The effects of recent fire activity in understory species richness and abundance at the National Bison Range

Author: Esmeralda Torres-Martínez

Mentor: Dr. Rick Everett & Dr. David Flagel

Abstract

With current shifts in climate and intensified fire seasons around the world, habitat, and restoration management strategies are considering the effects of fire disturbances on understory composition. This study focuses on the influence of recent fire activity on understory species richness at the National Bison Range. A total of ten 176.71m^2 West-facing plots were sampled at above 1,300m of elevation. Due to lack of records of recent fire frequency at the National Bison Range, evidence of recent fire activity was recorded as "presence of charcoal" in the soil <7cm deep. Percentage of ground and canopy cover, soil moisture, shrub and forb richness, and shrub mean height for each species were recorded for each plot. I found no relationship between recent fire activity and understory richness. However, I did find a significant relationship between charcoal presence and an abundance of a single shrub species. *Amelanchier alnifolia* showed a greater percentage of ground cover in sites with the presence of charcoal. This finding suggests that *Amelanchier alnifolia* has a great fire disturbance response. I believe that a limited sample size and the procedure that was used to identify recent fire activity in the soil are factors that may have altered results to establish recent fire activity.

Keywords: recent fire activity, understory species richness, understory abundance, fire ecology, *Amelanchier alnifolia*

Introduction

With current shifts in seasons, temperatures, precipitation, and intensified fire seasons around the world, habitat, and restoration management strategies should consider case by case forest dynamics in order achieve resilient forests for climate change (Kenzie et al., 2004). In recent years, federal agencies that manage forest environments have been urged to implement strategies to respond, mitigate and adapt to climate change (NPS, 2010; USFWS, 2010; US Forest Service, 2012). Moreover, to achieve resilient forests, researchers have actively studied climate change effects on forests and identified appropriate procedures to restore forests to their historic conditions (Wuebbles et al., 2017; Ziegler et al., 2017). However, due to the fact that forests are dynamic ecosystems, case by case studies should be considered in order to implement appropriate management strategies (Kenzie et al., 2004).

Forests are dynamic ecosystems that rely upon different factors such as species composition and disturbances to gain a dynamic equilibrium that supports resiliency for future changes in climate (Spies & Turner, 1999). Researchers in North America have looked at historical data to examine the effects of wildfires in forest composition (Boisramé et al., 2017; Girardin et al., 2013; Heyerdahl et al., 2006; Kenzie et al., 2004; Mell et al., 2009). They have found that generally, forest composition improves when fire disturbance plays a major role in regeneration. However, due to the fact that fire exclusion was and has been a common practice in North America since the last century, managers have used practices such as prescribed fire because they have proven to facilitate resiliency of conifer forests (Ares et al., 2010; Knapp et al., 2017; Maas-Hebner et al, 2005; Mell et al., 2009; Meng, et al, 2015). But even so, emphasis on the effect disturbances on forest understory composition needs further research (Knapp et al., 2017).

This study was conducted at the National Bison Rage in Montana. As the National Bison Range does not have records of fire frequency, recent fire activity was recorded by presence or absence of charcoal in the soil. This study sought to investigate whether recent fire activity influenced herbaceous and woody vegetation distribution. Namely, does recent fire activity influence understory richness? Can charcoal presence in the soil be a good non-historic indicator for recent fire activity? Does recent fire activity also influence woody vegetation growth? Do other physical factors such as soil moisture, rock and canopy cover have greater understory influence than Charcoal presence? I hypothesize that (1) understory richness will be greater in areas with presence of charcoal, (2) understory growth and abundance will be greater in areas with presence of charcoal, and (3) a combination of soil moisture, canopy cover, rock cover, and charcoal presence produces greater species abundance.

