Table 5: Correlations in the main matrix (species) of the NMS ordination. This table shows positive and negative associations with Axis 1 and Axis 2 (Figures 7 and 9), where R is the correlation coefficient, R^2 is the coefficient of determination, and tau is Kendall's rank coefficient, measuring ordinal association (McCune et al. 2002) (continued on next page).

N=195		**Axis 1**			**Axis 2**	
Species	R	R^2	tau	R	R^2	tau
Rhododendron groenlandicum	0.533	0.284	0.594	0.304	0.092	0.272
Rubus chamaemorus	0.459	0.211	0.567	0.161	0.026	0.217
Vaccinium oxycoccos	0.389	0.151	0.46	0.131	0.017	0.028
Salix spp.	-0.373	0.139	-0.468	-0.025	0.001	-0.098
Betula pumila	-0.356	0.127	-0.392	0.398	0.158	0.357
Chamaedaphne calyculata	0.325	0.106	0.374	0.137	0.019	0.237
Andromeda polifolia	0.269	0.072	0.306	0.08	0.006	0.153
Myrica gale	-0.246	0.061	-0.262	0.018	0	0.051
Vaccinium vitis-ideas	0.227	0.052	0.321	0.124	0.015	0.122
Purple herb	0.159	0.025	0.17	0.119	0.014	0.157
Mosses	0.155	0.024	0.118	-0.229	0.053	-0.17
Galium spp.	-0.153	0.023	-0.137	-0.021	0	0.002
Comarum palustre	-0.144	0.021	-0.114	-0.013	0	-0.066
Arum	-0.136	0.019	-0.113	-0.006	0	-0.008
Pinus banksiana	0.137	0.019	0.149	0.007	0	0.065
Polygonum	-0.139	0.019	-0.128	-0.063	0.004	-0.071
Rosa acicularis	0.131	0.017	0.044	0.052	0.003	-0.029
Arctostaphylos rubra	0.123	0.015	0.058	0.041	0.002	-0.006
Coptis trifolia	-0.118	0.014	-0.148	-0.039	0.002	-0.11
Liverwort	0.115	0.013	0.076	-0.287	0.082	-0.202
Grasses	0.11	0.012	0.022	-0.118	0.014	-0.175
Juncus balticus	0.103	0.011	0.115	0.079	0.006	0.084
Sedge	0.106	0.011	-0.011	0.013	0	0.032
Chamaenerion angustifolium	0.098	0.01	0.096	-0.319	0.102	-0.312
Dasiphora fruticosa	-0.099	0.01	-0.173	0.114	0.013	0.211
Scutellaria galericulata	-0.099	0.01	-0.094	-0.055	0.003	-0.066
Vaccinium angustifolium	0.095	0.009	0.117	0.088	0.008	0.175

Table 5 (continued).

N=195	**Axis 1**			**Axis 2**		
Species	R	R^2	tau	R	R^2	tau
Equisetum	-0.085	0.007	0.05	-0.098	0.01	-0.374
Kalmia polifolia	0.081	0.007	0.063	0.039	0.002	0.019
Betula papyrifera	0.074	0.006	0.083	-0.046	0.002	-0.082
Aster	-0.069	0.005	-0.12	-0.068	0.005	-0.119
Myosotis	-0.07	0.005	-0.044	0.092	0.009	0.085
Thistle	-0.071	0.005	0.005	-0.117	0.014	-0.131
Viburnum	-0.073	0.005	-0.046	-0.113	0.013	-0.086
Linnaea borealis	-0.066	0.004	-0.032	-0.087	0.008	-0.154
Phacelia franklinii	0.064	0.004	0.051	-0.135	0.018	-0.09
Unknown	-0.066	0.004	-0.032	-0.087	0.008	-0.154
Orchidacea	-0.059	0.003	-0.041	-0.023	0.001	-0.028
Larix laricina	0.043	0.002	0.056	0.021	0	0.014
Picea mariana	0.039	0.002	0.132	-0.22	0.048	-0.153
Populus tremuloides	-0.049	0.002	-0.029	0.046	0.002	0.045
Aquilegia brevistyla	0.027	0.001	0.032	-0.084	0.007	-0.098
Campanula rotundifolia	-0.024	0.001	-0.026	-0.084	0.007	-0.09
Cornus sericea	0.026	0.001	0.006	-0.042	0.002	-0.051
Dacus carota	-0.028	0.001	-0.026	-0.011	0	-0.054
Geranium maculatum	0.037	0.001	0.034	-0.036	0.001	-0.04
Maianthemum trifolium	-0.03	0.001	0.102	-0.044	0.002	-0.17
Alnus	0.021	0	-0.009	0.012	0	-0.026
Astraglus alpinus	0.021	0	0.01	-0.166	0.028	-0.096
Empetrum nigrum	0.013	0	0.003	0.02	0	0.011
Lactuca	0.018	0	-0.001	-0.14	0.02	-0.096
Lichen	0.018	0	-0.001	-0.14	0.02	-0.096
Populus balsamifera	-0.001	0	0.005	0.161	0.026	0.127
Solidago canadensis	-0.02	0	-0.015	-0.187	0.035	-0.127

Table 6: Correlations in the second matrix (environmental condition and burn severity class) of the NMS ordination. This table shows positive and negative associations with Axis 1 and Axis 2 (Figures 7 and 9), where R is the correlation coefficient, R^2 is the coefficient of determination, and tau is Kendall's rank coefficient, measuring ordinal association (McCune & Grace 2002).

N=195	**Axis 1**			**Axis 2**		
Environmental Condition	R	R^2	tau	R	R^2	tau
Litter Charred	0.504	0.254	0.29	-0.287	0.082	-0.196
Deciduous Regrowth	-0.472	0.223	-0.487	0.272	0.074	0.12
Ecozone	0.446	0.199	0.333	-0.233	0.054	-0.183
Shrub Consumed	0.393	0.154	0.197	-0.202	0.041	-0.142
Moss Moderate	0.38	0.145	0.245	-0.295	0.087	-0.179
Latitude	0.299	0.089	0.14	-0.229	0.052	-0.191
Shrub Limbs Left	-0.295	0.087	-0.105	0.065	0.004	0.022
Moss Singed	-0.287	0.083	-0.077	0.164	0.027	0.165
Shrub Scorched	-0.278	0.077	-0.122	0.165	0.027	0.122
Litter Ashed	-0.267	0.071	-0.222	-0.008	0	-0.084
Litter Singed	-0.25	0.062	-0.034	0.21	0.044	0.164
Shrub Unburned	0.217	0.047	0.171	0.125	0.016	0.119
Min. Primary Branches	0.209	0.044	0.164	-0.034	0.001	-0.061
Permafrost Condition	0.189	0.036	0.137	-0.136	0.019	-0.114
Abs. Consumption	0.181	0.033	0.139	-0.233	0.054	-0.162
Coniferous Regrowth	-0.136	0.018	-0.089	0.026	0.001	-0.047
Secondary Branches	0.131	0.017	0.178	-0.007	0	0.002
Percent Consumed	0.088	0.008	0.055	-0.203	0.041	-0.064
Litter Unburned	-0.083	0.007	0.001	0.175	0.031	0.144
Moss Lightly Burned	-0.08	0.006	-0.01	0.253	0.064	0.147
Charred Poles	-0.077	0.006	-0.027	-0.046	0.002	-0.043
Live Trees	-0.068	0.005	-0.058	-0.006	0	0.024
Depth to Thaw	0.064	0.004	0.072	0.311	0.097	0.254
Foliage Burned	0.064	0.004	0.098	-0.092	0.008	-0.005
Maj. Primary Branches	0.044	0.002	0.079	-0.139	0.019	-0.114
Foliage Intact	-0.025	0.001	-0.006	0.198	0.039	0.075
Live/Dead Ratio	0.021	0	0.059	-0.221	0.049	-0.107
Moss Unburned	0.019	0	0.09	0.176	0.031	0.165
Moss Severe	-0.01	0	0.145	-0.213	0.046	-0.201

8. Figures

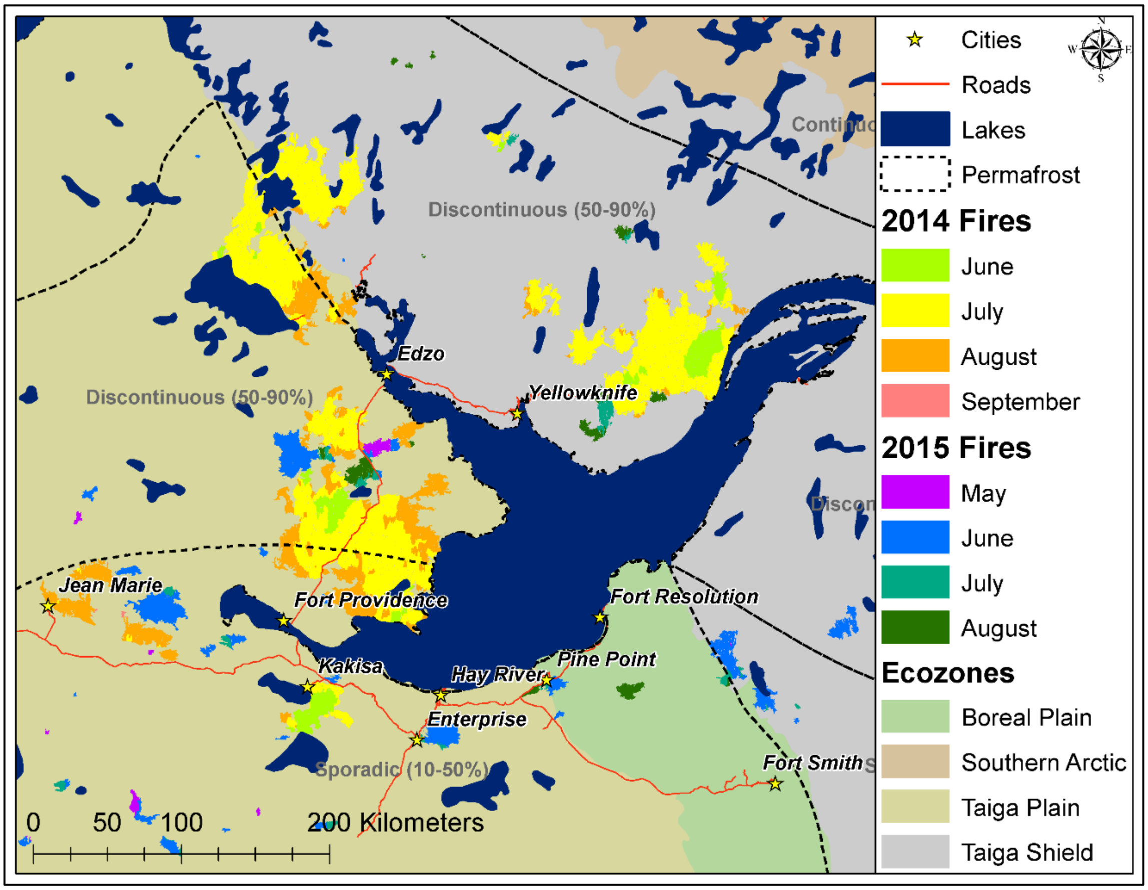

Figure 1: Study area spanning four ecozones, only three of which (the Boreal Plain, Taiga Plain, and Taiga Shield) burned. Permafrost condition (sporadic or discontinuous) is separated by dashed lines, and major cities (including the capital, Yellowknife) are marked with yellow stars. This map includes all 2014 and 2015 fires, and the months they started (credit: Sarah Endres, Appendix C).

