FINAL REPORT

Wildfire Event Patterns in the Northwest Territories

Final Report

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The contents of this report are being translated into a manuscript for peer review and publication.

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1.0 INTRODUCTION

The evolution of forest management in North America has been an ongoing process, but one that has inevitably been moving towards the goal of sustaining all forest values. Forest management is now expected to manage for a wide range of biological values including water and nutrient conservation, toxin filtration, carbon cycling, fish and wildlife habitat, food, pharmaceuticals, and timber (Seymour and Hunter Jr., 1999).

Under the auspices of this task, the concept of the using forest patterns created by natural processes as management guides is gaining favour in North America (Kuuluvainen and Grenfell, 2012). The theory is attractive: by maintaining the type, frequency, and pattern of change on a given landscape, we are more likely to sustain historical levels of the various biological goods and services. So-called "coarse-filter" knowledge can also be applied directly and immediately to planning and management programs.

Natural pattern knowledge can be applied to a wide range of forest management planning issues, at all levels of planning. Fine-scale information such as the density of disturbed patches or the amount and types of undisturbed vegetation

There has been considerable interest in using fire patterns as a benchmark to support sustainable forest management across the boreal regions. This is particularly evident in Canada, while in the Eurasian boreal forest the majority of the information to-date remains theoretical (Kuuluvainen and Grenfell, 2012). In particular, in the last two decades multiple management agencies and certification bodies in Canada required forest management plans to include some level of natural pattern approximation. This generally involves to apply knowledge of spatial mortality patterns created by fire as coarse-filter indicators to guide forest harvesting (Perera and Buse 2004). Several provincial guidelines have been implemented at the provincial level to emulate fire disturbances via characterizing the size of the clearcuts and the amount and spatial distribution of the tree vegetation remnants, such as in Ontario (OMNR 2001). Also certification agencies such as the Forestry Stewardship Council (FSC) have included fire pattern indicators as part of their requirements for the Canadian boreal region (FSC, 2004). In addition to guiding harvesting planning, there is an increasing interest in HRV to assess the risk of biodiversity loss via analyzing departure from the natural state of multiple anthropogenic activities (Pickell et al., 2016). Regardless of the application, a key requirement for the implementation of HRV approaches is the definition and characterization of the variability of spatial patterns created and maintained by fire (Boulanger et al., 2013, 2012).

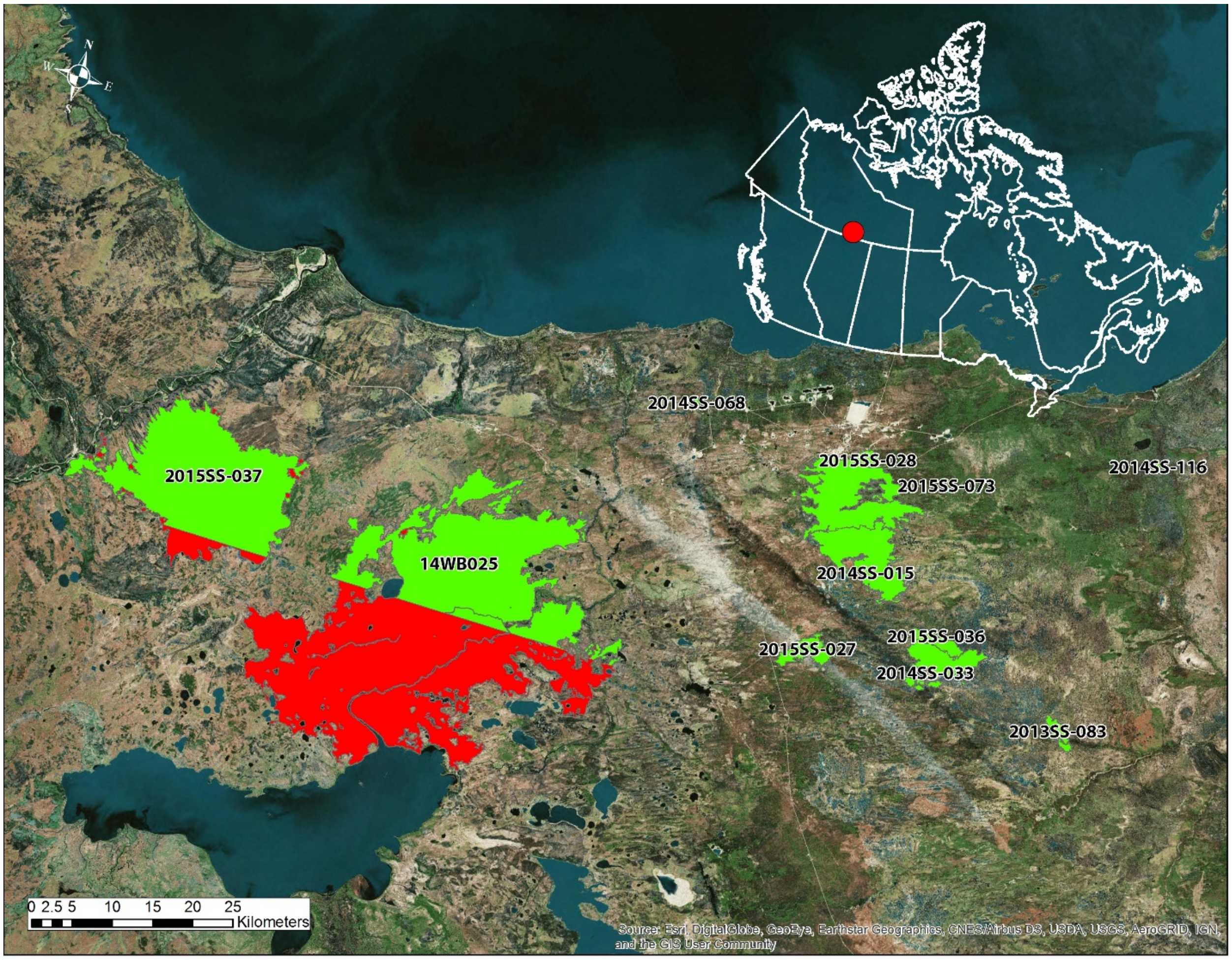
This report summarizes the detailed results from 11 fire events in the Taiga Plains ecozone of the Northwest Territories for which detailed polygons of mortality were available.