Methodology

Sampling Sites

For this research, data were recorded from two mountain peaks at the National Bison Range (47.31686 N, 114.24550 W & 47.32120 N, 114.25072 W) in Montana, United States. Both sites have an elevation greater than 1300 m and their slope aspect is West. Common trees of the area include Douglas-fir (*Pseudotsuga menziesii*) and Ponderosa pine (*Pinus Ponderosa*). Small frequent fires have been observed but not well recorded by NBR employees. However, no thinning activities have been implemented due to the cultural and spiritual significance of the sites.

Data Collection

a) Plot Composition

A total of ten circular 176.71m^2 plots were chosen to sample for this research. Plots were at least 35m away from each other and a minimum of three trees was required in order to sample. Percentage of ground cover (bare ground, rocks, forbs, grasses, shrubs, and other), as well as the percentage of canopy cover, were recorded. All tree species within each plot were documented as well as their height and diameter at breast height (DBH, $\geq$ 2.5cm). Distance and direction from the center were also recorded for future reference. For shrubs, their species, height, and percent of ground coverage were recorded. Herbaceous flowering plants (forbs) were identified and their forb cover percent was calculated. Distance and direction from plot center were also recorded for each tree.

b) Soil Data

With a small shovel, 2-3 small holes no more than 7cm deep were dug below the organic horizon. Evidence of recent fire activity was recorded by the presence or absence of charcoal in the soil < 7cm deep. A sample of soil was bagged to record soil moisture. Samples were left in a dry oven for 24 hours and weighed afterward.

Statistical Analysis

A Principal Component Analysis (PCA) with Pearson Average 0.5 similarity format, was tested with the percentage of forbs, shrubs, and grass cover to determine similarity between sites. Once clusters were identified, a discriminate stepwise analysis was tested with the percentage of canopy and rock cover, as well as soil moisture. Welch's t-test was used to study the relationship between Charcoal presence and species richness. The treatment variable was presence or absence of coal, while dependent variables include species richness and vegetation abundance. When data were not normally distributed, square root transformation was used and tested for normality. If the transformation was successful for normal distribution, Welch's t-test was used, if not Wilcoxon rank sum test was tested.

Results

A total of 39 trees with DBH ≥2.5cm were measured, 35 Douglas-fir and 4 Ponderosa Pine. The mean height for Douglas-fir (*Pseudotsuga menziesii*) and Ponderosa Pine (*Pinus Ponderosa*) were 12.68m and 18.89m respectively. Around 10 different species of shrubs were identified, with Saskatoon serviceberry (*Amelanchier alnifolia*), Lewis' mock orange (*Philadelphus lewisii*), mountain huckleberry (*Vaccinium membranaceum),* and creambrush (*Holodiscus discolor*) being the most common species. On the other hand, a total of 12 species of forbs were identified, with 4 common species found: arrowleaf balzamroot (*Balsamorhiza sagittata*), lupine (*Lupinus argenteus*), yarrow (*Achillea millefolium*), and narrow-leaved collomia (*Collomia linearis*).

PCA analysis showed two main clusters (Fig.1). Discriminate analysis showed canopy cover and soil moisture explain understory percent cover (Fig. 2; p=0.05; p=0.029). Both of these variables explain 80% of the PCA analysis (p=0.029). However, the percentage of rock cover had no significance. Understory species richness showed no effect with charcoal presence (Fig. 3). No significant results were found with mean heights of shrubs (Fig. 4). Understory abundance was also found to not have a direct relationship with charcoal presence (Fig. 5). Relationship between charcoal presence and percentage of each forb species showed no significance (yarrow-

p=0.2225; narrow-leaved collomia-*p*=0.3932; lupine-*p*=0.08767; arrowleaf balzamroot-*p*=0.3941). I also found that Saskatoon serviceberry (Fig. 6; *p*=0.04998) was the only shrub species to have a significant relationship with charcoal presence (Lewis' mock orange-*p*=1.0000; Huckleberry-*p*=0.4795*;* Creambrush-*p*=0.4795*).*

Discussion

My study showed understory abundance clustered significantly in two different community groups based on canopy cover and soil moisture. These results were expected due to the fact that soil moisture and canopy cover are key factors for forest distribution and composition in burned areas (Casals et al., 2018; Heyerdahl et al., 2006). I found that communities with higher canopy cover and soil moisture had higher shrub and forb cover, yet lower grass cover (Fig. 2). Studies have shown canopy opening may be beneficial to understory growth (Sabo et al., 2009). However, because I sampled on West-facing slopes, areas with less canopy cover could be exposed to excessive radiation. As a result, soil moisture would decrease and may decrease vegetation cover as well, thus heat tolerant species such as grasses could colonize.