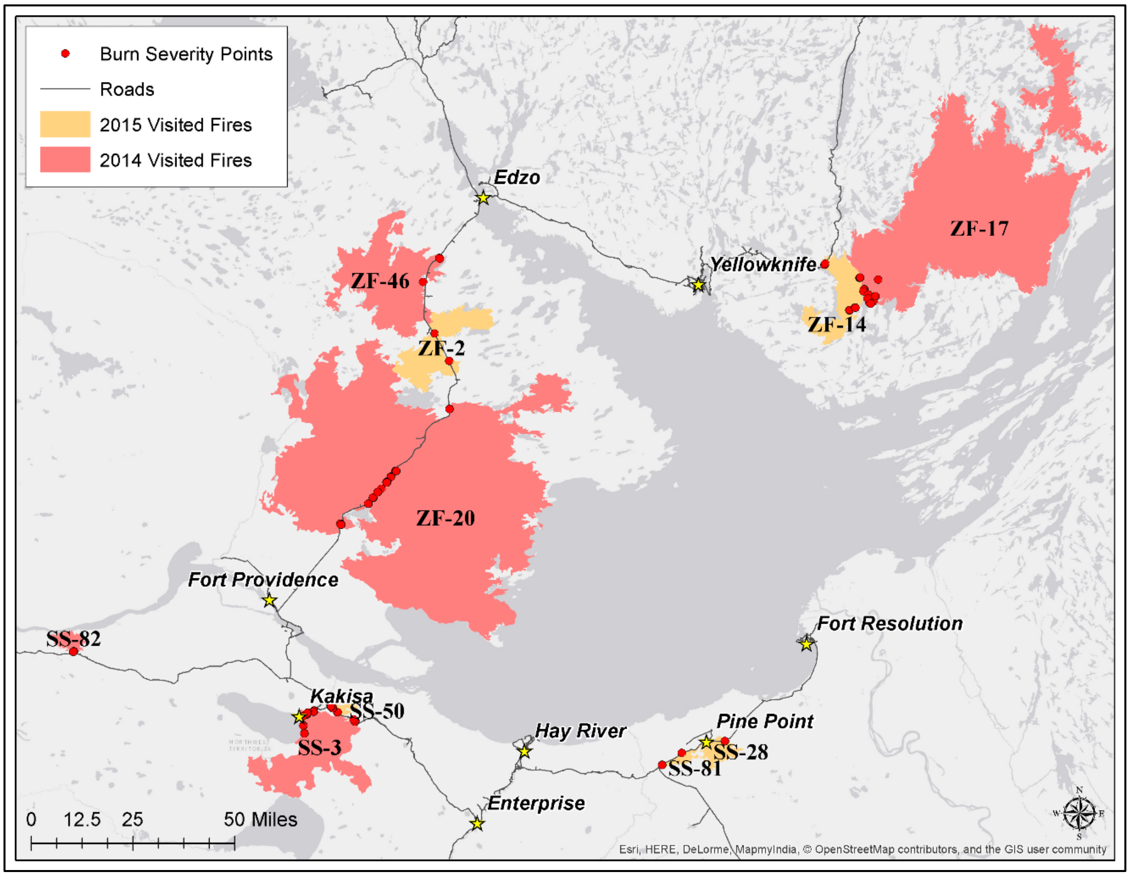

Figure 2: The burn extents of all 2014 (red) and 2015 (gold) fires, with the points sampled for burn severity shown by red dots. Cities are marked with yellow stars, and fire names are included (credit: Sarah Endres, Appendix C).

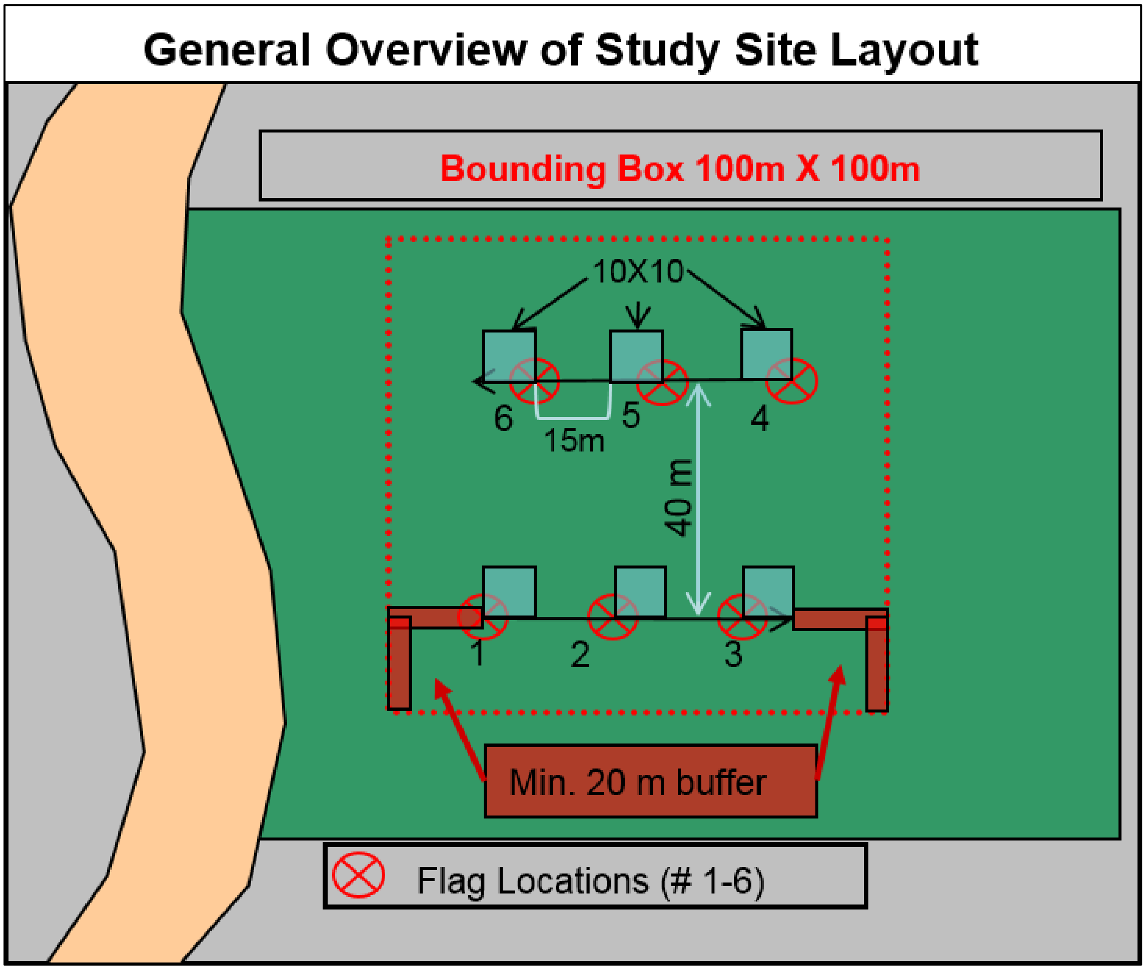

Figure 3: General layout of sample sites, including 4-6 10 m X 10 m plots per field site.

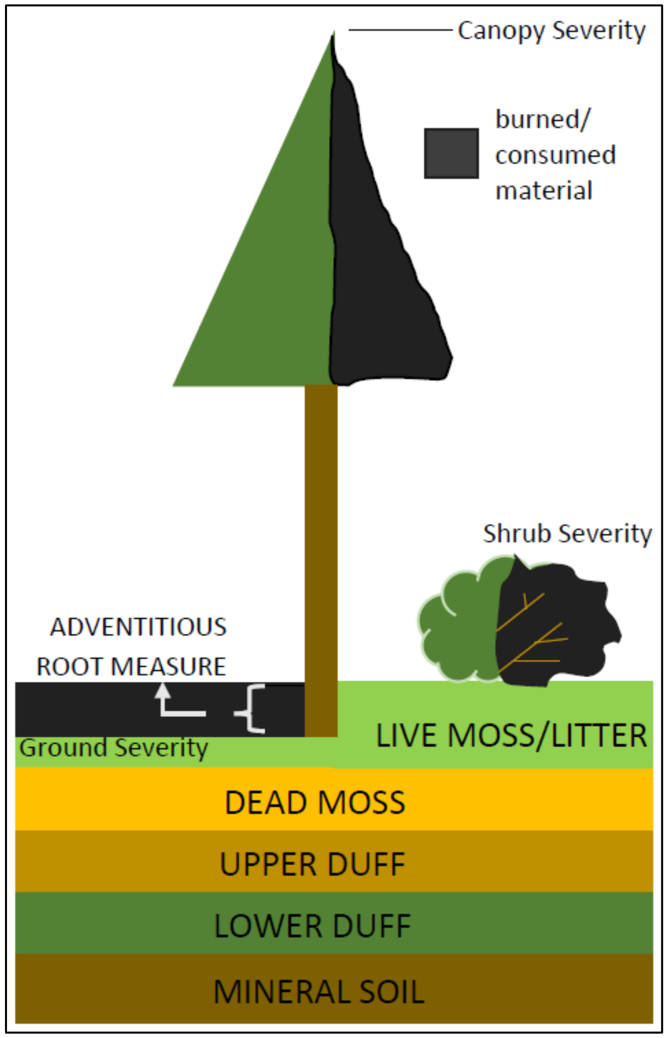

Figure 4: Typical boreal soil horizons and adventitious root measurements used to estimate absolute consumption during wildfires. The three layers (ground, shrub, and canopy) are also displayed to show how fire severity was classified at different levels.

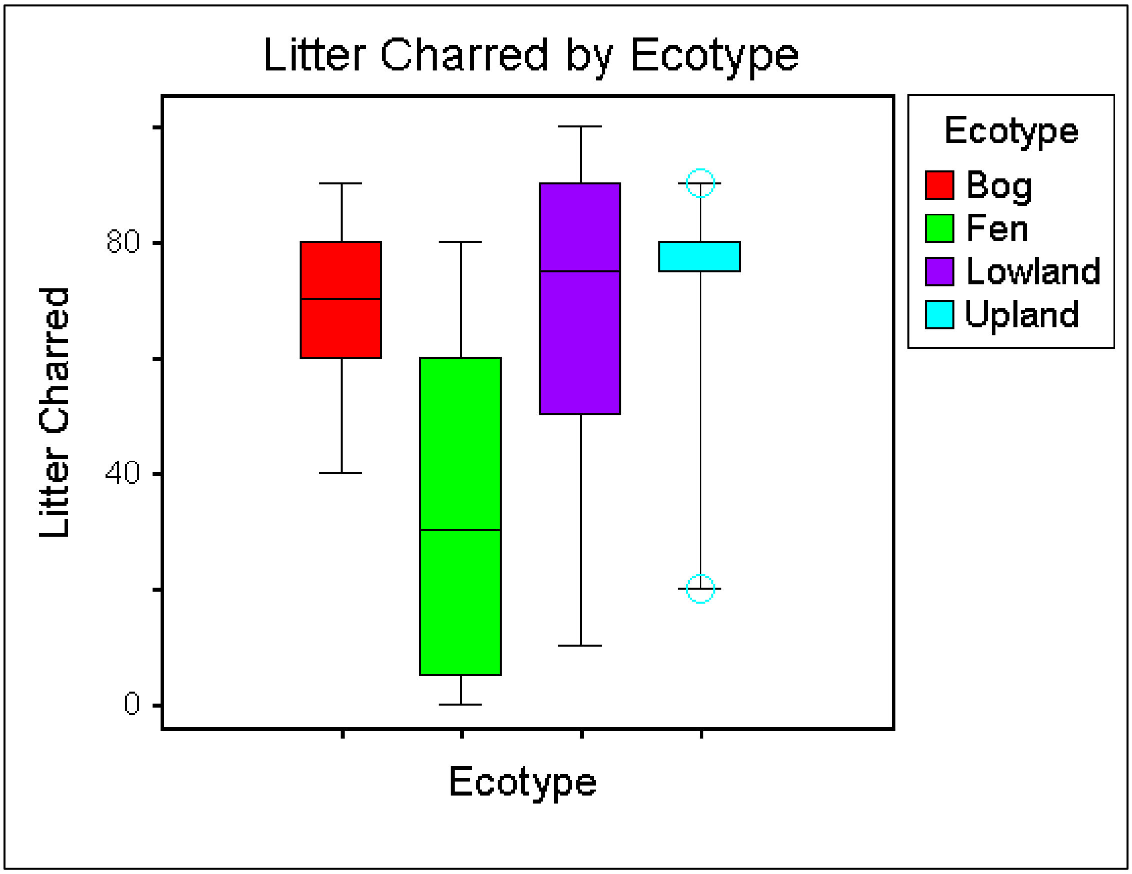

Figure 5: Boxplot displaying percent litter charred by ecotype, coded by color. The horizontal line in each box represents the median; the lower box boundary indicates the 25th percentile, the upper box boundary indicates 75th percentile, and the whiskers show the highest and lowest values.

