Pilot study of changes in fire pattern in the North Saskatchewan region over time through the use of repeat photography

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Introduction

Fire is a complex natural disturbance that creates landscape pattern and is governed by landscape structure. Forest fires range in intensity, severity and frequency resulting in a multitude of temporal and spatial patterns across the ecosystem (Peterson 2002). Three factors affect fire behavior: weather, available fuels, and topography. Fuel refers to the plant community and structure within the ecosystem at the time of the fire (Sackett et. al., 1995). The feedback loop between vegetative structure and fire behavior is exhibited by the instance of high intensity fires that now occur as a result of fire suppression.

Removal of fire as a disturbance factor through fire suppression has led to the homogenization of stand age and type in many regions, including the R11 management zone (Pengelly and Rogeau 2002; Delong and Pengelly 2002: as cited in Rogeau 2008). Since the mid-1980's, governmental organizations such as the Parks Canada Agency, and more recently, Alberta Sustainable Resource Development (ASRD), have began to reintroduce fire onto the landscape in order to restore vegetative communities that relied on historical fire regimes (White, 1985). In order to emulate fire effects on the ecosystem, land managers require information on the spatial and temporal patterns of historical fire regimes that maintained historical ecosystems (Weir et al., 2000; Andison, 2003).

Objectives and Project Design

Landscape ecology offers important tools for analyzing natural phenomena, such as fire, that occur at various scales both spatially and temporally. Fire creates heterogeneous pattern across the landscape known as the landscape mosaic, which consists of various patch types that vary in size, shape, and coverage (Turner et al., 2001). This project was designed to examine the differences in disturbance and landscape patterns between historical and repeat photographs through the use of landscape ecology metrics. Patch types were classified within spatially relevant subsets, referred to as photo plots, of the original and repeat images. Images were taken from selected sites, referred to as stations, along the North Saskatchewan River. The photo plots cover different regions of the valley before and after a prescribed burn, which was conducted in 2009 by the Parks Canada Agency and Alberta Sustainable Resource Development (ASRD). My null hypotheses are;

1) there is no difference in patch type, coverage or shape that indicates a decrease in heterogeneity between the original and repeat photo plots within each site,
2) and, the vegetative pattern existing prior to the prescribed burn had no influence on the burn pattern left by the prescribed burn.

Study Area

The study area encompasses a section of the south-facing North Saskatchewan River Valley. It extends north of the North Saskatchewan River from its intersection with Howse River in Banff National Park to the west, and east to the drainage from Abraham Lake within the R11 forest management unit. This region also includes the Kootenay Plains Road Corridor Wildlife Sanctuary. The selected study plots are within the Subalpine and Montane Natural Sub-Regions of Rocky Mountain Natural Region, and the dominant cover type is mature lodgepole pine (Rogeau, 2008).

Methods

Disturbance events, such as fire, that occur at large landscape scales can be difficult to study, as their scope is so broad. The term 'landscape' itself is ambiguous as it may apply to a variety of spatial scales. This study examines samples, or sub-landscapes (Andison, 2003), of the R11 region that may be representative of the entire landscape[1]. The photo plots represent sub-landscapes, as disturbance events such as fire are likely to extend beyond the plot boarders.

<u>Selecting Photo Plots:</u>

Panoramic images were made from both the original and repeat photos from stations in the North Saskatchewan Valley. Then, the photographic coverage of the panoramas from each station was mapped out in Google Earth in order to determine which photographs had the best coverage of the study region (Figure 1.1). Repeat photography of original images from stations in the North Saskatchewan Valley occurred in 2008 and 2009[2]. The 2008 repeats were taken prior to the PB, and the 2009 ones afterwards. Original and repeat photographs from station 420 were selected for coverage of the study region prior to the PB, and images from station 419 were selected for after the PB. The two stations are geographically close to one another, and for the purpose of this study I assumed that the vegetation, topography, soils, and microclimate to be relatively similar between the two sites. The last major burn that covered the majority of Plot 420 was in 1860 and the besides the recent PB, the last major fire to affect the majority of plot 419 occurred in 1890 (Rogeau and Gilbride, 1994).

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[1] This depends on how the landscape is defined.

[2] Repeat photography fieldwork done by the Mountain Legacy Project: www.mountainlegacy.ca

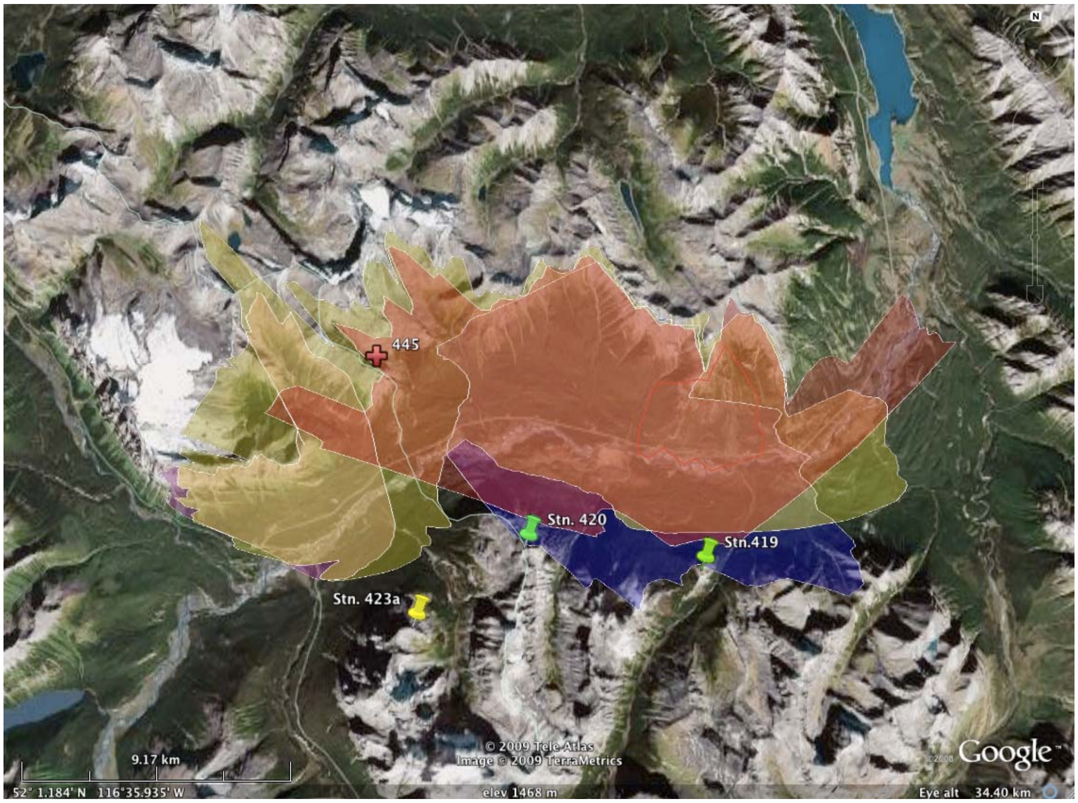


Figure 1.1: Photographic Coverage of Landscape from each Station

Subsets of the original and repeat panoramas from each of the selected stations (419 and 420) were made based on areas of the image that could be made spatially relevant through the same view in Google Earth (Figures 1.2, 1.3, 1.4, & 1.5).