I found no relationship between charcoal presence and understory richness, which is inconsistent with fire ecology literature (Day et al., 2017). This may be due to the fact that charcoal presence and absence in the soil may not the best and only method to establish recent post-fire conditions. Understory fires correlate with fire history, understory composition, climate, and soil nutrients (Girardin et al., 2006; Gundale et al., 2005; Hanson & Stuart, 2005). Therefore other factors should be documented and studied such as frequency and intensity of fires in order to clearly determine the effects of fire on the understory of forests at The National Bison Range.

It has been found that saskatoon cover was higher in areas recently affected by fire. My findings are consistent with other studies done in northeastern United States and Canada. For example, a study in 1988 researchers found that short-term effects of prescribed burning did not affect saskatoon productivity. In contrast, percent cover doubled in burned sites when compared to unburned sites (as cited in Fryer, 1997b; Thomson, 1988). In a previous study at the Lolo National Forest, saskatoon was subject to experimental fire treatments in different phenological states. Researchers found that total mortality was achieved in every treatment type, however, no significant relationship with was determined because saskatoon plants actively sprouted after each fire treatment regardless of phenological states (as cited in Fryer, 1997a; Noste, 1989). A relationship was found between the size of shrubs pre-fire and post-fire sprouts, which suggest fast regeneration after fire disturbances (as cited in Fryer, 1997a; Noste et al., 1989). Both of these studies, reviews, and findings validate the role of fire in species-specific responses to disturbances, therefore, species traits should also be studied in relationship with fire disturbances.

I found no relationship between charcoal presence and mean height of shrubs. Some researchers argue that shrubs with postfire advantages suffer the loss of height and productivity. Their result is likely due to the fact that browsing pressure increased for saskatoon and other species, that maintained the mean height below the browse line. Years after a fire, it is believed that saskatoon becomes more accessible for game herbivory, which inhibits its annual growth (as cited in Fryer, 1997c; Leege, 1979). Other types of disturbances such as ungulates browsing may have affected my shrub height data. Thus, these findings suggest that saskatoon may have reproductive advantages postfire above other sampled shrub species, yet future research should focus on the roles of fire and browsing combined.

Limitations in this study are mostly due to the fact that recent calendar and special fire records were not available for the sampling sites. Consequently, simple sampling methods were used to conduct the study in order to comply with time restrictions. Restricted statistical analysis was also problematic because recent fire activity data was categorical which limited the statistical tests that could be used to tests my hypotheses. Continuous charcoal data can be obtained if future studies focus on soil properties and their effects on understory vegetation. Other restrictions for this research include increasing sample data, sampling during different seasons, as well as different slope aspects. Future research should focus on combining historic and current records, as well as other studies such as dendrochronology and soil science in order to appropriately determine the effects of forest fires in understory communities. In addition, species-specific studies can be of good help to determine evolutionary traits that increment resistance and dispersion after a fire, and how those traits are associated with understory composition.

In conclusion, understory composition was determined by canopy cover and soil moisture rather than the presence of charcoal. Greater shrub and forb abundance was found at sites with higher canopy cover and soil moisture. On the other hand, grass abundance was greater in areas with less canopy cover and soil moisture, suggesting shrubs and forbs prefer areas with less acute radiation. But even so, regardless canopy and soils moisture, Saskatoon serviceberry showed evidence of greater abundance in areas with charcoal presence which suggests fast regeneration and dominance over other species and browsing impact. Management policies and future studies should focus on calendar and spatial records, as well as incorporating interdisciplinary research fields.