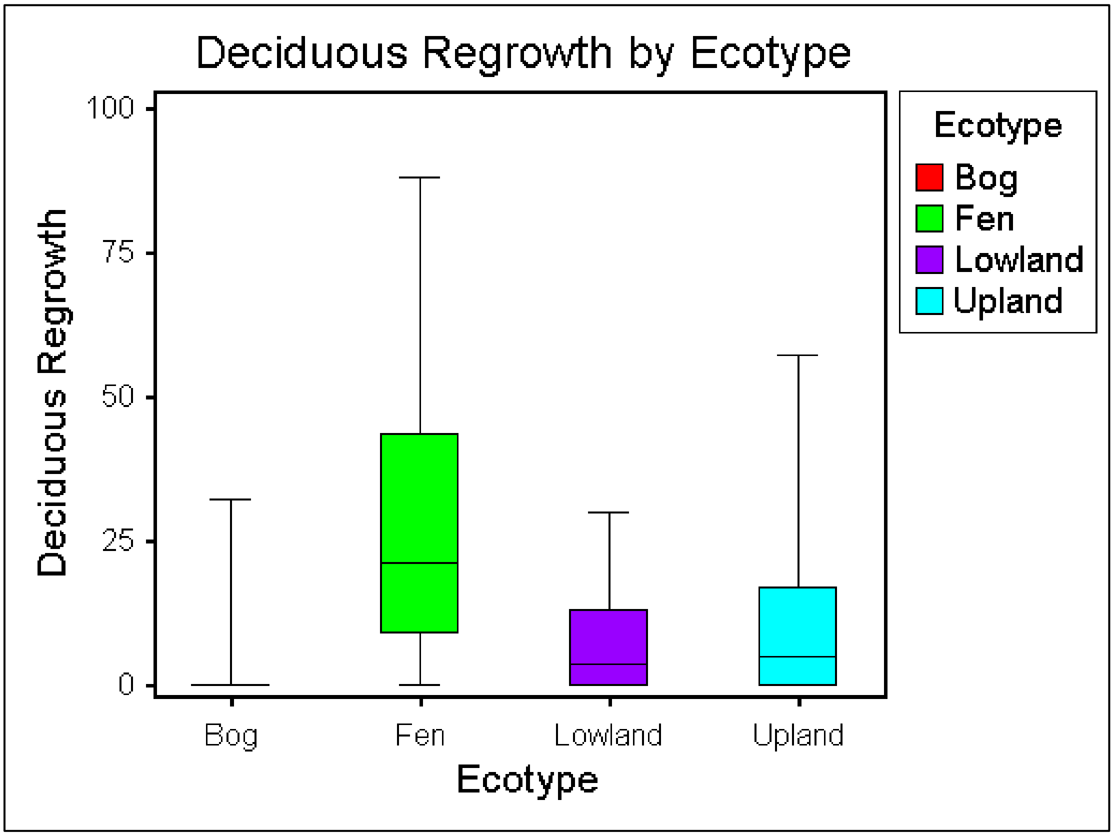

Figure 6: Boxplot showing deciduous regrowth by ecotype, coded by color. The horizontal line in each box represents the median; the lower box boundary indicates the 25th percentile, the upper box boundary indicates 75th percentile, and the whiskers show the highest and lowest values. There were few plots with deciduous regrowth in the bog ecotype.

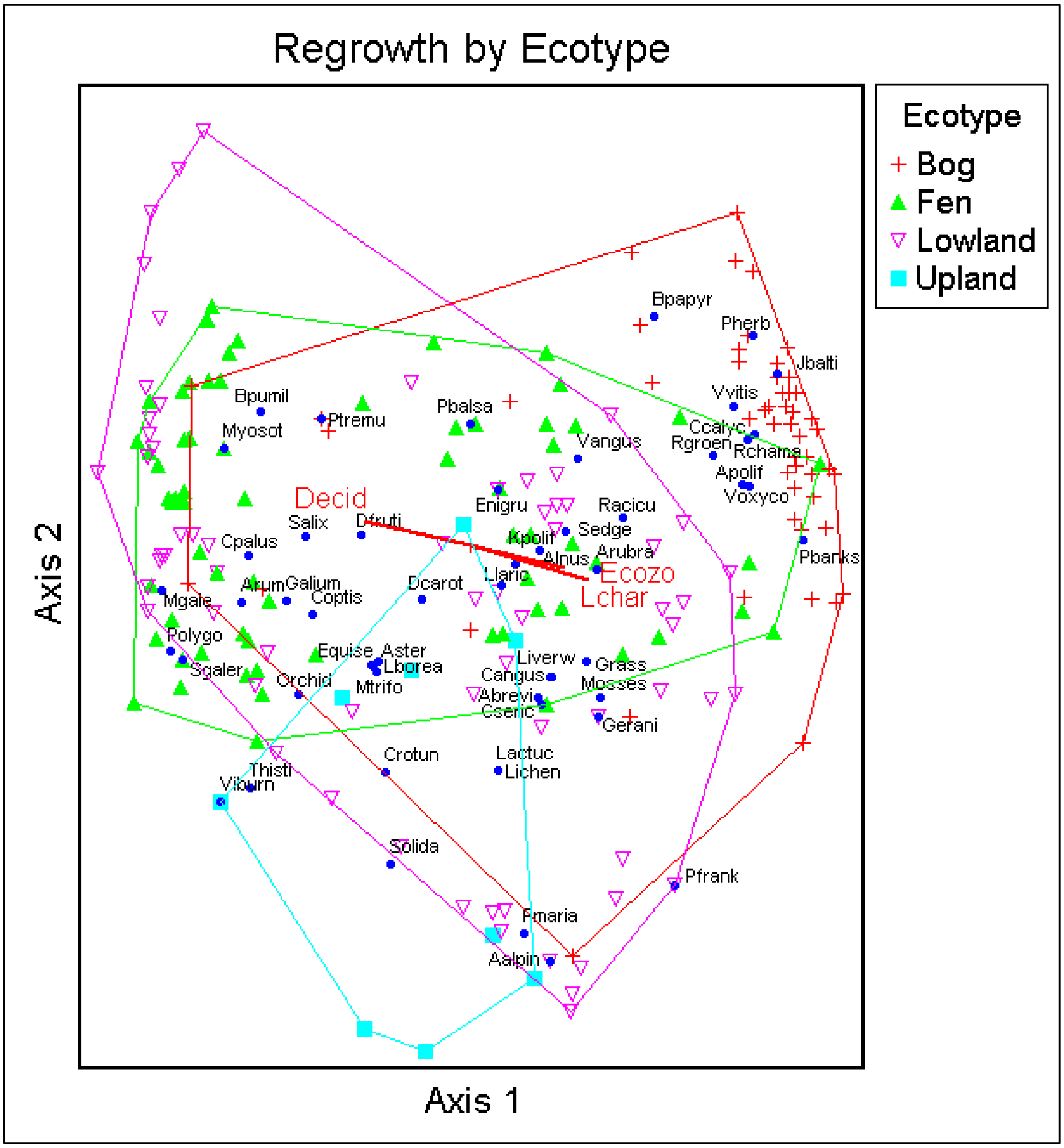

Figure 7: Ordination diagram of species separated by ecotype (bog, fen, lowland, and upland). Environmental factors/burn severity classes with a high relative association (r^2>0.20) to Axis 1 are shown with red lines. Decid is deciduous regrowth, Ecozo is ecozone, and Lchar is litter charred.

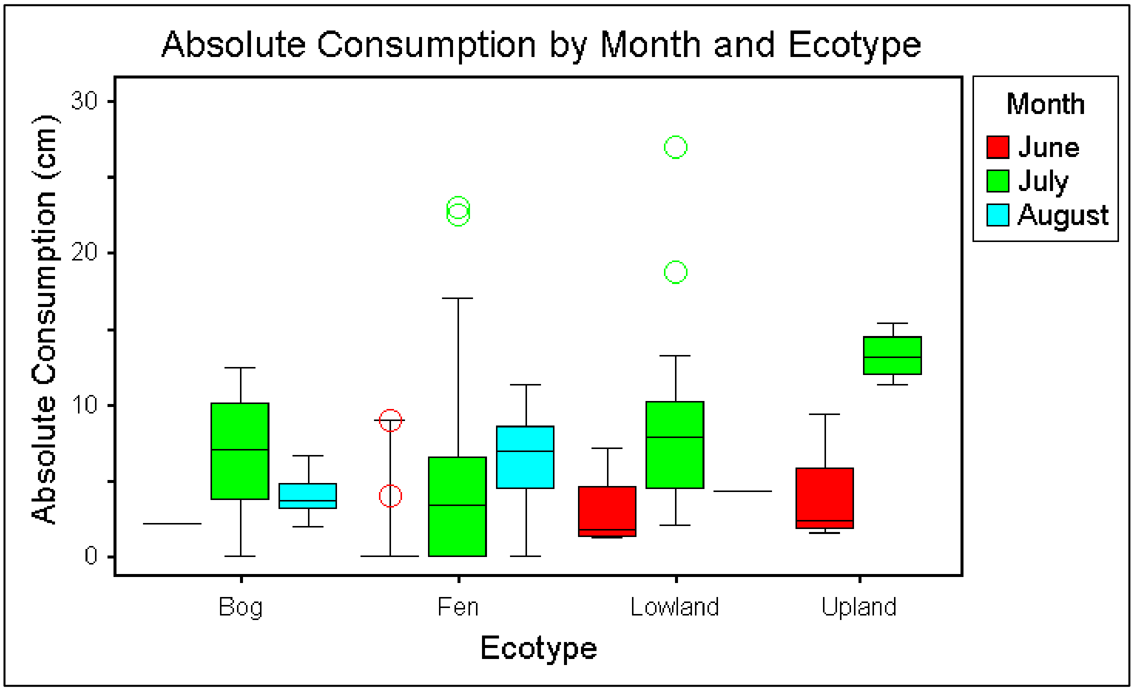

Figure 8: Boxplot showing the absolute consumption in each ecotype by fire start month, coded by color. The horizontal line in each box represents the median; the lower box boundary indicates the 25th percentile, the upper box boundary indicates 75th percentile, and the whiskers show the highest and lowest values.

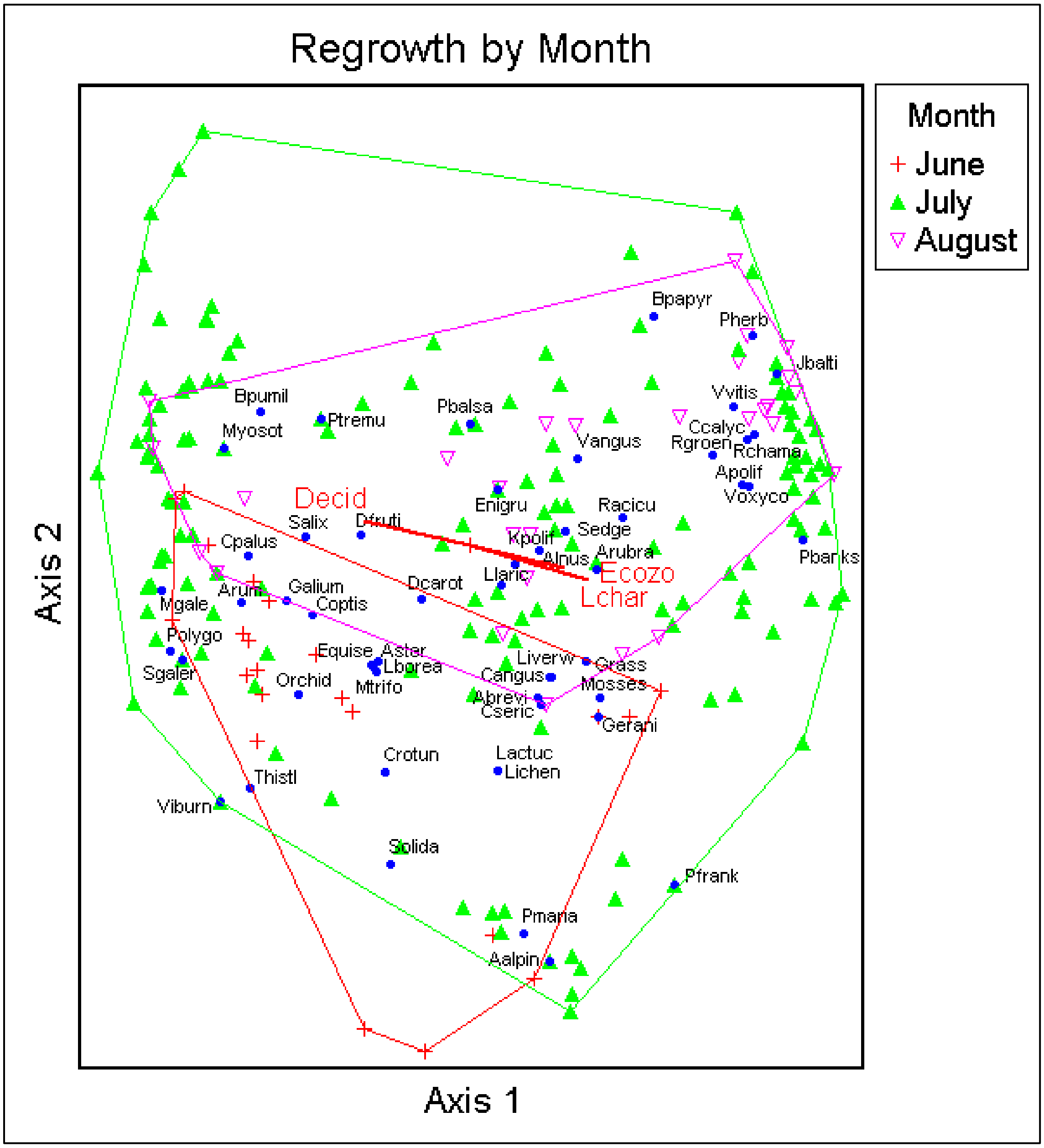

Figure 9: Ordination diagram of species separated by fire ignition month (June, July, August). Environmental factors/burn severity classes with a high relative association (r^2>0.20) to Axis 1 are shown with red lines. Decid is deciduous regrowth, Ecozo is ecozone, and Lchar is litter charred.