Figure 1.2: Shaded Subset of Panoramic View from Station 419

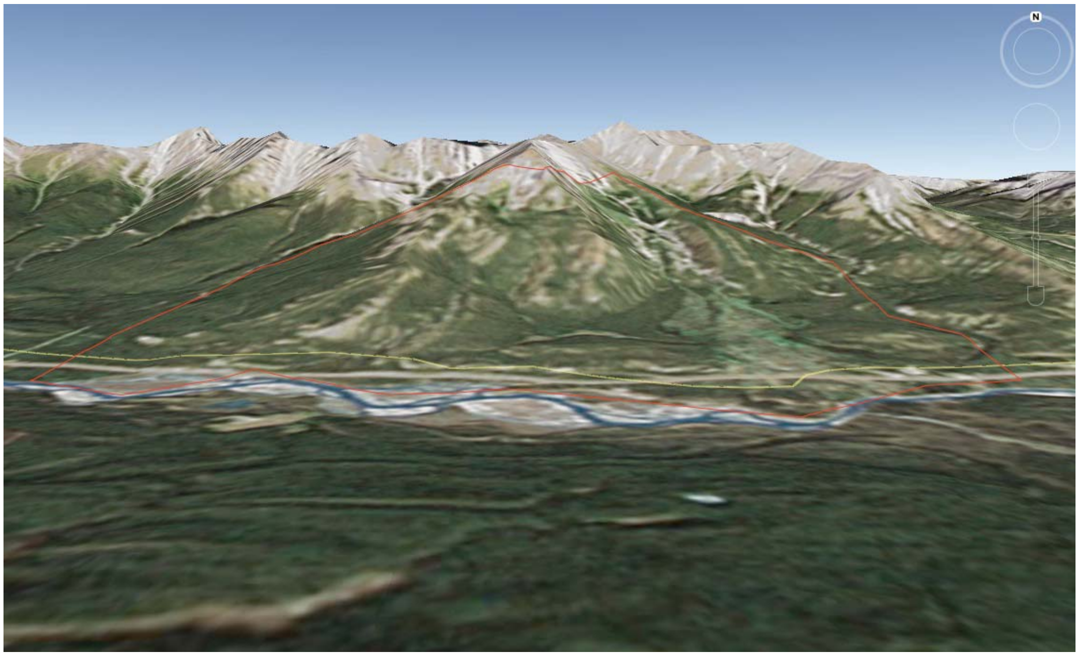


Figure 1.3: View of Station 419 Subset in Google Earth (outlined in red)

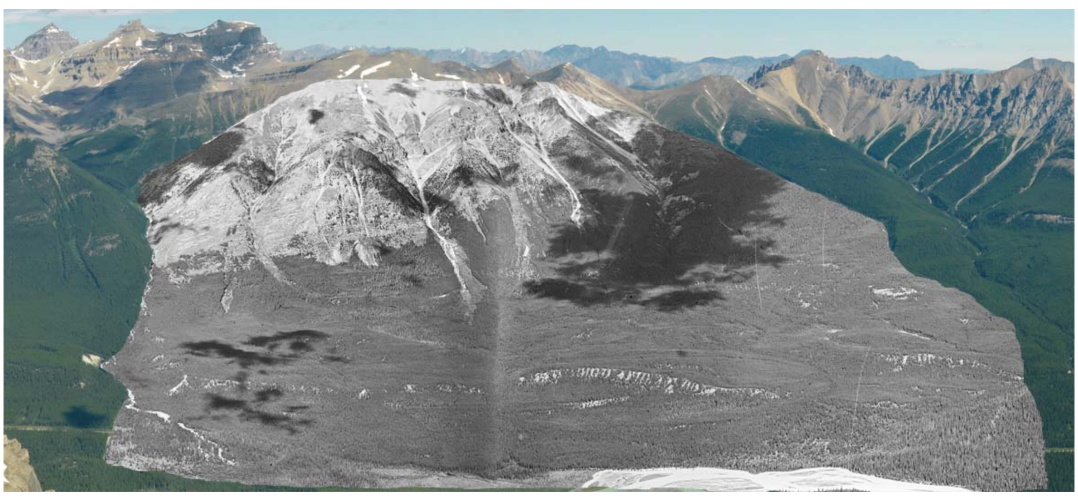


Figure 1.4: Subset of Panoramic View from Station 420 (original subset shown in context of repeat pano)