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Figures and Diagrams

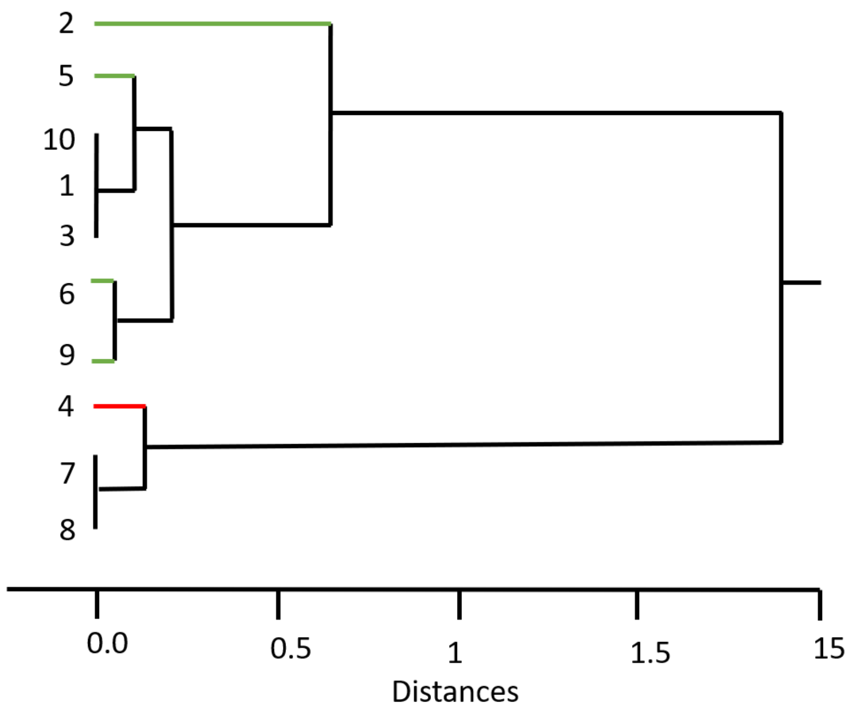

Figure 1: Principal Component Analysis of similarities between sites in respect to shrub, grass and forb percent cover.