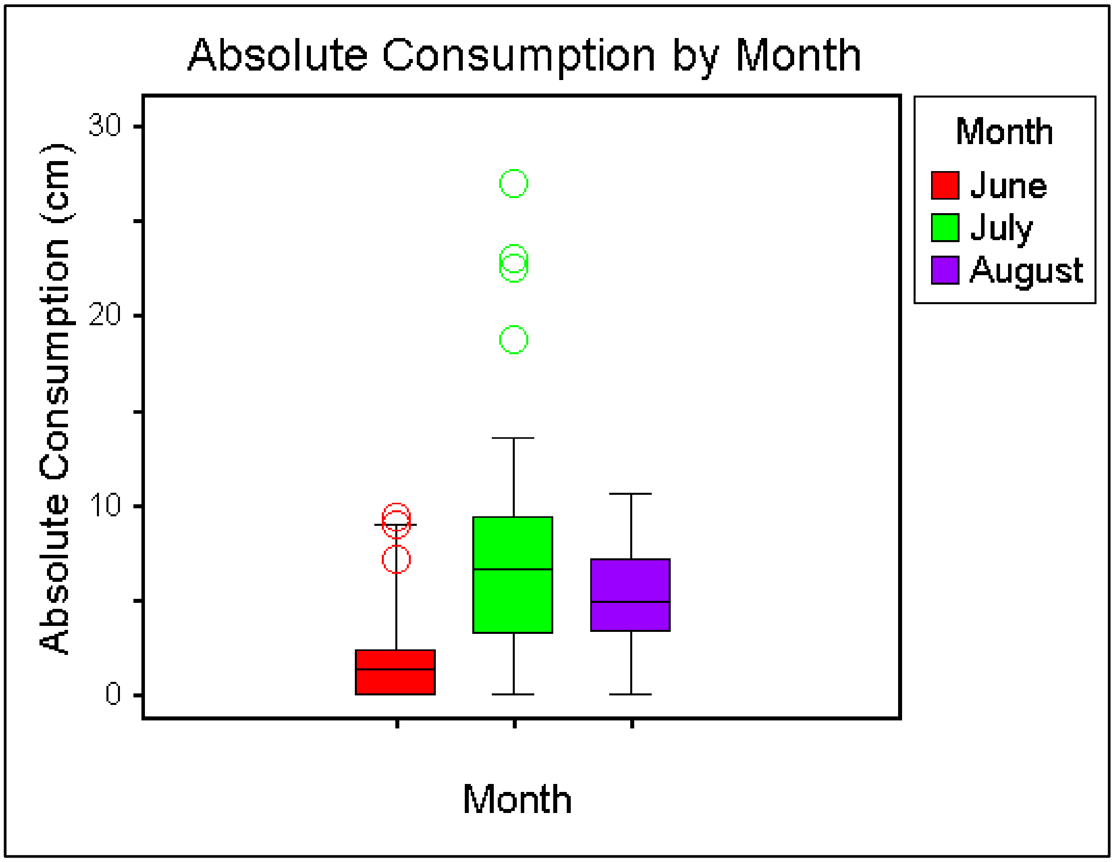

Figure 10: Boxplot showing the absolute consumption (using the adventitious root method) as it varies by fire start date. The horizontal line in each box represents the median; the lower box boundary indicates the 25th percentile, the upper box boundary indicates 75th percentile, and the whiskers show the highest and lowest values.

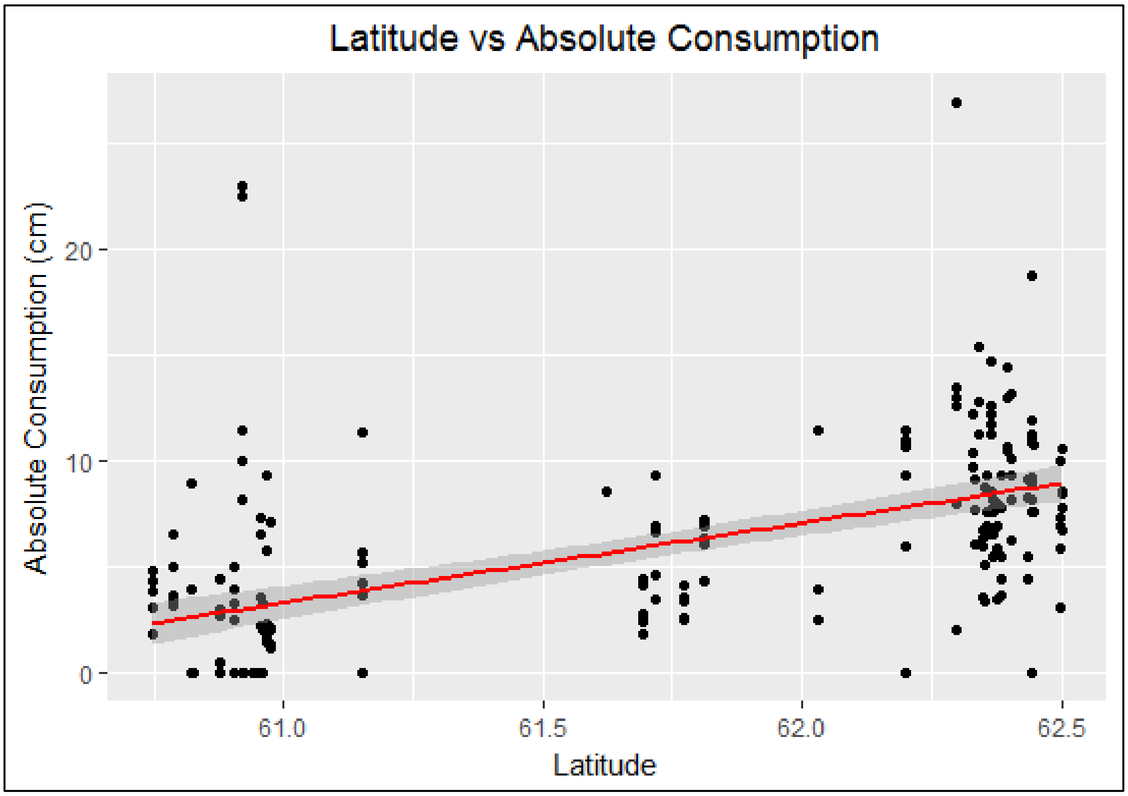

Figure 11: Regression plot of absolute consumption (cm) by degree of latitude. All sites north of 62 degrees in latitude are located in the Taiga Shield ecozone.

Appendix A

Table 7: Least squares estimate tables (coniferous ratio by ecotype, litter charred by ecotype, and absolute consumption by month).

Least Squares Means: Coniferous Ratio by Ecotype					
Ecotype	**Estimate**	**Standard Error (σ^2)**	**Degrees of Freedom**	**t Value (t-test)**	**Pr > |t|**
Bog	2.4697	14.1716	145	0.17	0.8619
Fen	5.8726	14.8311	145	0.4	0.6927
Lowland	1.0453	13.329	145	0.08	0.9376
Upland	192.6	32.0388	145	6.01	<.0001

Least Squares Means: Litter Charred by Ecotype					
Ecotype	**Estimate**	**Standard Error (σ^2)**	**Degrees of Freedom**	**t Value (t-test)**	**Pr > |t|**
Bog	70.6731	3.6464	191	19.38	<.0001
Fen	36.25	3.1887	191	11.37	<.0001
Lowland	67.1212	3.2366	191	20.74	<.0001
Upland	73.8889	8.7649	191	8.43	<.0001

Least Squares Means: Absolute Consumption by Month					
Month	**Estimate**	**Standard Error (σ^2)**	**Degrees of Freedom**	**t Value (t-test)**	**Pr > |t|**
June	3.9729	1.1852	160	3.35	0.001
July	7.7787	0.3672	160	21.18	<.0001
August	5.7365	0.8052	160	7.12	<.0001

Appendix B

Table 8: Bray-Curtis (r^2) Distance Measure Output from PC-ORD.

Coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space:

	R Squared	
Axis	Increment	Cumulative
1	.261	.261
2	.150	.410
3	.110	.520

Increment and cumulative R-squared were adjusted for any lack of orthogonality of axes.

Axis pair	r	Orthogonality,% = 100(1-r^2)
1 vs 2	0.000	100.0
1 vs 3	0.000	100.0
2 vs 3	0.000	100.0

Number of entities = 195
Number of entity pairs used in correlation = 18915
Distance measure for ORIGINAL distance: Sorensen (Bray-Curtis)

****************** Operation completed ********************
26 Mar 2017, 12:50:30

Appendix C

Laura Bourgeau-Chavez
to Sarah, me

Yes it is fine to use the 2 figures from the project in the thesis.

On Mon, Apr 10, 2017 at 8:24 AM, Sarah Endres <slendres@mtu.edu> wrote:

> Hi Laura,
>
> Is it ok if Liz has permission to use those figures and site set up figure?
>
> Sarah
>
> ...
>
> --
> Sarah Endres
> Assistant Research Scientist
> Michigan Tech Research Institute (MTRI)
> 3600 Green Court, Suite 100
> Ann Arbor, MI 48105
>
> #952-200-6995
> slendres@mtu.edu
> www.mtri.org

Figure 12: Permission from Sarah Endres and Laura Bourgeau-Chavez (collaborators) to use Figures 1 and 2.

Appendix D

Table 9: Raw data used for statistical analyses (pages 55-81).

Plot	Latitude	Fire History	Ecotype	Seedbed	Month	Permafrost Condition	Ecozone
SS2821	60.8242	2015	2	1	1	1	1
SS2822	60.82421	2015	2	1	1	1	1
SS2823	60.82415	2015	2	1	1	1	1
SS2824	60.82461	2015	2	1	1	1	1
SS2825	60.8246	2015	2	1	1	1	1
SS2826	60.82457	2015	2	1	1	1	1
SS31041	60.93871	2014	2	1	2	1	2
SS31042	60.93853	2014	1	3	2	1	2
SS31043	60.93836	2014	1	3	2	1	2
SS31045	60.93859	2014	1	3	2	1	2
SS31046	60.93839	2014	1	3	2	1	2
SS31091	60.90604	2014	1	1	2	1	2
SS31092	60.90599	2014	1	3	2	1	2
SS31093	60.90595	2014	1	3	2	1	2
SS31094	60.90557	2014	1	3	2	1	2
SS31095	60.90554	2014	1	3	2	1	2
SS3641	60.92128	2014	2	3	2	1	2
SS3642	60.92112	2014	2	3	2	1	2
SS3643	60.92098	2014	2	3	2	1	2
SS3644	60.92083	2014	2	3	2	1	2
SS3645	60.92069	2014	2	3	2	1	2
SS3646	60.92057	2014	2	3	2	1	2
SS3651	60.92358	2014	2	3	2	1	2
SS3652	60.92348	2014	2	3	2	1	2
SS3653	60.92342	2014	2	3	2	1	2
SS3654	60.92305	2014	2	3	2	1	2
SS3655	60.92295	2014	2	3	2	1	2
SS3656	60.92292	2014	2	3	2	1	2
SS501201	60.96872	2015	4	4	1	1	2
SS501202	60.96883	2015	4	4	1	1	2
SS501203	60.96898	2015	4	4	1	1	2
SS501205	60.96851	2015	4	4	1	1	2
SS501206	60.96864	2015	4	4	1	1	2
SS5031	60.97414	2015	1	2	1	1	2
SS5032	60.97431	2015	3	2	1	1	2