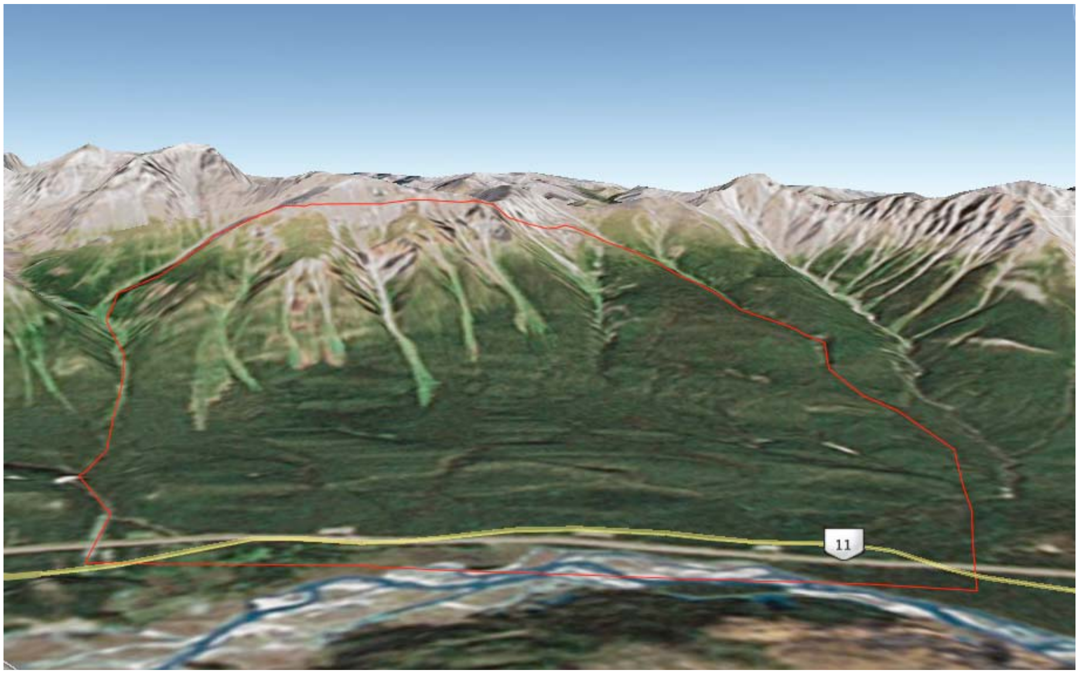


Figure 1.5: View of Station 420 Subset in Google Earth (outlined in red)

The repeat and original images used in this study are oblique and cannot be georeferenced in the same way air photos can be using GIS software. Google Earth Pro allows the user to make perimeter and area measurements from an oblique view. By matching sections of the photographs with the same view in Google Earth Pro, I was able to establish the size of the photo plots[3]. The original and repeat photo plots for station 419 have an area of ~11.74 km^2 and a perimeter of ~15.05 km. The plots for station 420 have an approximate area of 18.69 km^2 and a perimeter of ~16.99 km. The repeat photos from before the PB were taken from station 420, southwest of the burn. The photographs taken after the PB were taken from station 419, which is south of the burn. The photo plots for each station covered different regions of the study area.

Classifying Patches

Fire is a regenerative, natural disturbance process that maintains species diversity by creating a patch-like mosaic of different seral stages across the landscape (DeLong, 1998). The effective exclusion of wildfire over the last 100 years has drastically altered the historical fire regime and changed the vegetative composition of the R11 management zone, putting the region at risk for high intensity, wide spread fires (Rogeau, 2008). Change in the fire cycle alters vegetative succession, which in turn affects fire pattern and behavior. All of the classes in this study represent different seral stages that may be created

[3] The subsets of the panoramic images, which coincide with the boundaries of the photograph's extent in Google Earth, are referred to as photo plots 419 and 420 for the purpose of this study.

or maintained by disturbance such as fire. The vegetative patches that exist on the landscape also tell us something about the fire regime; moderate severity fires are characterized by a multiple-age vegetative structure, while high severity fires often replace entire stands of trees, reverting the region uniformly into a more homogenous seral stage (Agee 1998).

The patches in each class were outlined by hand in Adobe Photoshop CS4 by creating shape layers using the pen tool. A patch, defined by Andison (2003) is "a contiguous area of land that share common physical or biological characteristics" (p. 3). The different patch classes for both the repeat and original plots included 1) meadow/open ground, 2) reduced stem density, 3) second growth/aspen stands, and 4) obvious fire evidence. For the purpose of this project, the matrix was considered to be the prevailing forest cover in which each of the patch classes occurred and were evident due to their contrast with the forested matrix. Andison (2003) defines a matrix as "all undisturbed land outside of a disturbance event" (p. 3). Since the boundaries of a fire event characteristic of the historical fire regime in the R11 is likely beyond the limits of the plot boundaries, the matrix shown within the plot boundaries are most likely matrix remnants or islands. According to Andison, (2003) the landscape is a mosaic of disturbance patches with small islands of original matrix within those patches. The matrix is left unclassified for this study, as it is the disturbed patches that are of interest. However, it is likely that the unclassified matrix regions have been disturbed at earlier points in history. Other areas that were not classified and therefore considered part of the overall matrix were areas with no vegetation including bare ground/rock, sand bars, and roads. Fire needs fuel to burn and therefore leave a pattern, which is why patches without some type of vegetative cover were not of interest for the purpose of this study and left out of the classification. Sparse vegetation above the solid tree line as well as areas directly beside or within the major river feature and avalanche chutes were also left unclassified as these vegetative patterns are most likely caused and/or maintained by other types of natural or anthropogenic disturbance such as floods or avalanches. The goal of this study is to focus on vegetative pattern that is likely to have been created or maintained by fire disturbance.

1) <u>Meadow/Open Ground (MG)</u>: This class includes meadows or areas of open, but vegetated ground, in both the original and repeat images. Bare ground, or areas that had high reflectance and were therefore most likely comprised of rock, were not included in this class. In the montane ecoregion, meadows have been associated with areas that historically had shorter fire cycles (White et. al., 2002).

2) <u>Reduced Stem Density (RSD)</u>: As forests age, stem density and crown foliage increases (White et. al., 2003). Areas of reduced stem density indicate regions that may have been maintained by frequent lower

intensity fires, or regions that are succeeding from an older, stand replacing fire.

3) Aspen/Second Growth (ASG): Aspen is associated with the early seral stages of forest regeneration and stands of aspen are often indicative of a recent disturbance event (White & Feller, 2004). For the purpose of this project, 'second growth' includes regions of similar species composition that stand out from the older forest matrix remnants; i.e. tree cover lighter in color in both the repeat and original photos. These stands are harder to identify in the photographs than the aspen stands, but are important indicators of another earlier seral stage that may reflect a disturbance event such as fire.

4) Visible Fire Evidence[4] (VFE): Visible fire evidence in the original photos may consist of blackened or bleached dead standing and/or fallen trees. Visible fire evidence in the repeat photos is what can be seen as a result of the prescribed burn. These areas the easiest to classify as trees are obviously blackened, or orange due to scorched needles.

After all the patches of interest within the photo plots were classified, I merged patches together that were in the same class and overlapping, or were close enough to each other that they were likely attributable to similar disturbance events (Figures 2.1, 2.2, 2.3, and 2.4 in appendix). No two different patch types overlapped in this study; i.e. a disturbed patch could only belong to one class. Classifying regions in the photographs that are in different seral stages highlighted vegetative patterns that contribute to the forest mosaic as a result of disturbance events such as fire.

Calculating Class Metrics

In order to compare patch classes between all of the photo plots, I first converted the classes from the color repeat plots to grayscale in Photoshop CS4. Each class layer was then turned on one at a time for both the original and repeat plots, and selected with selection tool. Then the respective repeat or original plot layer was turned on, and all the shape layers in each class cut out of the photo plot. New layers for each of the classes from the cut outs of the photo plots were created. This ensured that the patches in each class were represented by the actual pixels from each photograph as opposed to the primary shape layers. The metrics[5] for each class were then calculated in

[4] Includes historical fires and the prescribed burn.
[5] See Analysis section for detailed breakdown of calculated patch metrics from photo plots.