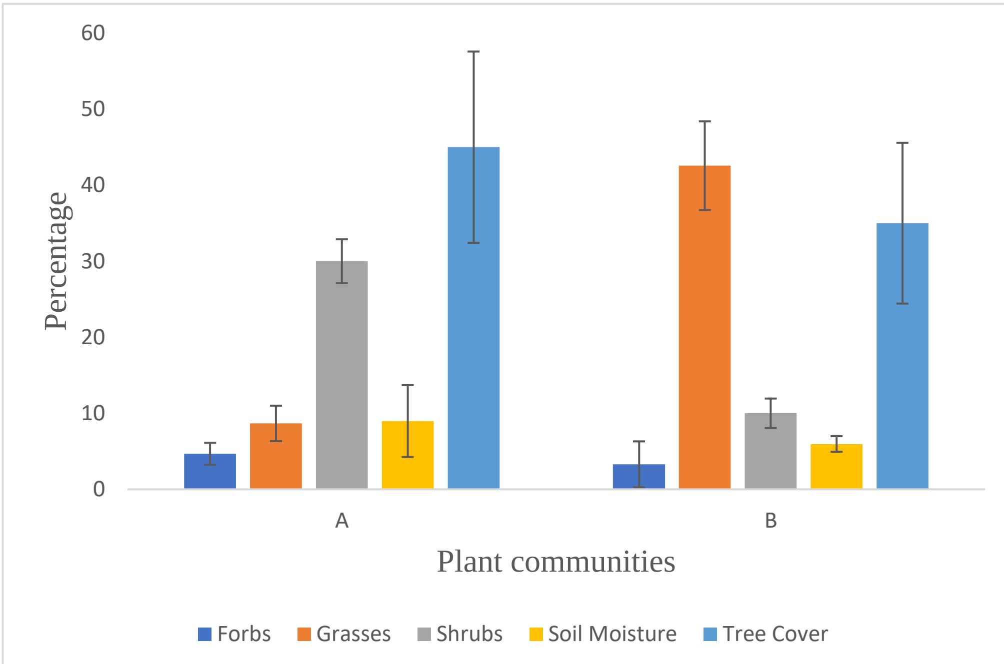

Figure 2: Understory conditions and composition based on Principal Component Analysis (PCA) (p=0.029). Sites with high canopy cover and higher soil moisture had high percentage of shrubs and forbs, yet less percentage of grasses.