Plot	Latitude	Fire History	Ecotype	Seedbed	Month	Permafrost Condition	Ecozone
SS5033	60.97437	2015	3	2	1	1	2
SS5034	60.97417	2015	3	2	1	1	2
SS5035	60.97401	2015	3	2	1	1	2
SS5071	60.95345	2015	2	1	1	1	2
SS5072	60.95362	2015	2	1	1	1	2
SS5073	60.95381	2015	2	2	1	1	2
SS5074	60.95349	2015	2	1	1	1	2
SS5075	60.95367	2015	2	3	1	1	2
SS5076	60.95386	2015	2	3	1	1	2
SS8121	60.74876	2015	1	3	3	1	2
SS8122	60.74863	2015	1	1	3	1	2
SS8123	60.74844	2015	1	3	3	1	2
SS8124	60.74829	2015	1	3	3	1	2
SS8125	60.74811	2015	1	1	3	1	2
SS8171	60.78909	2015	1	3	3	1	2
SS8172	60.78897	2015	1	1	3	1	2
SS8173	60.78886	2015	1	1	3	1	2
SS8174	60.7887	2015	1	1	3	1	2
SS8175	60.78862	2015	1	3	3	1	2
SS8176	60.78853	2015	1	3	3	1	2
ZF14101	62.44361	2015	3	3	2	2	3
ZF14102	62.44368	2015	3	3	2	2	3
ZF14103	62.44374	2015	3	4	2	2	3
ZF14104	62.44418	2015	3	3	2	2	3
ZF14105	62.44423	2015	3	3	2	2	3
ZF14106	62.44429	2015	3	3	2	2	3
ZF14171	62.33949	2015	4	2	2	2	3
ZF14172	62.33935	2015	4	2	2	2	3
ZF14174	62.33911	2015	4	3	2	2	3
ZF14191	62.33079	2015	1	3	2	2	3
ZF14192	62.33077	2015	1	3	2	2	3
ZF14193	62.33064	2015	1	3	2	2	3
ZF14194	62.33097	2015	1	3	2	2	3
ZF14195	62.33109	2015	1	3	2	2	3
ZF14196	62.3314	2015	1	3	2	2	3
ZF1421	62.49755	2015	2	3	3	2	3
ZF1422	62.49737	2015	2	3	3	2	3
ZF1423	62.49722	2015	2	3	3	2	3
ZF1424	62.497	2015	2	3	3	2	3
ZF1425	62.49682	2015	2	3	3	2	3

Plot	Latitude	Fire History	Ecotype	Seedbed	Month	Permafrost Condition	Ecozone
ZF1431	62.50097	2015	2	3	3	2	3
ZF1432	62.50082	2015	2	3	3	2	3
ZF1433	62.50067	2015	2	3	3	2	3
ZF1434	62.5007	2015	2	3	3	2	3
ZF1435	62.50085	2015	2	3	3	2	3
ZF14401	62.44481	2015	3	3	2	2	3
ZF14402	62.44465	2015	3	3	2	2	3
ZF14403	62.44447	2015	3	3	2	2	3
ZF14411	62.44421	2015	3	3	2	2	3
ZF14412	62.44434	2015	3	3	2	2	3
ZF14413	62.4456	2015	3	3	2	2	3
ZF171001	62.43362	2014	3	3	2	2	3
ZF171002	62.43379	2014	3	3	2	2	3
ZF171003	62.43398	2014	3	3	2	2	3
ZF171004	62.43397	2014	3	3	2	2	3
ZF171005	62.43383	2014	3	3	2	2	3
ZF171011	62.37524	2014	1	3	2	2	3
ZF171013	62.375	2014	2	3	2	2	3
ZF171014	62.37532	2014	2	3	2	2	3
ZF171015	62.37545	2014	2	3	2	2	3
ZF171301	62.36904	2014	3	3	2	2	3
ZF171302	62.36886	2014	3	3	2	2	3
ZF171303	62.36863	2014	3	3	2	2	3
ZF171304	62.36869	2014	3	3	2	2	3
ZF171305	62.36883	2014	2	3	2	2	3
ZF171306	62.36902	2014	3	3	2	2	3
ZF1761	62.3646	2014	1	3	2	2	3
ZF1762	62.36484	2014	1	3	2	2	3
ZF1763	62.36507	2014	1	3	2	2	3
ZF1764	62.36533	2014	1	3	2	2	3
ZF1765	62.36534	2014	1	3	2	2	3
ZF1766	62.36536	2014	1	3	2	2	3
ZF1771	62.35011	2014	2	3	2	2	3
ZF1772	62.35032	2014	2	3	2	2	3
ZF1773	62.35046	2014	2	3	2	2	3
ZF1774	62.35072	2014	2	3	2	2	3
ZF1775	62.35057	2014	2	3	2	2	3
ZF1776	62.35037	2014	2	3	2	2	3
ZF1791	62.35486	2014	1	3	2	2	3
ZF1792	62.35464	2014	1	3	2	2	3

Plot	Latitude	Fire History	Ecotype	Seedbed	Month	Permafrost Condition	Ecozone
ZF1794	62.35428	2014	1	3	2	2	3
ZF20101	61.71507	2014	1	2	2	2	2
ZF20102	61.71521	2014	1	2	2	2	2
ZF20103	61.71535	2014	1	2	2	2	2
ZF20104	61.71549	2014	1	2	2	2	2
ZF20105	61.71565	2014	1	2	2	2	2
ZF201051	61.69424	2014	2	1	2	2	2
ZF201052	61.69436	2014	2	3	2	2	2
ZF201053	61.69452	2014	2	3	2	2	2
ZF201054	61.69397	2014	2	3	2	2	2
ZF201055	61.69407	2014	2	2	2	2	2
ZF201056	61.69422	2014	2	2	2	2	2
ZF2121	62.20004	2015	1	3	2	2	2
ZF2122	62.2001	2015	1	3	2	2	2
ZF2123	62.20017	2015	1	3	2	2	2
ZF2124	62.19968	2015	1	3	2	2	2
ZF2125	62.19974	2015	1	3	2	2	2
ZF2126	62.19982	2015	1	3	2	2	2
ZF221	62.29814	2015	4	2	2	2	2
ZF222	62.29831	2015	3	2	2	2	2
ZF223	62.29837	2015	3	2	2	2	2
ZF224	62.29775	2015	3	2	2	2	2
ZF225	62.29789	2015	3	2	2	2	2
ZF226	62.29803	2015	3	2	2	2	2
SS3101	60.87818	2014	1	3	2	1	2
SS3102	60.87811	2014	3	3	2	1	2
SS3103	60.87797	2014	3	3	2	1	2
SS3104	60.87753	2014	3	3	2	1	2
SS3105	60.87761	2014	3	3	2	1	2
SS3106	60.8777	2014	3	3	2	1	2
SS3401	60.95485	2014	2	3	2	1	2
SS3403	60.9543	2014	2	3	2	1	2
SS3404	60.95439	2014	2	3	2	1	2
SS3405	60.95445	2014	2	3	2	1	2
SS3406	60.95491	2014	2	3	2	1	2
SS3421	60.95918	2014	2	1	2	1	2
SS3422	60.95921	2014	2	1	2	1	2
SS3423	60.95928	2014	2	3	2	1	2
SS3424	60.95874	2014	2	3	2	1	2

Plot	Latitude	Fire History	Ecotype	Seedbed	Month	Permafrost Condition	Ecozone
SS3425	60.95879	2014	2	3	2	1	2
SS3426	60.95884	2014	2	3	2	1	2
SS8211	61.1538	2014	3	3	3	1	2
SS8212	61.15382	2014	2	3	3	1	2
SS8221	61.15207	2014	2	3	3	1	2
SS8223	61.15203	2014	2	3	3	1	2
SS8224	61.15256	2014	2	3	3	1	2
SS8225	61.15261	2014	2	3	3	1	2
SS8226	61.15201	2014	2	3	3	1	2
ZF1711	62.35648	2014	1	3	2	2	3
ZF1712	62.35659	2014	1	3	2	2	3
ZF17151	62.38293	2014	3	1	2	2	3
ZF17152	62.38269	2014	3	2	2	2	3
ZF17153	62.38251	2014	3	3	2	2	3
ZF17155	62.38236	2014	3	3	2	2	3
ZF17156	62.38258	2014	3	3	2	2	3
ZF17221	62.40242	2014	3	3	2	2	3
ZF17222	62.40219	2014	3	3	2	2	3
ZF17223	62.40198	2014	3	3	2	2	3
ZF17224	62.40189	2014	3	3	2	2	3
ZF17225	62.40205	2014	3	3	2	2	3
ZF17401	62.39437	2014	3	3	2	2	3
ZF17402	62.39429	2014	3	3	2	2	3
ZF17403	62.39424	2014	3	2	2	2	3
ZF17404	62.39417	2014	3	2	2	2	3
ZF20271	61.77214	2014	3	3	2	2	2
ZF20272	61.77197	2014	3	3	2	2	2
ZF20273	61.77181	2014	3	3	2	2	2
ZF20274	61.77251	2014	3	3	2	2	2
ZF20275	61.77234	2014	3	3	2	2	2
ZF20404	61.62341	2014	3	3	2	2	2
ZF2041	61.81021	2014	3	3	2	2	2
ZF2042	61.81035	2014	3	3	2	2	2
ZF2043	61.81048	2014	3	3	2	2	2
ZF2044	61.81032	2014	3	3	2	2	2
ZF2045	61.81075	2014	3	3	2	2	2
ZF2046	61.8108	2014	3	3	2	2	2
ZF20472	62.02958	2014	3	3	2	2	2
ZF20473	62.02947	2014	3	3	2	2	2
ZF20476	62.02911	2014	3	3	2	2	2

Plot	Depth to Thaw (cm)	Absolute Consumption (cm)	Percent Consumed	Live/Dead Conifer	Decididous Regrowth	Moss Unburned
SS2821	60	4	0.11	0.00	11	40
SS2822	53	9	0.19	0.00	17	40
SS2823	105	0	0.07	0.00	18	40
SS2824	50	0	0.00	0.00	17	20
SS2825	72	0	0.00	2.08	38	40
SS2826	70	0	0.00	0.00	22	25
SS31041	170	0	0.00	0.00	17	20
SS31042	84	0	0.00	7.50	21	5
SS31043	140	0	0.00	0.00	0	5
SS31045	81	0	0.00	0.00	8	0
SS31046	82	0	0.00	0.00	0	0
SS31091	73	0	0.12	10.26	0	0
SS31092	108	2.5	0.15	0.00	0	0
SS31093	126	4	0.14	0.00	0	0
SS31094	90	3.3	0.17	2.94	0	20
SS31095	107	5	0.15	0.00	0	60
SS3641	188	23	0.90	0.00	15	10
SS3642	177	8.25	0.53	0.00	102	25
SS3643	163	0	0.00	0.00	96	10
SS3644	74	10	0.25	0.00	80	10
SS3645	120	11.5	0.27	0.00	35	5
SS3646	137	22.5	0.39	0.00	96	15
SS3651	165	0	0.00	0.00	65	60
SS3652	230	0	0.00	0.00	41	10
SS3653	200	0	0.00	0.00	49	10
SS3654	127	0	0.00	0.00	21	5
SS3655	140	0	0.00	0.00	22	5
SS3656	161	0	0.00	0.00	56	5
SS501201	2	1.5	0.70	17.97	0	0
SS501202	0	2.375	0.92	141.67	0	0
SS501203	13	1.8	0.28	12.50	5	0
SS501205	0	5.8	0.95	325.00	0	0
SS501206	0	9.4	0.94	1233.33	0	0
SS5031	40	2.1	0.12	0.00	2	0
SS5032	17	2	0.26	20.73	1	0