Photoshop CS4 using the measurement tool and the results exported to Microsoft Excel 2008 for further analysis.

Analysis

The metrics for each class calculated in Photoshop CS4 included; the total count of all patches within the class, area, perimeter, and circularity. Area and perimeter were both measured in pixels and calculated for each patch as well as for the entire class. Circularity was calculated using the formula 4pi ($area/permiter^2$), where 1.0 is a perfect circle and 0.0 is an increasingly elongated polygon (Weir et al., 2000). A shape ratio was calculated separately using a simple perimeter and area ratio (Turner et al., 2001).

Area: measured by percent coverage. Because the photo plots were different in size, each the area covered by each class (measured in pixels) was converted to a percentage by dividing the number of pixels for each class by the total number of pixels in the photo plot.

Shape: measured by complexity and circularity. Complexity was calculated by creating a ratio by dividing the perimeter of the patch by the area. The higher the ratio, (i.e. higher levels of perimeter to area) indicates a higher amount of complexity as the shape has more edge (Turner et al., 2001). Circularity indicates the shape of a patch as it approaches an elongated polygon. Fire shape is expected to be ellipsoidal in homogenous environments (Alexander 1985; as cited in Finney 2001). Homogenous environments are considered to be stable and continuous fuel, weather, and topographic conditions; the three factors that govern fire behavior. Deviation from an ellipse indicates change, or complexity in one of these factors.

Percent Overlap: The percent overlap for each class between the original and repeat photo plots from 419 and 420 was calculated but turning on, one at a time, each group of patches from the original and repeat plots, selecting the regions that overlapped for each class between the original and repeat plots, and then creating a new layer with the patches from that class that were present at both times. Metrics were calculated for each of these overlap regions, in the same way that metrics were calculated for all the classes previously, and exported to excel. I then calculated the percentage of overlap for each class by dividing the total area for all the patches present in both the original and repeat plots for each class, and dividing that by the total area of that class present in the original plot. This allowed me to determine how much of the vegetative pattern for each class in the original photo plots persisted over time in the repeat photo plots.

The analysis of the patch classes is divided into three parts in accordance with the study objectives. Metrics between the historical and current landscapes from prior to the PB are compared, than metrics between the historical and current landscape after the PB and finally metrics between the two sites are compared.

Historical and Current Landscapes Prior to the Prescribed Burn: Plot 420

Area: The original photo plot had patches in all four patch classes, and the repeat photo plot had patches in three, with the exception of VFE. The patch class that covered the largest percentage of both the original and repeat plots was ASG. The number of patches in that class doubled in the repeat plot, and as did the percentage coverage (Charts 1 & 2). The RSD class had the second highest percent coverage in the original photo plot, and the highest number of patches. In the repeat plot, the number of patches in that class was reduced by over 80%. The RSD and MG classes covered the same amount of area in the repeat photo plot (only 0.6%), but there were almost twice as many MG patches as RSD patches. There was a slightly higher percentage of area covered by the MG class in the original photo plot, and three times as many patches. The original photo plot had five patches of VFE that covered close to 3% of the total plot area. In the end, however, the total percent coverage of all the classes was very similar, 22% and 26% for the original and repeat photo plots, respectively. However, there were twice as many patches in the original photo plot as there was in the repeat photo plot.

Shape: The patches in the VFE class of the original photo plot had the least complex shape, followed by the ASG class and then the RSD class. The MG class had the highest perimeter ratio (Chart 3). The same order of complexity occurs between the classes in the repeat plot. The shapes for each class between the original and repeat plots change only minimally between the time frames; aspen/second growth remained the same, while the average shape of a patch in the reduced stem density class of the repeat image was slightly more complex then in the original plot, and vice versa for shape complexity between plots for the average meadow/open ground patch.

The classes that exhibited the most ellipsoidal shape in the original photo plots were first VFE, then ASG, RSD, and finally, MG was the most circular. In the repeat photo plot, which had no VFE patches, the ASG class was the most ellipsoidal, followed this time by MG, and RSD was the most circular. There was little change in the ellipsoid measurement for each class between the original and repeat photo plots, except for MG, with a shift from 0.5 in the original photo plot to 0.36 in the repeat photo plot. This indicates that the average meadow shape had become increasingly ellipsoidal over time.

Percent Overlap: The highest amount of percent overlap by far for this plot occurred in ASG class (59.87%), followed by MG (4.35%), and RSD (2.34%) (See Table 1).

Historical and Current Landscapes Post Burn: Plot 419

Area: The original photo plot had patches in all classes except for VFE. RSD had the highest percent coverage, followed by ASG, and then MG. ASG had the smallest number of patches, followed by RSD. The MG class had by far the highest amount of patches even though it had the lowest percent coverage. The repeat photo plot had patches in all of the classes, but the majority of the percent coverage (over 50%) was the VFE class, which is attributable to the prescribed burn. The rest of the classes combined covered less then 10% of the landscape (Charts 1 & 2). Although the original photo plot had over three times the total amount of patches compared to the repeat photo plot, the total class percent coverage between the two plots only differed by 5%.

Shape: ASG had the least complex average patch shape in the original 419 photo plot, followed by RSD, and then MG. The average shape of the MG class in the repeat photo plot was the most complex; followed by RSD, ASG, and the VFE class was the least complex (Chart 3).

There was very little change in ellipsoidal shape between the classes in the original and repeat photo plots. In the original photo plot, the most ellipsoidal class was RSD, followed by ASG, then MG. In the repeat photo plot, the most ellipsoidal class was ASG, followed by RSD, then MG and VFE was the least ellipsoidal (Chart 3).

Percent Overlap: ASG had the highest percent overlap between the current and original extent (15.1%), followed by MG (3.5%) and RSD had less than 1% overlap between the historical and current landscapes (Table 1).

<u>Comparing Pre and Post Burn Plots 420 and 419</u>:

Area: The total class coverage varied more between stations then it did between the original and repeat photo plots from each station (Charts 1 & 2). The difference between stations in total class coverage was ~33%, while the difference between each stations' original and repeat photo plots was ~5% for both sites. At both stations, this difference was shown as increased class coverage in the repeat plot.

Shape: The difference in complexity for each class, both within stations and between stations was not great (Chart 3). The biggest difference (0.06) in complexity was between the ASG class in original and repeat photo plots.