2.0 STUDY AREA

The area of study comprises 11 fire events in the Taiga Plains ecozone of the Northwest Territories that occurred in 2013 (1), 2014 (5) and 2015 (5) and covered 87,046 ha (Figure 1).

According to the forest inventory data (FID) 53% of the total area is forested (>10% canopy coverage (cc)); of which <1% is dense forest (>60% cc), 54% corresponds to open forest (25-60% cc), and 45% is sparse forest (10-25% cc). 62% of that forest is dominated by conifers (mostly black and white spruce, and jack pine on drier, sandy to gravelly sites), 37% by mixed conifer and hardwoods (on well drained sites white and black spruce with balsam poplar or aspen with highly diverse understory are typical of early to mid-successional landscapes), and 1% by hardwoods alone (balsam poplar and/or aspen). The terrain is flat and generally with high phreatic level (38% of the total study area corresponds to wetlands), thus the forest most often occurs on the uplands such as alluvial terraces. The difference between wetland and upland is often only several meters, thus episodic tree flooding mortality is common throughout.

Of the 47% that corresponds to non-forested vegetation 94% is vegetated (>5% vegetation cover) most often occurring in flat poorly drained sites that support fen and bog development. These areas are dominated by tall shrubs (>2m), followed by short shrubs, bryoids, herbs and graminoids, with some stunted black spruce. The reminder 6% of the non-forested area is non-vegetated of which 65% was water and 45% bare land.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 1. Fire sample selection for the aerial photo-interpretation process (south of the Great Slave Lake). In green are the areas selected for the photo-interpretation process. In red are the two missing pieces for which we did not have complete image coverage belonging to the fires with ID 2015SS-37 and 14WB025.

3.0 METHODS

3.1 AERIAL PHOTO-INTERPRETATION DATA

The process of photo-interpretation (API) involved the production of vector (i.e., polygon) delineations of tree mortality. The photo-interpreter, Derek Fisher from Greenlink Forestry Inc., delineated polygons of tree mortality using Softcopy software (for 3D visualization) from overlapping post-fire aerial digital scans of photo negatives by identifying dead trees or shrubs (where available) or changes in colors and texture attributable to the fire event and indirectly by interpreting the context and other signs of fire activity (e.g. vegetation residuals and presence of char or ash) based on 0.3m spatial resolution acquired within two years of the fire. The six classes were defined based on the percentage of crown loss or degree of consumption of lower vegetation attributable to the fire event, as follows: 0-5, 6–25, 26–50, 51–75, 76–94 and 94%. The minimum mapping unit was set conservatively to 0.01 ha, or 10 m^2, which represents a clump of approximately three trees. (Figure 2).