Plot	Depth to Thaw (cm)	Absolute Consumption (cm)	Percent Consumed	Live/Dead Conifer	Decididous Regrowth	Moss Unburned
SS5033	8	1.4	0.37	2.05	0	0
SS5034	23	7.1	0.31	14.58	15	0
SS5035	11	1.2	0.29	2.78	2	0
SS5071	160	0	0.00	25.00	46	0
SS5072	135	0	0.00	2.78	43	0
SS5073	165	0	0.00	0.00	36	0
SS5074	130	0	0.00	0.00	21	20
SS5075	145	0	0.00	0.00	8	0
SS5076	150	0	0.00	0.00	13	0
SS8121	140	4.8	0.00	0.00	0	0
SS8122	163	3.1	0.17	0.00	0	0
SS8123	193	3.9	0.14	0.00	0	1
SS8124	183	1.9	0.15	0.00	0	0
SS8125	206	4.4	0.11	0.00	0	0
SS8171	196	5	0.16	0.00	0	15
SS8172	190	3.2	0.17	0.00	0	25
SS8173	195	6.6	0.14	0.00	0	20
SS8174	176	3.5	0.20	0.00	0	5
SS8175	194	3.7	0.14	0.00	0	0
SS8176	172	3.2	0.15	0.00	0	5
ZF14101	5.1	18.75	0.00	0.00	0	0
ZF14102	67	11.25	0.53	0.00	0	0
ZF14103	5	11	0.75	0.00	0	0
ZF14104	18	8.25	0.71	0.00	14	0
ZF14105	5.5	9	0.83	0.00	8	0
ZF14106	7.5	0	0.67	0.00	0	0
ZF14171	0	15.4	0.00	0.00	22	0
ZF14172	0	11.3	0.78	0.00	57	0
ZF14174	1	12.8	0.63	2.94	16	0
ZF14191	53	12.2	0.47	0.00	0	0
ZF14192	57	10.4	0.67	0.00	0	2
ZF14193	40	9.7	0.56	0.00	0	18
ZF14194	22	6.1	0.93	0.00	0	1
ZF14195	48	7.7	0.90	0.00	0	0
ZF14196	43	9.2	0.88	0.00	0	0
ZF1421	55	5.9	0.86	0.00	29	0
ZF1422	52	7	0.19	0.00	25	0

Plot	Depth to Thaw (cm)	Absolute Consumption (cm)	Percent Consumed	Live/Dead Conifer	Decididous Regrowth	Moss Unburned
ZF1423	64	3.1	0.20	3.13	35	0
ZF1424	51	10	0.14	2.00	13	0
ZF1425	52	7.3	0.38	26.92	47	0
ZF1431	52	8.6	0.20	0.00	17	0
ZF1432	31	6.8	0.23	0.00	2	0
ZF1433	40	8.5	0.20	0.00	31	0
ZF1434	32	10.6	0.23	0.00	0	0
ZF1435	40	7.8	0.26	0.00	5	0
ZF14401	8	7.6	0.54	2.17	3	0
ZF14402	82	9.3	0.26	0.00	5	0
ZF14403	9	10.9	0.24	0.00	7	0
ZF14411	2	7.6	0.26	6.25	162	0
ZF14412	21	12	0.21	1.06	6	0
ZF14413	24	10.8	0.32	0.00	21	0
ZF171001	25	8.3	0.00	0.00	0	0
ZF171002	61	4.5	0.00	0.00	47	0
ZF171003	20	9.2	0.00	0.00	7	0
ZF171004	37	5.5	0.00	0.00	0	0
ZF171005	18	9.2	0.00	0.00	0	0
ZF171011	52	5.9	0.00	0.00	0	0
ZF171013	48	7	0.00	0.00	0	40
ZF171014	43.2	8	0.00	0.00	0	0
ZF171015	49	3.5	0.00	0.00	4	20
ZF171301	23.5	7.8	0.00	0.00	0	0
ZF171302	17.5	7.8	0.00	0.00	1	0
ZF171303	20	8.2	0.00	0.00	6	0
ZF171304	39	6.6	0.00	0.00	0	0
ZF171305	45	5.5	0.00	0.00	0	0
ZF171306	20	7.6	0.00	0.00	5	0
ZF1761	63	14.75	0.47	46.15	0	7
ZF1762	57	11.25	0.33	5.88	0	10
ZF1763	42	12.625	0.46	0.00	5	10
ZF1764	78	12.25	0.28	7.69	0	5
ZF1765	65	11.75	0.27	0.00	0	5
ZF1766	65	8.625	0.21	0.00	0	10
ZF1771	0	6	0.19	0.00	2	2
ZF1772	0	6.375	0.29	3.13	4	10
ZF1773	0	3.625	0.63	2.94	10	10
ZF1774	0	5.125	0.39	8.70	44	5

Plot	Depth to Thaw (cm)	Absolute Consumption (cm)	Percent Consumed	Live/Dead Conifer	Decididous Regrowth	Moss Unburned
ZF1776	0	6.75	0.35	1.39	12	15
ZF1791	0	6.6	0.59	15.79	0	10
ZF1792	0	9.375	0.47	0.00	0	10
ZF1793	0	8.75	0.35	17.39	0	20
ZF1794	0	5.125	0.51	0.00	0	10
ZF20101	14	3.5	0.17	0.00	1	0
ZF20102	14	6.625	0.24	0.00	41	0
ZF20103	12.5	9.375	0.00	0.00	2	0
ZF20104	32	7	0.64	0.00	49	0
ZF20105	17.5	4.625	0.50	0.00	32	0
ZF201051	77	2.7	0.78	0.00	88	40
ZF201052	26	2.4	0.08	0.00	20	30
ZF201053	78	2.8	0.08	0.00	30	20
ZF201054	0	4.5	0.09	0.00	55	0
ZF201055	73	1.9	0.15	0.00	51	5
ZF201056	30	4.2	0.22	0.00	29	30
ZF2121	68	0	0.15	0.00	0	10
ZF2122	64	10.75	0.00	0.00	2	50
ZF2123	50	6	0.26	0.00	2	20
ZF2124	43	11	0.27	0.00	0	10
ZF2125	78	11.5	0.34	0.00	0	25
ZF2126	57	9.333333	0.00	0.00	0	40
ZF221	13	13.5	0.42	0.00	17	0
ZF222	19	8	0.18	0.00	13	5
ZF223	20	13	0.70	3.64	16	0
ZF224	5	27	0.43	0.00	0	0
ZF225	16	2	0.47	0.00	10	0
ZF226	2	12.66667	0.43	0.00	2	0
SS3101	40	0	0.13	0.00	1	0
SS3102	3	2.75	0.13	0.00	2	0
SS3103	3	3	0.00	0.00	9	0
SS3104	2	0	0.08	0.00	5	0
SS3105	6	0.5	0.15	0.00	2	20
SS3106	3	4.5	0.00	0.00	1	10
SS3401	40	7.3	0.21	0.00	8	2
SS3403	40	6.6	0.20	0.00	34	10
SS3404	40	2.26	0.12	1.92	17	40
SS3405	40	0	0.00	0.00	22	20

Plot	Depth to Thaw (cm)	Absolute Consumption (cm)	Percent Consumed	Live/Dead Conifer	Decididous Regrowth	Moss Unburned
SS3421	40	0	0.00	0.00	15	0
SS3422	40	0	0.00	0.00	64	0
SS3423	40	0	0.00	0.00	56	1
SS3424	40	2.25	0.73	0.00	38	0
SS3425	40	3.25	0.52	16.67	67	0
SS3426	40	2	0.63	0.00	71	10
SS8211	38	4.25	0.14	0.00	6	0
SS8212	40	11.33333	0.16	150.00	2	0
SS8221	40	3.666667	0.00	0.00	1	0
SS8223	40	5.75	0.23	0.00	0	10
SS8224	40	0	0.18	0.00	0	10
SS8225	40	5.25	0.00	0.00	0	0
SS8226	40	0	0.17	0.00	11	0
ZF1711	43	7.6	0.25	0.00	0	10
ZF1712	48	7	0.57	0.00	0	5
ZF17151	23.5	9.4	0.58	0.00	5	20
ZF17152	4	3.7	0.87	0.00	0	5
ZF17153	13	7.8	0.29	0.00	0	5
ZF17155	17.5	4.5	0.15	0.00	0	3
ZF17156	7.6	5.5	0.15	0.00	0	0
ZF17221	14	10.125	0.24	0.00	3	0
ZF17222	22	13.25	0.19	0.00	2	0
ZF17223	8	6.25	0.16	0.00	28	0
ZF17224	33	8.25	0.20	0.00	10	0
ZF17225	31	9.375	0.25	0.00	3	0
ZF17401	7	14.5	0.28	0.00	0	20
ZF17402	10	10.75	0.35	0.00	0	5
ZF17403	0	10.5	0.46	0.00	0	5
ZF17404	3	13	0.57	0.00	18	10
ZF20271	35	2.6	0.31	0.00	56	2
ZF20272	35	2.5	0.23	0.00	27	5
ZF20273	35	4.2	0.27	0.00	22	0
ZF20274	35	3.6	0.58	0.00	1	0
ZF20275	30	3.4	0.06	0.00	4	0
ZF20404	1	8.6	0.21	0.00	3	0
ZF2041	40	6.2	0.29	0.00	13	0
ZF2042	25	7	0.72	0.00	4	0
ZF2043	30	4.4	0.39	0.00	27	0

Plot	Depth to Thaw (cm)	Absolute Consumption (cm)	Percent Consumed	Live/Dead Conifer	Decididous Regrowth	Moss Unburned
ZF2044	40	6.4	0.42	0.00	17	0
ZF2045	40	7.2	0.38	0.00	30	0
ZF2046	40	6.1	0.23	0.00	19	0
ZF20472	35	11.5	0.16	0.00	3	0
ZF20473	35	4	0.24	0.00	8	0
ZF20476	35	2.5	0.23	1.09	1	0

Plot	Moss Singed	Moss Light	Moss Moderate	Moss Severe	Litter Unburned	Litter Singed	Litter Charred
SS2821	30	30	0	0	20	70	10
SS2822	10	50	0	0	10	40	50
SS2823	10	50	0	0	10	70	20
SS2824	10	50	20	0	10	30	60
SS2825	20	20	20	0	20	50	30
SS2826	15	40	20	0	10	30	60
SS31041	20	30	20	10	20	30	50
SS31042	10	65	20	0	10	30	60
SS31043	25	30	30	10	5	45	50
SS31045	30	10	50	10	0	30	70
SS31046	5	20	55	20	0	20	80
SS31091	30	5	35	30	0	30	70
SS31092	20	10	30	40	0	20	80
SS31093	15	5	30	50	0	20	80
SS31094	20	45	10	5	5	30	65
SS31095	20	10	5	5	0	60	40
SS3641	80	0	10	0	0	0	0
SS3642	75	0	0	0	10	0	0
SS3643	90	0	0	0	15	0	0
SS3644	50	20	20	0	10	70	20
SS3645	20	65	10	0	5	70	25
SS3646	75	15	0	0	0	70	30
SS3651	40	0	0	0	80	0	0
SS3652	90	0	0	0	20	0	0
SS3653	90	0	0	0	20	0	0
SS3654	75	20	0	0	20	80	0
SS3655	65	30	0	0	20	80	0
SS3656	75	20	0	0	5	95	0
SS501201	0	10	20	70	0	20	80
SS501202	0	0	0	100	0	0	80
SS501203	0	20	50	30	0	20	80
SS501205	0	0	50	50	0	0	70
SS501206	0	0	0	100	0	0	20
SS5031	0	5	65	30	0	10	90
SS5032	0	20	70	10	0	10	90
SS5033	0	0	70	30	0	10	85
SS5034	0	15	25	60	0	10	60
SS5035	20	10	60	10	0	20	70
SS5071	40	50	10	0	0	80	20

Plot	Moss Singed	Moss Light	Moss Moderate	Moss Severe	Litter Unburned	Litter Singed	Litter Charred
SS5072	60	40	0	0	0	60	40
SS5073	20	70	10	0	0	70	30
SS5074	60	20	0	0	20	50	30
SS5075	30	60	10	0	0	40	60
SS5076	20	60	20	0	0	60	40
SS8121	10	10	60	20	0	20	80
SS8122	20	15	60	5	0	30	70
SS8123	34	5	55	5	5	30	65
SS8124	30	10	50	10	0	30	70
SS8125	30	20	40	10	0	30	70
SS8171	15	10	40	20	15	15	70
SS8172	15	30	10	20	25	20	55
SS8173	20	10	10	40	20	20	60
SS8174	15	20	50	10	5	25	70
SS8175	15	15	35	35	0	15	85
SS8176	20	5	55	15	10	10	80
ZF14101	10	40	50	0	0	10	90
ZF14102	0	20	60	20	0	0	100
ZF14103	0	33	33	34	0	0	100
ZF14104	0	20	50	30	0	0	70
ZF14105	0	20	60	20	0	0	70
ZF14106	0	5	50	45	0	0	40
ZF14171	0	0	60	40	0	5	75
ZF14172	0	0	50	50	0	5	90
ZF14174	0	0	50	50	0	0	90
ZF14191	10	75	15	0	0	10	90
ZF14192	20	70	8	0	2	20	78
ZF14193	7	35	40	0	0	0	100
ZF14194	9	65	20	5	1	10	89
ZF14195	10	50	30	10	0	10	90
ZF14196	10	40	40	10	0	10	90
ZF1421	0	70	25	5	0	30	70
ZF1422	0	50	30	10	0	40	60
ZF1423	0	30	50	20	0	40	60
ZF1424	0	30	60	10	0	20	80
ZF1425	5	25	40	40	0	30	70
ZF1431	0	10	60	30	0	10	60
ZF1432	0	50	30	20	0	15	70
ZF1433	10	40	30	20	0	30	70