The largest difference in circularity (Chart 3) between the stations occurs between the average for the historical burn in the original plot 420 (0.18) and the average for the PB in the repeat plot 419 (0.38). ASG and RDS all had greater differences in circularity between stations then between original and repeat photo plots. MG had very similar circularity values for all of the plots (0.35-0.36), with the exception of the original photo plot from station 420

(0.5), indicating a considerably more circular average meadow shape for that plot.

The historical burn had the most ellipsoidal shape out of all the classes in both the original and repeat photo plots from stations 419 and 420, while the prescribed burn had the least ellipsoidal shape out of all the classes.

Percent Overlap: In order to make comparisons between the two sites, I calculated the total percent overlap for all the classes combined divided by the total cumulative class area of the original photo plot for each station. In plot 420, there was 45.9% overlap between the cumulative repeat and original classes. In plot 419, 65.8% of the of the repeat patch classes overlapped with the patch classes in the original photo plot (Table 1). However, a large amount of this overlap can be attributed to the extensive area affected by the prescribed burn, which was encompassed by the VFE class in the repeat photo plot.

To examine how the prescribed burn responded to previous vegetative patterning, I calculated the percent of overlap for the prescribed burn by comparing how much of the burn overlapped with all the original classes combined, and this was 56.6%. I also calculated the percent overlap from the VFE class in the original photo plot 420 with the cumulative repeat patch classes, and this amounted to 3.5%. The percent overlap for the each of the patch classes was similar between the two stations, except for the ASG class. In plot 419 there was 15.1% overlap for this class, and in plot 420, the ASG class had 59.8% overlap (Table 1), however, this is also likely attributable to the dominance of the VFE class in 419, covering regions that may have otherwise been considered ASG prior to the burn.

Discussion

Fire regimes in montane regions that historically had mixed fire regimes can be difficult to establish (Morgan, 2001). Analysis of spatial patterns of disturbance events that contribute to vegetative mosaic is critical for better understanding historical fire regimes and for effective landscape management (Andison, 2003). Patch analysis offers insights into landscape structure and disturbance regimes that may otherwise be overlooked in traditional fire history studies such as time since fire mapping and dendrochronological work (White, 2002). This study outlines possible ways of classifying patches to make temporal comparisons between two landscapes, both over time, and before and after a disturbance event.

Both stations show a dramatic decrease in the number of patches between the original and repeat photo plots. However, the total amount of class coverage increased slightly between the original and repeat photo plots at each station. At station 420, this increase was in ASG, but all other classes had decreased. The decrease in the number of patches and diversity of coverage type may be attributable to decreased fire events caused by fire suppression that leads to the homogenization of forest cover and forest in growth (Agee, 1998). This would explain the decrease in the MG and RSD class coverage at this station. The increase of the number of ASG patches and coverage in the repeat plot from the original plot does not indicate an increase in Aspen, however, and the generality of this class may be misleading. This class was designed to show an earlier seral stage then the matrix, not to identify solely Aspen stands. White & Feller (2004) document decreases in aspen stands over time in montane ecosystems, and these are attributed to changes in the fire cycle. Further patch analysis would benefit from a more comprehensive classification scheme then outlined in this study.

Patch complexity and circularity appear to be proportionately related at station 420, i.e. the rank from lowest to highest circularity generally follows the same lowest-highest ranking for complexity. There is little variation in either of these metrics at station 419, with the exception of the PB class, which is discussed later. It is difficult to say at what point a change in either metric is ecologically significant as this level of statistical analysis was outside the scope of the study. The pattern from these two shape metrics does show, however, that all classes increased slightly in both complexity and circularity in the repeat plot for station 420, except for MG. This change in meadow shape may indicate a change in size as previous studies have documented loss of meadows in the montane and alpine environments (Shaw, 2009, unpublished manuscript). The increase in complexity and circularity of the rest of the classes in the repeat may also be attributable to a change in the size of the patches. The decrease in the diversity of class coverage shown in the percent coverage analysis, which also favored an increase of ASG coverage, indicates a trend towards homogenization in the repeat plot. The decrease in the number of patches, yet maintenance of overall coverage in the repeat plot may be linked the shape change in the classes (Agee, 1998). The high circularity of the PB class for the repeat plot at station 419 may indicate that the fire was influenced by heterogeneous fuel and/or weather conditions (Finney, 2001). It should be noted that the Fire Evidence class in the original photo plot at station 420 had the lowest amount of circularity compared to the other classes. This indicates a change in fuel and weather conditions between the two events. In his study of patch edge characteristics, Agee (1998) found that “moderate-severity fire regimes appear to have considerably more edge than low- or high-severity fire regimes (p. 29). This may explain the slightly higher value in the complexity of the historical Fire Evidence class in comparison to the PB class. Had a fire occurred in the modern landscape outside the controlled parameters and weather conditions of the PB, then the difference in this value may have been even greater.

According to Andison (2003) meadow patches tend to be more persistent over time, and forested patches more dynamic. This may explain some of the trends in the percent overlap (Table 1) for the classes at both stations. The overlap for MG is similar at both stations, and the percent coverage at station 420 is also close. The decrease in meadow percent coverage at station 419 may be attributable more so to the overall coverage of the prescribed burn, and perhaps less to the actual decrease in meadow extent, but further analysis is required to support this. Finney (2001) reiterates van Wagtendonk's (1995) work in Yosemite National Park that documented fire behavior being affected by the landscape structure of previously burnt regions. Finney than goes on to state that Finney (2001) states that fuel type has little affect on the shape of a fire, but greatly affects the size of a fire as intrinsic spread rates vary in different fuel types. Fire behavior is governed by three things, fuel, weather and topography (Agee, 1998). Under extreme weather conditions or at larger scales, fuel may play a relatively minor role in dictating fire behavior (Johnson et al., 2000). At smaller scales fuel (i.e. vegetative pattern) may have a larger influence on the pattern left behind by fire. This should be taken into account when considering PB fire behavior, as burning often occurs under favorable weather conditions to prevent major conflagrations or fire escapes. In plot 419, the PB class had a high amount of overlap with rest of the existing classes, indicating that the underlying vegetative pattern may have contributed the pattern left by the fire. Further research into developing a metric like percent overlap could potentially give land managers a tool for identifying regions that are more or less likely to succumb to catastrophic fires based on existing vegetative pattern.