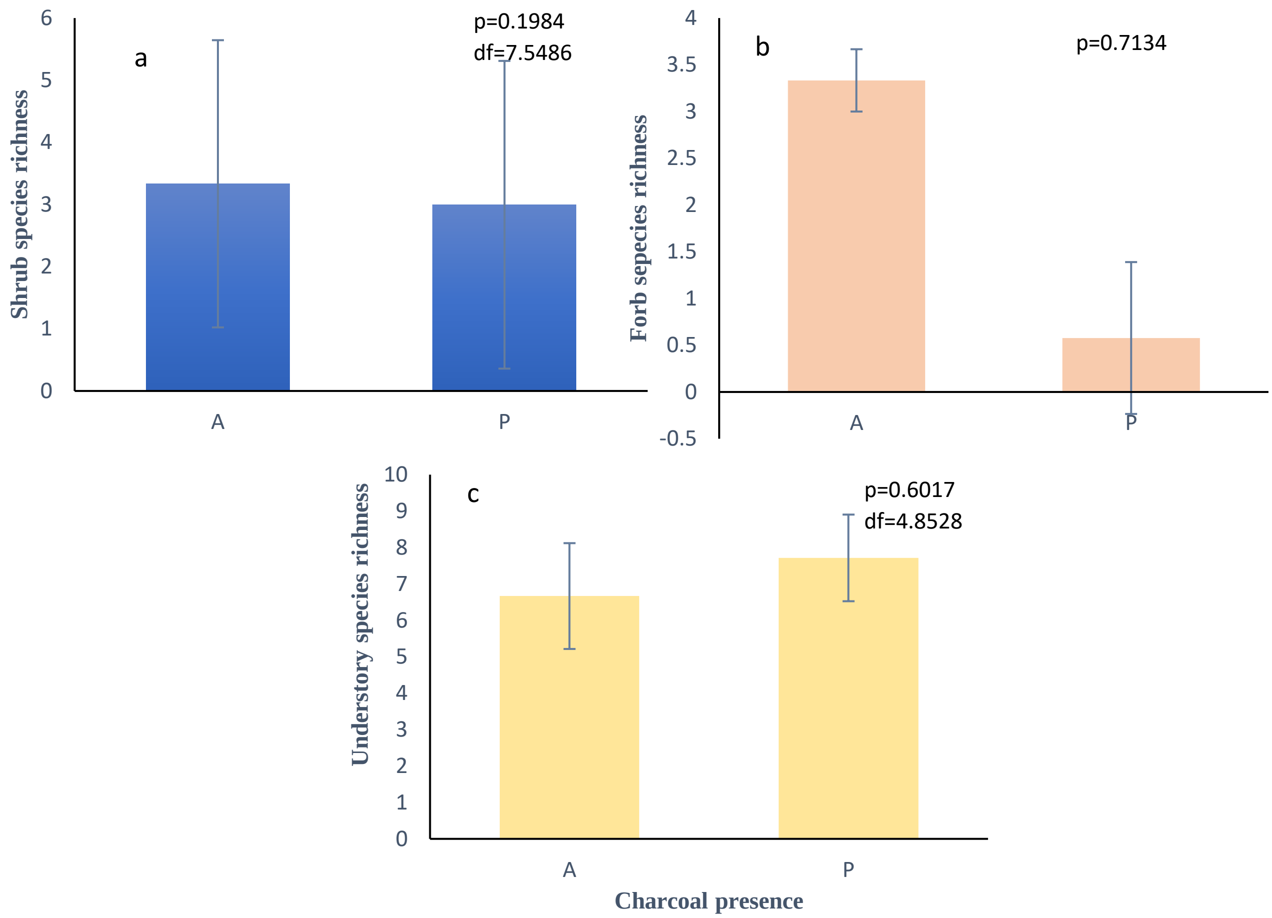

Figure 3: Relationship between recent charcoal presence and understory richness. Presence of charcoal is identified as P and absent as A. (a) Charcoal presence relationship to forb richness. Data was normally distributed. Welch Two Sample t-test showed no significant results. (b) Charcoal presence relationship to shrub richness. Data were not normally distributed. Wilcoxon rank sum test showed no significance. (c) Charcoal presence relationship to understory richness. Species count was calculated with shrubs, forbs and trees with DBH <2.5 species. Data was normally distributed. Welch Two Sample t-test showed no significant results.

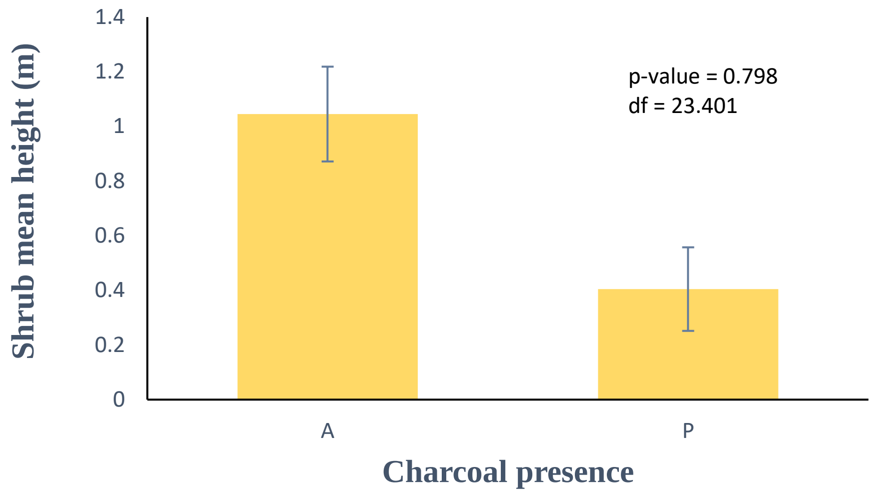

Figure 4: Relationship between shrubs mean heights and charcoal presence. Presence of charcoal is identified as P and absent as A. Species were not taken into consideration for this analysis. Data was normally distributed. Welch Two Sample t-test showed no significance.