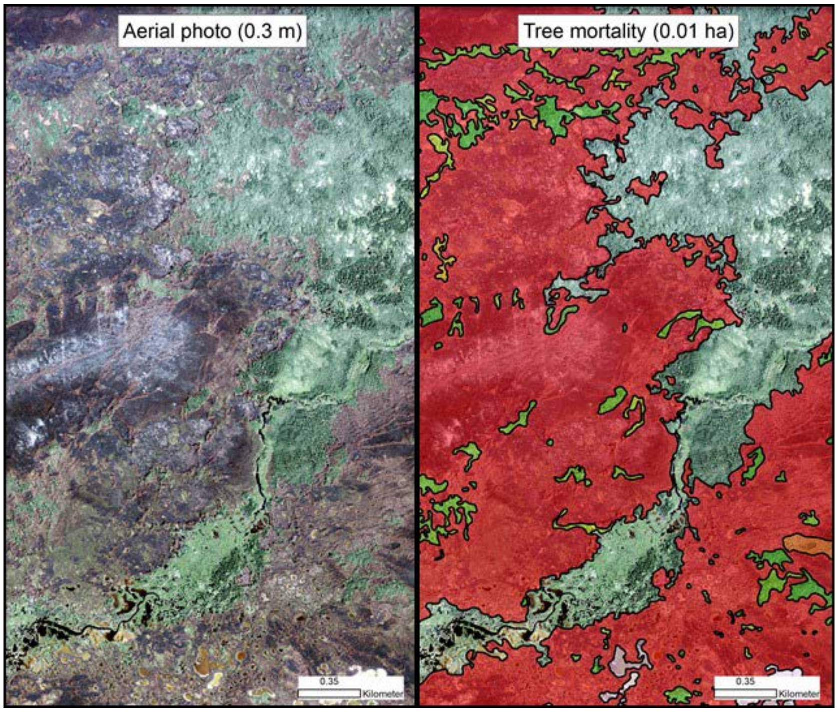


Figure 2. Comparison of aerial imagery (left), polygons of tree mortality from aerial photo-interpretation (middle) and Landsat differenced Normalized Burn Ratio (right)

3.2 SPATIAL LANGUAGE FOR DESCRIBING FIRE PATTERNS

The study of spatial fire patterns requires thematic maps of mortality that identify areas with relatively homogeneous fire effects (Key and Benson, 2006). It also requires of a consistent spatial language to translate the thematic maps of mortality into simplified and spatially-discrete units, or patches, whose patterning can be described via different key attributes, or landscape metrics (Mcgarigal and Marks, 1994). This generally involves the definition of the area of influence of a fire and the different patch-types within. Concepts such as 'fire perimeter' or 'island remnant' may be intuitively obvious but they have resulted in a range of spatial interpretations that make comparing or combining fire pattern studies difficult (Andison, 2012; Perera et al., 2007). To guarantee the comparability of the fire pattern study results, Andison (2012) proposed a universal spatial language and associated fire pattern metrics that we here adopted to define and characterize fire events from pixel mortality maps derived from aerial photo-interpretation. A detailed explanation of the process is provided below.

The spatial language by Andison (2012) converts raw mortality maps into three patch types: 'disturbed areas', 'island remnants', and 'matrix remnants'. Disturbed areas and island remnants are both elements of fire mortality maps, and are commonly referred to in studies about vegetation remnants, although rarely similarly defined. Matrix remnants was added by Andison (2012) to capture other areas of influence of a fire that lie beyond the boundaries of disturbed patches, such as corridors between and peninsulas within disturbed patches. The disturbance event boundary was originally generated by Andison (2012) using a 200 m in-and-out buffering algorithm using polygon data. Disturbance events are created as follows. First, all polygons of the complete mortality class (94-100% mortality) from the raw mortality maps are assigned to the disturbed class; likewise, polygons of the partial mortality class (6-94% mortality) become island remnants. Second, the disturbed and island remnant areas are combined to delineate the boundaries of individual disturbed patches within each fire. Third, disturbed patch boundaries were buffered out 200 m, and any internal holes or donuts filled in. Lastly, the result was buffered back 200 m. The final product defined the outer boundary of a disturbance event. The new vegetation remnants areas created by this buffering exercise are called matrix remnants. A conceptualization of the process is included in Figure 3.