While previous vegetative pattern plays a role on fire behavior and burn pattern, large fire events are expected to be driven more by weather conditions then fuel conditions (Bessie & Johnson, 1995; Agee, 1998). However, the loss of historical vegetative pattern has a more dramatic effect in regions with historically moderate or mixed fire regimes. The loss of pattern through in-growth and densification increases the fuel load in these regions making them much more susceptible to high intensity fires, especially in the context of extreme weather conditions (Agee, 1998). Montane landscapes such as the R11 may have had less severe, and more frequent fires historically than today, but also infrequent, high intensity fires, that have the longest lasting effects on vegetative pattern (Rogeau, 2008).

A number of elements associated with the study design may be potential limiting factors in the results of this study. This includes the mis-classification of a patch or stand in the repeat or original photograph and the generalization of seral stages into only four classes. Because all the patches were classified by hand, I was limited to how many classes I could easily identify, as well as how many plots I could classify. A more comprehensive study would benefit from automating the classification based on pixel values. However this would require developing a way to match exposure values between the repeat an original photographs with was too complex for the scope of this study. I did compare grayscale values for the classes to see if a range of values could be defined for each class, but there was too much overlap between the classes based on exposure values, which didn't accurately depict the vegetative coverage. Cloud cover, for example, could greatly alter the pixel value of forested patch, compared to the same patch in sunlit conditions. These differences were accounted for to the best of my abilities by visually classifying the photographs myself.

Conclusion

Fire as a natural ecosystem disturbance is affected by its interaction with the landscape (Peterson 2002). In turn, vegetative pattern is shaped by disturbance events, such as fire (Turner & Romme, 2004). This study explores a number of methods that can be applied using repeat photo pairs in comparing variations in vegetative pattern over time, as well as before and after disturbance events—in this case, prescribed fire. The results of this study show that between the original and repeat photo plots at both stations, the number and diversity of patches decreased, but the overall percent coverage increased slightly. The decrease in the number of patches, yet maintenance of overall coverage in the repeat plot may be linked the shape change in the classes (Agee, 1998). These results support my first hypothesis that there are differences in patch type, coverage, and shape that indicate a decrease in heterogeneity between original and repeat photographs. This is supported by literature stating that smaller, less intense disturbances historically maintained more heterogeneity in the landscape. My second hypothesis, that vegetative pattern exiting prior to the PB influenced the pattern left by the prescribed burn, may be supported by the degree of percent overlap between the repeat and original photos, but further analysis of this metric is required before making any concrete statements. Comparing patch size, shape, and density between historical and current landscapes provides insight to changes in landscape pattern over time, as well as the basis for reflection on potential drivers of change and their ecological implications.

References

Agee, J.K. (1998). The lanscape ecology of western forest fire regimes. *Northwest Science*, *72*, special issue, 24-34.

Andison, D.W. (2003). Patch and event sizes on foothills and mountain landscapes of Alberta. *Alberta foothills disturbance ecology research series, report No.4*. Hinton: Foothills Model Forest.

Andison, D.W. (2003). Disturbance events on foothills and mountain landscapes of Alberta (Part 1). *Alberta foothills disturbance ecology research series, report No.5*. Hinton: Foothills Model Forest.

Bessie, W.C. and Johnson, E.A. (1995). The relative importance of fuels and weather on fire behavior in subalpine forests. *Ecology, 76(3)*, 747-762.

DeLong, S.C. (1998). Natural disturbance rate and patch size distribution of forests in northern British Columbia: Implications for forest management. *Northwest Science 72*, special issue, 35-48.

Finney, M.A. (2001). Design of regular landscape fuel treatment patterns for modifying fire growth and behavior. *Forest Science, 47(2)*, 219-228.

Morgan, P., Hardy, C.C., Swetnam, T.W., Rollins, M.G., and Long, D.G. (2001). Mapping fire regimes across time and space: understanding coarse and fine-scale fire patters. *International Journal of Wildland Fire, 10*, 329-342.

Peterson, Garry, D. (2002). Contagious disturbance, ecological memory, and the emergence of landscape pattern. *Ecosystems* vol. 5, pp.329-338.

Rogeau, M.P. (2008). *R11 forest management plan (Part 1)*. Rocky Moutain House: Alberta Sustainable Resource Development, Forestry Division, Clearwater Forest Area.

Rogeau, M.P., and Gilbride, D. (1994). Fire history of Banff National Park, Alberta. *Resource Conservation, Banff National Park.* Courtesy of Rick Arthur, February 10, 2010.

Sackett, S.S., Haase, S.M., and Harrington, M.G. (1995). *Lessons learned from fire use for restoring southwestern ponderosa pine ecosystems*. Presented at the Conference on Adaptive Ecosystem Restoration and Management.

Shaw, A.K. (2009). *Conservation and ecological restoration of Rocky Mountain subalpine meadows: understanding vegetation responses to tree encroachment.* Unpublished masters thesis, University of Victoria, 2009.

Turner, M.G., and Romme, W.H. (1994) Landscape dynamics in crown fire ecosystems. *Landscape Ecology* vol. 9, no. 1 pp. 59-77.

Turner, M.G., Gardner, R.H., and O'Neill, R.V. (2001). *Landscape ecology in theory and practice: pattern and process*. Springer Science and Business Media, LLC.

White, C.A. (1985). *Wildland fires in Banff National Park 1880-1980.* Occasional Paper No.3. National Parks Branch, Parks Canada, Environment Canada.

White, C.A., Feller, M.C., Pengelly, I., and Vera, P. (2002). New approaches for testing fire history hypotheses in the Canadian Rockies. In Bonrup-Nielson, S., N.W.P. Munroe, G. Nelson, J.H.M. Willison, P. Herman, and P. Eagles (Eds.) *Managing protected areas in a changing world: Proceedings of the fourth international conference on science and management of protected area* (pp. 398-411). Wolville: SAMPAA.

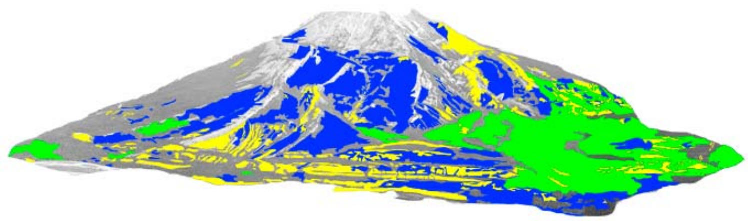
White, C.A., Pengelly, I.R., Zell, D., and Rogeau, M.P. (2003). Landscape fire regimes and vegetation restoration in Banff National Park, Alberta. *Parks Canada Occasional Paper.* Banff: Parks Canada.