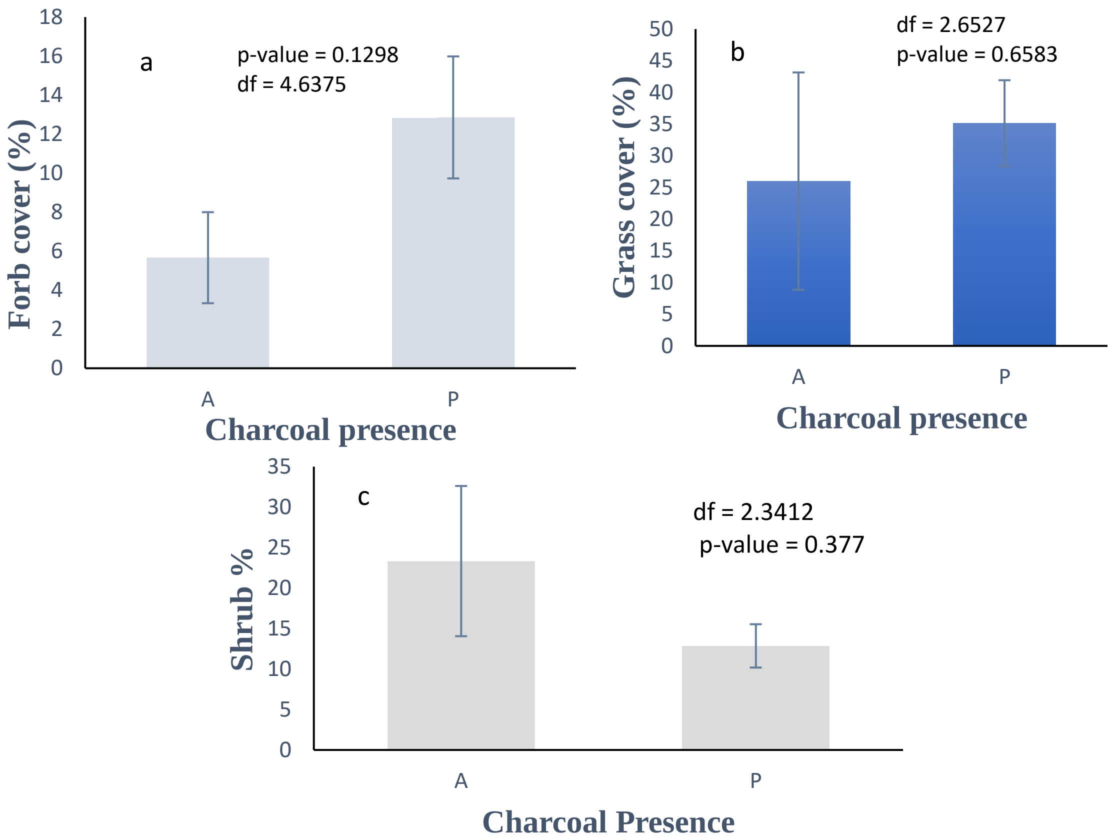

Figure 5: Relationship between vegetation ground cover and charcoal presence in the soil. Presence of charcoal is identified as P and absent as A. Square root transformation was used to normalize data. Welch Two Sample t-test showed no significance. (a) Charcoal presence relationship to percent of forbs cover. (b) Charcoal presence relationship to percent of grass cover. (c) Charcoal presence relationship to percent of shrub cover.

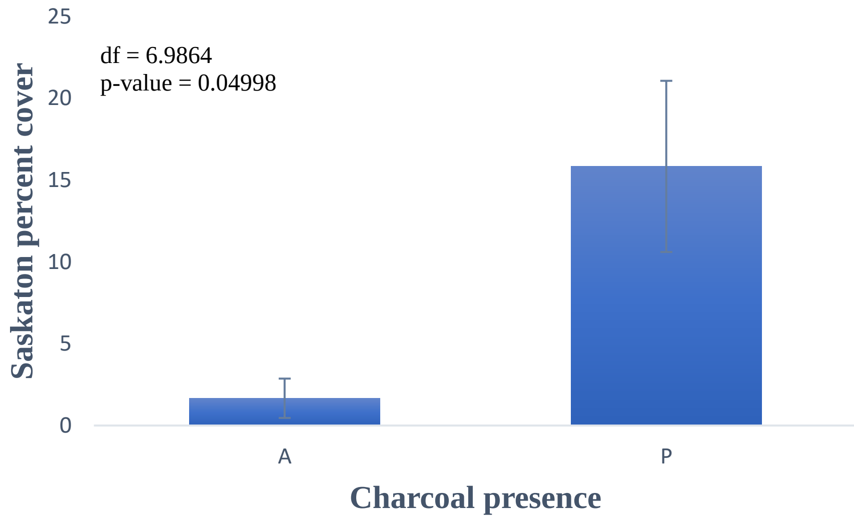

Figure 6: Analysis of Saskatoon percent cover in relationship with recent fire activity. Presence of charcoal is identified as P and absent as A. Data was transformed with square root to attain normal distribution. Welch Two Sample t-test was used and significance was obtained

Apendix (A)