Plot	Moss Singed	Moss Light	Moss Moderate	Moss Severe	Litter Unburned	Litter Singed	Litter Charred
ZF1434	10	30	40	20	0	10	60
ZF1435	0	30	50	20	0	0	80
ZF14401	0	10	60	30	0	0	100
ZF14402	10	20	50	20	0	10	90
ZF14403	0	10	40	50	0	0	50
ZF14411	0	30	60	10	0	30	50
ZF14412	0	15	40	45	0	0	100
ZF14413	0	0	40	60	0	0	95
ZF171001	10	50	30	10	0	10	90
ZF171002	5	70	20	5	0	10	90
ZF171003	5	45	50	0	0	0	100
ZF171004	10	30	50	10	0	5	95
ZF171005	30	50	20	0	0	30	70
ZF171011	50	10	30	10	0	50	50
ZF171013	20	35	5	0	40	40	20
ZF171014	30	50	20	0	0	30	70
ZF171015	30	25	25	0	20	20	60
ZF171301	0	25	60	15	0	0	50
ZF171302	15	25	45	15	0	0	90
ZF171303	25	10	55	10	0	0	90
ZF171304	0	50	40	10	0	10	90
ZF171305	10	60	20	10	0	20	80
ZF171306	5	70	20	5	0	20	80
ZF1761	10	50	33	0	7	10	83
ZF1762	20	50	20	0	10	20	70
ZF1763	20	60	10	0	10	20	70
ZF1764	20	55	20	0	5	20	75
ZF1765	35	50	10	0	5	35	60
ZF1766	25	55	10	0	10	25	65
ZF1771	18	30	50	0	0	10	85
ZF1772	10	20	50	10	0	5	90
ZF1773	10	20	55	5	5	10	75
ZF1774	25	50	20	0	5	15	80
ZF1775	35	50	5	0	10	50	40
ZF1776	15	60	5	5	10	30	60
ZF1791	30	5	45	10	0	20	80
ZF1792	30	0	50	10	0	30	70
ZF1793	40	30	10	0	20	20	60
ZF1794	20	30	30	10	0	10	90
ZF20101	20	0	60	20	0	20	55

Plot	Moss Singed	Moss Light	Moss Moderate	Moss Severe	Litter Unburned	Litter Singed	Litter Charred
ZF20102	25	25	25	25	0	0	100
ZF20103	40	25	25	10	0	5	90
ZF20104	20	55	20	5	0	30	70
ZF20105	25	15	50	10	0	15	70
ZF201051	60	0	0	0	50	50	0
ZF201052	30	40	0	0	40	40	20
ZF201053	30	50	0	0	20	60	20
ZF201054	10	80	10	0	10	20	70
ZF201055	20	75	0	0	10	20	70
ZF201056	20	30	20	0	20	50	30
ZF2121	10	10	60	10	10	30	60
ZF2122	10	10	25	5	50	20	30
ZF2123	25	10	40	5	20	25	55
ZF2124	10	10	55	15	10	15	75
ZF2125	10	15	45	5	25	25	50
ZF2126	10	15	20	15	40	20	40
ZF221	0	30	60	10	0	20	80
ZF222	20	35	35	5	0	20	80
ZF223	0	50	35	15	0	70	30
ZF224	5	25	40	30	0	5	95
ZF225	0	5	10	85	0	10	90
ZF226	0	10	30	60	0	0	100
SS3101	0	0	0	100	0	0	50
SS3102	0	0	0	100	0	0	40
SS3103	0	0	0	100	0	0	40
SS3104	0	0	0	100	0	0	70
SS3105	30	30	20	0	25	25	25
SS3106	10	10	20	50	5	10	55
SS3401	18	60	20	0	0	80	10
SS3403	40	40	10	0	10	75	10
SS3404	5	50	5	0	0	0	95
SS3405	30	40	10	0	5	75	20
SS3406	15	45	35	0	0	20	60
SS3421	0	0	0	0	0	0	0
SS3422	20	80	0	0	0	0	0
SS3423	5	94	0	0	0	0	0
SS3424	2	58	40	0	0	0	0
SS3425	20	70	10	0	0	0	0
SS3426	0	60	30	0	0	80	20
SS8211	40	45	10	5	0	30	60

Plot	Moss Singed	Moss Light	Moss Moderate	Moss Severe	Litter Unburned	Litter Singed	Litter Charred
SS8221	15	40	35	10	0	90	10
SS8223	30	20	40	0	10	80	10
SS8224	20	0	70	0	10	0	80
SS8225	50	0	50	0	25	25	0
SS8226	10	0	90	0	0	25	25
ZF1711	15	50	25	0	10	15	75
ZF1712	10	45	40	0	5	10	85
ZF17151	5	10	40	25	20	30	50
ZF17152	5	10	80	0	5	5	89
ZF17153	4	5	86	0	5	4	91
ZF17155	2	0	90	5	3	2	95
ZF17156	5	5	60	30	0	5	75
ZF17221	5	10	40	45	0	5	95
ZF17222	10	10	40	40	0	5	75
ZF17223	30	10	30	30	0	0	90
ZF17224	10	20	30	40	0	10	70
ZF17225	10	10	60	20	0	10	80
ZF17401	40	20	20	0	20	20	60
ZF17402	15	40	30	10	0	10	90
ZF17403	15	20	40	20	0	10	90
ZF17404	20	30	25	15	10	20	70
ZF20271	10	88	0	0	0	80	10
ZF20272	10	80	5	0	0	90	10
ZF20273	15	70	15	0	0	0	85
ZF20274	30	50	20	0	30	40	30
ZF20275	30	60	10	0	10	50	40
ZF20404	0	0	0	100	0	0	0
ZF2041	50	45	5	0	10	80	10
ZF2042	60	30	10	0	5	75	20
ZF2043	70	20	10	0	10	80	10
ZF2044	10	60	25	5	0	10	90
ZF2045	20	60	20	0	0	50	50
ZF2046	30	50	20	0	0	60	40
ZF20472	20	45	30	5	0	20	75
ZF20473	50	30	20	0	0	40	50
ZF20476	10	40	0	50	5	20	0

Plot	Litter Ashed	Shrub Unburned	Shrub Scortched	Shrub Limbs Left	Shrub Consumed	Live Trees
SS2821	0	0	50	50	0	0
SS2822	0	0	10	90	0	0
SS2823	0	0	10	85	5	0
SS2824	0	0	20	60	20	0
SS2825	0	0	0	80	20	0
SS2826	0	0	10	70	20	0
SS31041	0	20	30	30	20	0
SS31042	0	5	0	10	85	0
SS31043	0	5	0	35	60	0
SS31045	0	0	0	10	90	0
SS31046	0	0	0	10	90	0
SS31091	0	0	10	30	60	0
SS31092	0	0	0	20	80	0
SS31093	0	0	0	10	90	0
SS31094	0	0	20	30	50	0
SS31095	0	10	60	20	10	0
SS3641	100	0	0	80	20	0
SS3642	90	0	80	20	0	0
SS3643	85	0	10	50	40	0
SS3644	0	0	5	90	5	0
SS3645	0	0	10	60	30	0
SS3646	0	0	40	30	30	0
SS3651	40	0	90	10	0	0
SS3652	80	0	75	10	15	0
SS3653	80	0	85	10	5	0
SS3654	0	0	10	30	60	0
SS3655	0	0	10	60	30	0
SS3656	0	0	10	60	30	0
SS501201	0	0	0	0	100	0
SS501202	20	0	0	0	100	0
SS501203	0	0	0	30	70	0
SS501205	30	0	0	80	20	0
SS501206	80	0	0	0	100	0
SS5031	0	0	0	20	80	0
SS5032	0	0	0	10	90	0

Plot	Litter Ashed	Shrub Unburned	Shrub Scortched	Shrub Limbs Left	Shrub Consumed	Live Trees
SS5033	5	0	0	0	100	0
SS5034	30	0	0	0	100	0
SS5035	10	0	0	50	50	0
SS5071	0	0	80	10	10	0
SS5072	0	0	80	20	0	0
SS5073	0	0	80	20	0	0
SS5074	0	5	30	55	10	100
SS5075	0	0	90	10	0	0
SS5076	0	0	50	50	0	0
SS8121	0	0	0	30	70	0
SS8122	0	0	0	20	80	0
SS8123	0	0	15	20	65	0
SS8124	0	0	0	40	60	0
SS8125	0	0	0	20	80	0
SS8171	0	20	5	10	65	0
SS8172	0	10	25	15	50	0
SS8173	0	20	20	10	50	0
SS8174	0	0	0	15	85	0
SS8175	0	0	0	15	85	0
SS8176	0	20	10	20	50	0
ZF14101	0	0	0	5	95	0
ZF14102	0	0	0	0	100	0
ZF14103	0	0	0	10	90	0
ZF14104	30	0	0	10	90	0
ZF14105	30	0	0	10	90	0
ZF14106	60	0	0	0	100	0
ZF14171	20	0	0	5	95	0
ZF14172	5	0	0	50	50	0
ZF14174	10	0	0	50	50	0
ZF14191	0	0	0	10	90	0
ZF14192	0	0	5	35	60	0
ZF14193	0	5	0	15	80	0
ZF14194	0	0	2	28	70	0
ZF14195	0	0	5	15	80	0
ZF14196	0	0	5	20	75	0
ZF1421	0	0	0	50	50	0
ZF1422	0	0	0	20	80	0
ZF1423	0	0	0	20	80	0
ZF1424	0	0	0	30	70	0
ZF1425	0	0	0	10	90	0

Plot	Litter Ashed	Shrub Unburned	Shrub Scortched	Shrub Limbs Left	Shrub Consumed	Live Trees
ZF1431	30	0	0	5	95	0
ZF1432	15	0	0	5	95	0
ZF1433	0	0	0	50	50	0
ZF1434	30	0	0	10	90	0
ZF1435	20	0	0	20	80	0
ZF14401	0	0	0	10	90	0
ZF14402	0	0	0	10	90	0
ZF14403	50	0	0	20	80	0
ZF14411	20	0	40	30	30	30
ZF14412	0	0	10	70	20	0
ZF14413	5	0	0	25	75	0
ZF171001	0	0	0	30	70	0
ZF171002	0	0	0	30	70	0
ZF171003	0	0	2	20	78	0
ZF171004	0	0	10	10	80	0
ZF171005	0	0	0	20	80	0
ZF171011	0	0	0	20	80	5
ZF171013	0	40	50	10	0	50
ZF171014	0	0	30	50	20	0
ZF171015	0	20	20	20	40	5
ZF171301	50	0	0	10	90	0
ZF171302	10	0	0	30	70	0
ZF171303	10	0	0	10	90	0
ZF171304	0	0	0	60	40	0
ZF171305	0	0	0	40	60	0
ZF171306	0	0	0	20	80	0
ZF1761	0	0	50	0	50	0
ZF1762	0	0	40	0	60	0
ZF1763	0	0	10	30	60	0
ZF1764	0	0	10	25	65	0
ZF1765	0	0	10	10	80	0
ZF1766	0	0	10	20	70	0
ZF1771	5	0	0	10	90	0
ZF1772	5	0	20	30	50	0
ZF1773	10	0	0	20	80	0
ZF1774	0	0	5	25	70	5
ZF1775	0	0	10	30	60	0
ZF1776	0	0	10	30	60	0
ZF1791	0	0	0	30	70	0
ZF1792	0	0	0	10	90	0