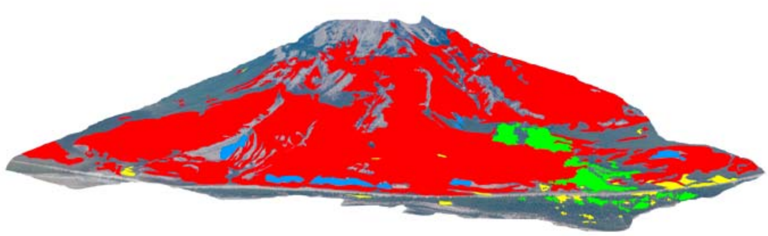
White C.A., and Feller, M.C. (2004). Repeat photography of montane trembling aspen in the Canadian Rockey Mountains. In Engstrom, R.T., K.E.M. Galley, and W.J. de Groot (Eds.), *Proceedings of the 22nd Tall Timbers fire ecology conferences: fire in Temperate, Boreal, and Montane ecosystems* (pp. 2-22). Tallahasee: Tall Timbers Fire Ecology Research Station.

Weir, J.M.H., Johnson, E.A, & Miyanishi, K. (2000). Fire frequency and the spatial age mosaic of the mixed-wood boreal forest in western Canada. *Ecological Applications 10(4),* 1162-117.

Appendix

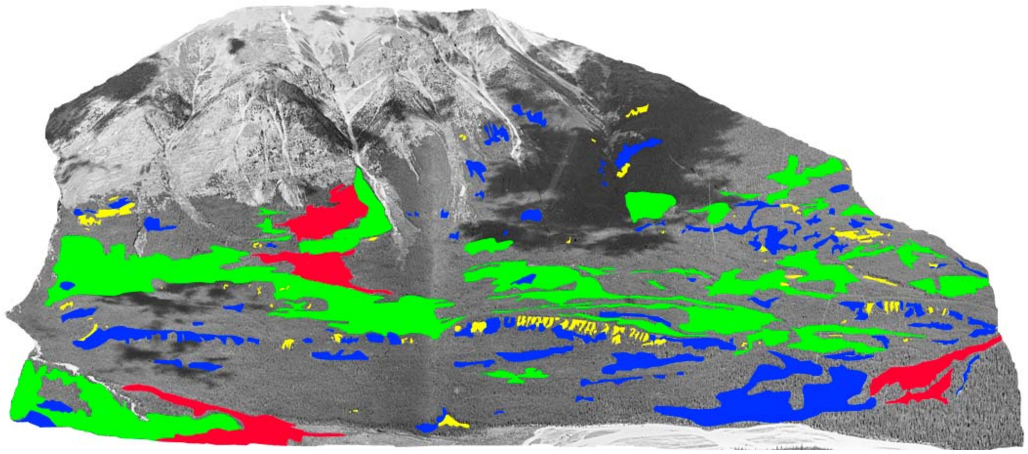
Figures 2.1 and 2.2: Original and Repeat 419 Classified[6] Plots

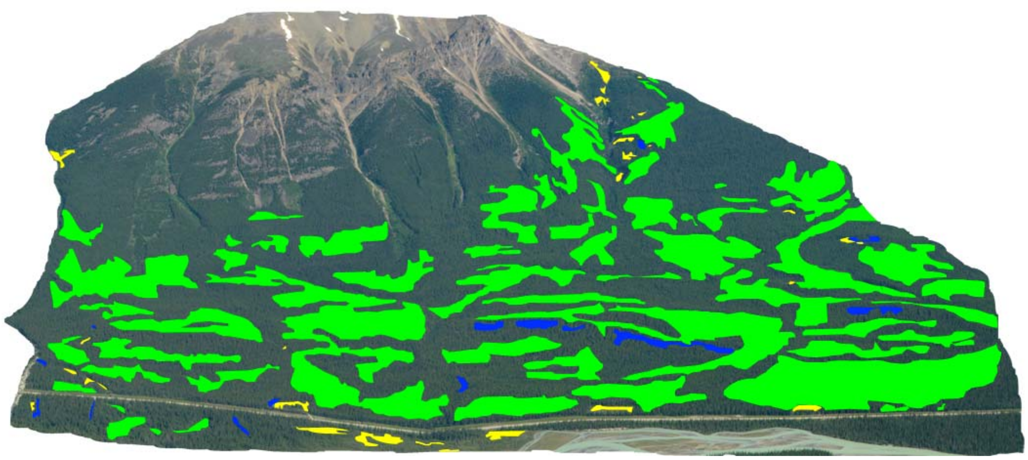




[6] Red=Visible Fire Evidence, Green=Aspen/Second Growth, Blue=Reduced Stem Density, Yellow=Meadows/Open Ground

Figures 2.3 and 2.4: Original and Repeat 420 Classified[7] Plots





[7] Red=Visible Fire Evidence, Green=Aspen/Second Growth, Blue=Reduced Stem Density, Yellow=Meadows/Open Ground