Protocol: Research project of understory community and charcoal presence

Mentor: Rick Everett and David Flagel

I. List of materials

Datasheets	GPS Garmin	Pedo-marker
Permanent Stake (wood)	DBH measure tape	Range finder
Distillated water	clinometer	Ziploc bags
Ph Meter	AA batteries	Flagging
Measuring tape	Car plug	Sharpie
Rubber hammer	Small shovel	Compass
Masking tape	Camera/cellphone	Cellphone charger

II. Arriving at site & setting up plot
   A. Localize first plot to work with
      1.Observe surroundings for any visible burned logs or burn marks on trees.
      2.Record visual information in notes from site
   B. Determine the center of plot
      1.**Place stake** in the center point
      2.Take coordinates from plot center
   C. Delimit a **7.5m radius** from plot center

III. Data Collection
   A. Sketch every important factor of the plot
      1.Up to 3 trees that are inside the plot
         a. Make sure to write their ID from the second data sheet
      2. Locations of Soil data taken
   B. Plot Compositing
      1. % Tree Cover
         a. Canopy Cover
      2. % Bare Ground*
      3. % Rock*
      4. % Forbes*
      5. % Grasses*
      6. % Shrubs*
      7.% Other*

C. Soil Data

1. Presence or Absence of coal and ash
    a. With a small shovel dig a small **sample** below the top soil from the center of the plot, as well as the center of each quadrant of the plot that are possible. **Quadrants will be labels as C for center, NE, SE,SW, NW.****
    b. Identify if Presence or Absence of charcoal (non-organic Carbon) particles.
        i. Carbon particles
            a) Organic matter
                i. **WILL NOT MEASURE**: Organic matter will be predominant in the first layer, Horizon O and near the A Horizon. Texture is drifty and sticky.
            b) Charcoal
                i. Charcoal particles are less than an inch long, have long angular shape. Texture of charcoal is not as drifty or sticky as organic matter. To the touch, carbon particles will break and will easily stain your hand black.
            c) Ash
                i. Soil aspect looks from black to gray. Is a very fine coarse material, therefore, the texture is soft to the touch when compared to adjacent soil. To make sure it is ash, you could:
                    a. Take a bit of the soil and pour water in your hand. **If the particles float its ash.**
                    b. If you are low on water, use just a few drops of water to mix the particles in your hand. **If the area in your hand feels oily its ash.**

2. Soil Moisture
    a. From the same hole used for charcoal
        i. Take a small soil samples the size of the small shovel.
        ii. Place in a labeled zip lock bag
    b. Record the % of soil moisture of the soil were is possible with the plot. A sample from the center is highly encouraged. Dry samples for 24 hours

$$\left|\frac{g\ after - g\ before}{g\ before}\right| \times 100$$

3. pH
    a. Calibrate the pH meter according to user manual before going out to the field
    b. Turn on the meter
    c. Record the pH of soil at center of plot and each quadrant (**C, NE, SE,SW, NW**)
        i. Take a small sample of soil, approximately 2.54cm (1 inch) below organic horizon.
        ii. Mix the sample inside the hole add around 10ml of distilled water.
        iii. Place the meter in the solution and record the pH

D. Woody Vegetation Data

1.ID
    a. **Identify trees based on North direction**, e.g. the first tree that is clockwise from the North will be ID as one.

2. Record the species of the plant, common or scientific names are acceptable. If unknown, write SP#, take a sample and bag it with proper Identification (Plot ID, SP#). If bagging is not possible, take decent pictures.
    a. Cones, needles, leaves, branches, flowers, fruits, complete individual.

3. Record the height of trees with and shrubs with clinometer and range finder for tall trees and wish a measuring tape for smaller individuals.

4. Record DBH with DBH tape for trees higher with a DBH of 2.5 or higher.

5. Record Distance and direction from center of Plot
    a. ONLY FOR TREES

6. Notes
    a. Record anything that might be important about the tree, such as fire scars, diseases or death.