Plot	Litter Ashed	Shrub Unburned	Shrub Scortched	Shrub Limbs Left	Shrub Consumed	Live Trees
ZF1793	0	10	40	20	30	10
ZF1794	0	0	0	10	90	0
ZF20101	25	0	0	5	95	0
ZF20102	0	0	0	0	100	0
ZF20103	5	0	0	0	100	0
ZF20104	0	0	0	10	90	0
ZF20105	15	0	0	0	100	0
ZF201051	0	0	0	60	40	0
ZF201052	0	0	0	80	20	0
ZF201053	0	0	0	60	40	0
ZF201054	0	0	0	40	60	0
ZF201055	0	0	5	85	10	0
ZF201056	0	0	0	80	20	0
ZF2121	0	10	10	30	50	0
ZF2122	0	30	30	30	10	0
ZF2123	0	25	5	10	60	0
ZF2124	0	15	0	20	65	0
ZF2125	0	20	10	30	40	0
ZF2126	0	20	25	10	45	0
ZF221	0	0	0	20	80	0
ZF222	0	0	0	70	30	0
ZF223	0	0	5	60	35	0
ZF224	0	0	0	10	90	0
ZF225	0	0	0	20	80	0
ZF226	0	0	0	30	70	0
SS3101	50	0	0	0	100	0
SS3102	60	0	0	0	100	0
SS3103	60	0	0	5	95	0
SS3104	30	0	0	0	100	0
SS3105	25	10	10	0	80	10
SS3106	30	5	0	0	95	2
SS3401	10	0	85	15	0	10
SS3403	5	0	60	40	0	5
SS3404	5	0	45	40	15	10
SS3405	0	0	50	40	10	5
SS3406	20	0	40	10	50	0
SS3421	0	0	100	0	0	0
SS3422	0	0	100	0	0	0
SS3423	0	0	95	5	0	0
SS3424	0	10	60	20	10	0

Plot	Litter Ashed	Shrub Unburned	Shrub Scortched	Shrub Limbs Left	Shrub Consumed	Live Trees
SS3425	0	0	100	0	0	5
SS3426	0	10	70	0	20	0
SS8211	10	0	25	40	35	0
SS8212	0	0	50	50	0	25
SS8221	0	20	25	25	30	0
SS8223	0	10	50	20	20	0
SS8224	10	0	25	25	50	10
SS8225	50	0	15	75	10	0
SS8226	50	0	80	10	10	25
ZF1711	0	0	0	20	80	0
ZF1712	0	0	0	20	80	0
ZF17151	0	30	10	10	50	0
ZF17152	1	0	30	10	60	0
ZF17153	0	0	10	0	90	0
ZF17155	0	0	50	0	50	0
ZF17156	20	0	60	0	40	0
ZF17221	0	0	0	5	95	0
ZF17222	20	0	0	5	95	0
ZF17223	10	0	0	10	90	0
ZF17224	20	0	0	0	100	0
ZF17225	10	0	0	10	90	0
ZF17401	0	0	20	40	40	0
ZF17402	0	0	10	20	70	0
ZF17403	0	0	0	30	70	0
ZF17404	0	10	10	10	70	0
ZF20271	10	0	0	90	10	0
ZF20272	0	0	10	85	5	0
ZF20273	15	0	0	90	10	0
ZF20274	0	0	5	65	30	0
ZF20275	0	0	10	70	20	0
ZF20404	100	0	0	0	100	0
ZF2041	0	0	25	50	25	0
ZF2042	0	0	10	60	30	0
ZF2043	0	0	0	60	40	0
ZF2044	0	0	0	20	80	0
ZF2045	0	0	0	20	80	0
ZF2046	0	0	20	40	40	0
ZF20472	5	0	10	60	30	0
ZF20473	10	0	30	60	10	0
ZF20476	75	0	90	0	10	20

Plot	Foliage Intact	Foliage Burned	Second Branches Remain	Minor Primary Branches Remain	Major Primary Branches Remain	Charred Poles
SS2821	5	50	45	0	0	0
SS2822	0	10	90	0	0	0
SS2823	0	0	0	0	0	0
SS2824	10	20	70	0	0	0
SS2825	0	0	100	0	0	0
SS2826	0	10	90	0	0	0
SS31041	0	70	20	10	0	0
SS31042	0	0	90	10	0	0
SS31043	0	5	40	45	10	0
SS31045	0	0	10	50	30	10
SS31046	0	0	70	20	0	10
SS31091	0	0	80	0	0	20
SS31092	0	0	20	25	25	30
SS31093	0	0	50	50	0	0
SS31094	5	5	20	30	30	10
SS31095	0	60	20	10	10	0
SS3641	70	20	10	0	0	0
SS3642	80	20	0	0	0	0
SS3643	80	15	5	0	0	0
SS3644	0	0	100	0	0	0
SS3645	30	60	10	0	0	0
SS3646	0	60	40	0	0	0
SS3651	0	0	0	0	0	0
SS3652	0	0	0	0	0	0
SS3653	0	100	0	0	0	0
SS3654	0	0	0	0	0	0
SS3655	0	0	0	0	0	0
SS3656	0	0	0	0	0	0
SS501201	0	0	30	25	25	20
SS501202	0	0	0	0	100	0
SS501203	0	0	5	15	50	30
SS501205	20	5	15	10	30	20
SS501206	0	20	50	10	10	10
SS5031	0	0	50	30	10	10
SS5032	0	5	10	35	40	10

Plot	Foliage Intact	Foliage Burned	Second Branches Remain	Minor Primary Branches Remain	Major Primary Branches Remain	Charred Poles
SS5033	0	0	10	50	20	20
SS5034	0	0	0	60	20	20
SS5035	0	0	20	60	20	0
SS5071	0	0	0	0	0	0
SS5072	0	0	100	0	0	0
SS5073	0	20	70	10	0	0
SS5074	0	0	0	0	0	0
SS5075	0	30	70	0	0	0
SS5076	0	0	100	0	0	0
SS8121	10	30	50	10	0	0
SS8122	0	0	40	20	10	30
SS8123	15	20	65	0	0	0
SS8124	0	10	30	25	15	20
SS8125	0	5	25	40	20	10
SS8171	0	5	60	35	0	0
SS8172	5	25	50	10	10	0
SS8173	0	10	50	35	5	0
SS8174	0	5	40	30	15	10
SS8175	0	0	75	10	10	5
SS8176	0	40	15	15	20	10
ZF14101	0	0	70	20	10	0
ZF14102	0	40	15	20	25	0
ZF14103	0	25	35	30	10	0
ZF14104	20	40	10	10	10	10
ZF14105	0	20	35	20	5	20
ZF14106	0	10	30	50	5	5
ZF14171	0	0	60	25	10	5
ZF14172	0	100	0	0	0	0
ZF14174	0	100	0	0	0	0
ZF14191	0	85	15	0	0	0
ZF14192	25	50	25	0	0	0
ZF14193	3	97	0	0	0	0
ZF14194	25	55	20	0	0	0
ZF14195	10	50	25	15	0	0
ZF14196	20	60	15	5	0	0
ZF1421	0	0	10	50	25	15
ZF1422	0	10	20	50	15	5
ZF1423	0	20	40	25	10	5

Plot	Foliage Intact	Foliage Burned	Second Branches Remain	Minor Primary Branches Remain	Major Primary Branches Remain	Charred Poles
ZF1425	0	40	30	20	5	5
ZF1431	0	0	10	20	50	20
ZF1432	0	0	20	50	25	5
ZF1433	0	10	40	30	15	5
ZF1434	0	0	20	40	30	10
ZF1435	0	0	25	50	20	5
ZF14401	0	0	5	25	30	40
ZF14402	0	0	0	20	40	40
ZF14403	0	0	5	20	25	50
ZF14411	50	15	5	0	0	0
ZF14412	0	70	30	0	0	0
ZF14413	0	50	25	25	0	0
ZF171001	0	20	60	15	5	0
ZF171002	0	20	40	30	10	0
ZF171003	0	30	50	10	10	0
ZF171004	0	0	30	30	40	0
ZF171005	0	0	40	30	20	10
ZF171011	10	30	35	10	10	0
ZF171013	30	15	5	0	0	0
ZF171014	20	60	15	5	0	0
ZF171015	5	40	20	30	0	0
ZF171301	0	0	0	0	90	10
ZF171302	0	0	0	0	90	10
ZF171303	0	0	10	35	35	20
ZF171304	10	40	30	10	5	5
ZF171305	0	30	40	20	10	0
ZF171306	0	5	15	30	30	20
ZF1761	85	15	0	0	0	0
ZF1762	90	10	0	0	0	0
ZF1763	90	10	0	0	0	0
ZF1764	70	20	10	0	0	0
ZF1765	80	20	0	0	0	0
ZF1766	70	20	10	0	0	0
ZF1771	0	20	53	20	5	2
ZF1772	0	60	20	10	10	0
ZF1773	0	50	30	15	5	0
ZF1774	20	25	40	10	0	0

Plot	Foliage Intact	Foliage Burned	Second Branches Remain	Minor Primary Branches Remain	Major Primary Branches Remain	Charred Poles
ZF1775	0	75	10	10	5	0
ZF1776	0	40	50	10	0	0
ZF1791	0	40	30	20	10	0
ZF1792	0	10	40	20	10	20
ZF1793	20	25	25	10	10	0
ZF1794	0	20	40	15	20	5
ZF20101	10	75	0	0	10	5
ZF20102	0	0	40	0	50	10
ZF20103	0	0	0	80	10	10
ZF20104	0	0	20	10	40	30
ZF20105	0	0	20	30	10	40
ZF201051	0	0	100	0	0	0
ZF201052	0	0	0	30	40	30
ZF201053	0	0	20	0	60	20
ZF201054	0	0	20	40	20	20
ZF201055	0	0	30	50	10	10
ZF201056	0	10	30	15	15	30
ZF2121	0	30	60	10	0	0
ZF2122	0	40	60	0	0	0
ZF2123	0	10	50	30	5	5
ZF2124	0	0	70	15	15	0
ZF2125	0	10	60	10	10	10
ZF2126	0	30	25	25	10	10
ZF221	0	0	30	30	30	10
ZF222	0	10	40	30	10	10
ZF223	0	0	60	30	5	5
ZF224	0	0	20	20	40	20
ZF225	0	0	20	35	35	10
ZF226	0	0	20	40	20	20
SS3101	0	10	30	20	20	20
SS3102	0	30	30	10	20	10
SS3103	0	10	20	30	25	15
SS3104	0	10	10	40	20	20
SS3105	10	10	20	10	10	30
SS3106	3	10	30	30	20	5
SS3401	40	40	10	0	0	0
SS3403	25	60	10	0	0	0

Plot	Foliage Intact	Foliage Burned	Second Branches Remain	Minor Primary Branches Remain	Major Primary Branches Remain	Charred Poles
SS3405	60	30	5	0	0	0
SS3406	75	0	20	0	0	5
SS3421	0	0	0	0	0	0
SS3422	0	0	0	0	0	0
SS3423	0	0	0	0	0	0
SS3424	0	0	0	0	0	0
SS3425	35	60	0	0	0	0
SS3426	0	0	0	0	0	0
SS8211	30	40	20	10	0	0
SS8212	50	25	0	0	0	0
SS8221	50	20	30	0	0	0
SS8223	50	10	10	30	0	0
SS8224	35	55	0	0	0	0
SS8225	75	25	0	0	0	0
SS8226	60	15	0	0	0	0
ZF1711	0	0	30	30	30	10
ZF1712	0	30	30	30	10	0
ZF17151	0	90	10	0	0	0
ZF17152	5	40	5	0	0	50
ZF17153	0	98	0	0	0	2
ZF17155	0	85	15	0	0	0
ZF17156	0	100	0	0	0	0
ZF17221	0	0	10	20	40	30
ZF17222	0	0	20	40	30	10
ZF17223	0	0	30	10	30	30
ZF17224	0	0	10	15	60	15
ZF17225	0	0	0	20	20	60
ZF17401	40	20	20	20	0	0
ZF17402	10	30	10	30	20	0
ZF17403	20	10	30	20	20	0
ZF17404	10	25	25	10	20	10
ZF20271	50	50	0	0	0	0
ZF20272	5	80	15	0	0	0
ZF20273	50	40	10	0	0	0
ZF20274	40	40	20	0	0	0
ZF20275	20	70	10	0	0	0
ZF20404	5	0	0	40	45	10

Plot	Foliage Intact	Foliage Burned	Second Branches Remain	Minor Primary Branches Remain	Major Primary Branches Remain	Charred Poles
ZF2042	0	0	100	0	0	0
ZF2043	0	0	60	10	20	10
ZF2044	0	20	40	25	10	5
ZF2045	0	0	0	0	0	100
ZF2046	0	0	0	50	0	50
ZF20472	0	0	0	25	25	50
ZF20473	10	10	45	20	10	5
ZF20476	40	10	10	20	0	20
	70	10	0	0	0	0