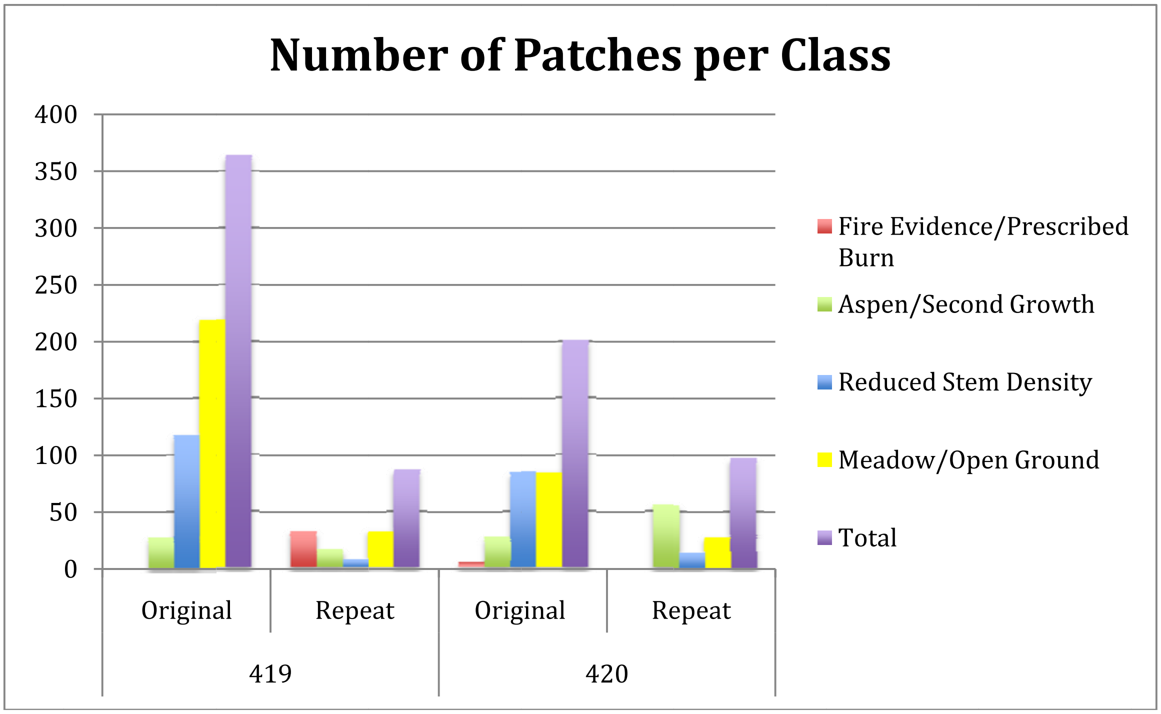


Chart 1: Number of Patches Per Class in the Original and Repeat Photo Plots for Stations 419 and 420.

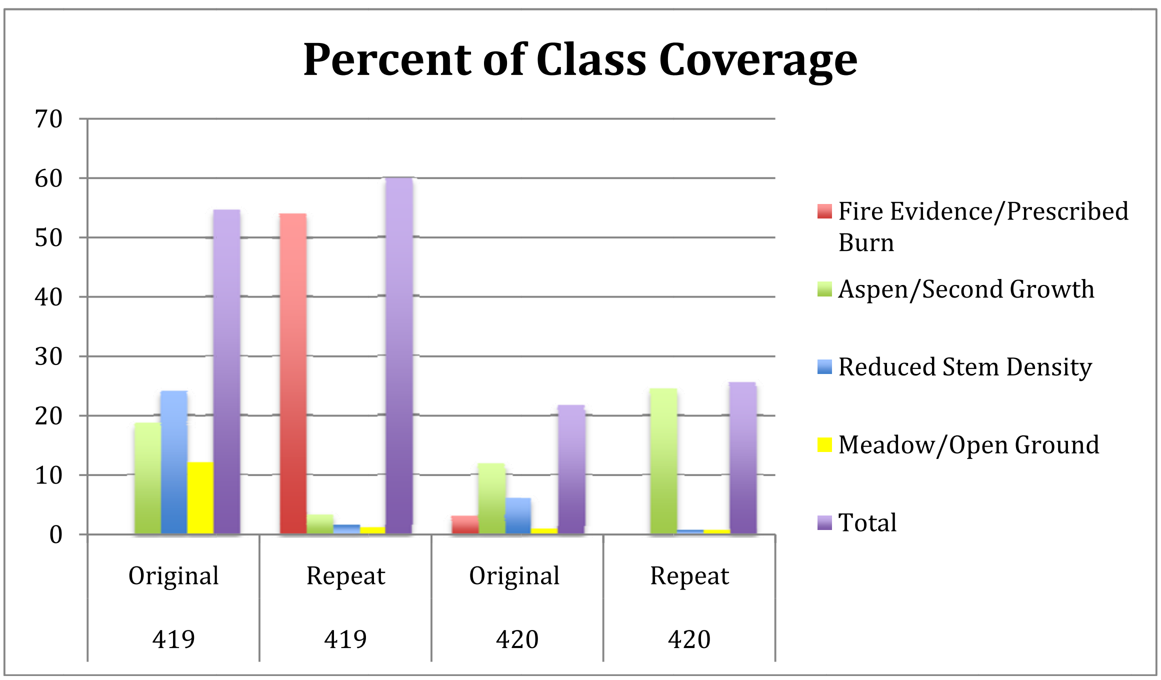


Chart 2: Percent of Class Coverage in the Original and Repeat Photo Plots for Stations 419 and 420.

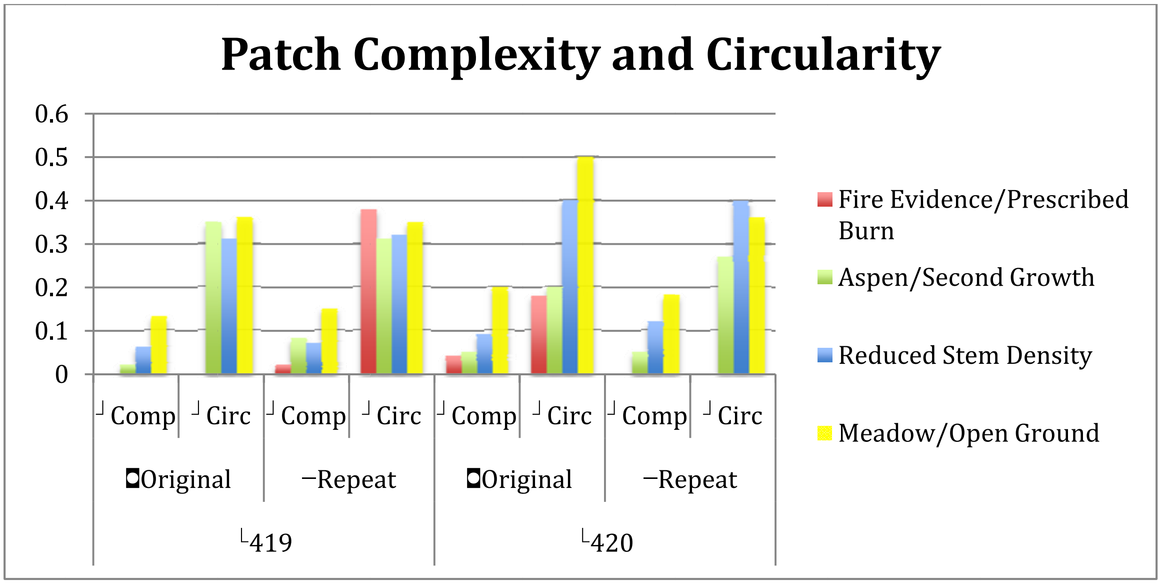


Chart 3: Patch Complexity and Circularity for the Original and Repeat Photo Plots at Stations 419 and 420.

Percent Overlap	**419**	**420**
Aspen/Second Growth	15.14	59.87
Reduced Stem Density	0.65	2.34
Meadow/Open Ground	3.8	4.35
Prescribed Burn[8]	56.5	n/a
Fire Evidence[9]	n/a	3.48
Total Overlap	65.81	45.91

Table 1: Amount of Percent Overlap Between the Original and Repeat Classes at Stations 419 and 420.

[8] Percent of PB that overlapped with total original classes.
[9] Percent of fire evidence that overlapped with the total repeat classes.