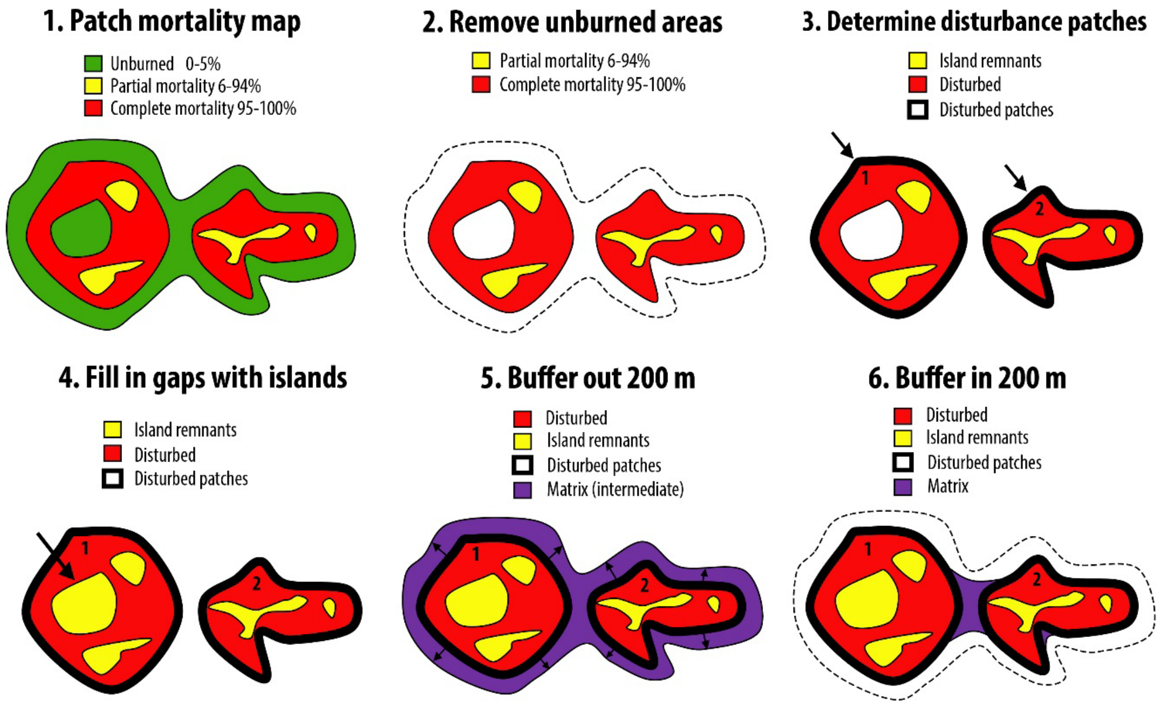


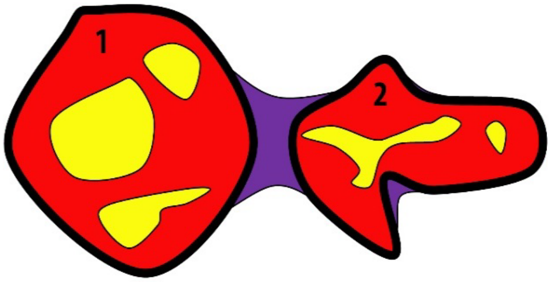
Figure 3. Conceptualization of the spatial language and metrics proposed by Andison (2012).

3.3 FIRE PATTERN METRICS FOR SINGLE FIRES

The characterization of fire patterns typically involves the use of a suite of metrics that represent the spatial distribution of fire patterns at fine to meso-scales on the landscape (Keane et al., 2009). When information from various fire events is combined, the broad-scale patch arrangement within fire events can be analyzed in both temporal and spatial scales to inform management plans (Morgan et al., 2001). Many metrics can be generated to quantify landscape structure of landscape patterns, with the most relevant often depending on the application (Landres et al., 1999). To characterize the amount and arrangement of fire patterns from the discrete patch-fire events Andison (2012) proposed ten fire pattern metrics that have been used to help guide harvesting planning in Alberta and Saskatchewan over the last 10 years (Andison and McCleary, 2014). We chose to calculate eight of those metrics, plus one additional one here (Table 1). To characterize the size and complexity of the fire event perimeter, we used the 1) event area and 2) the shape index metrics, respectively. To characterize the details of the amount of remnants we used 3) the percentage of total remnants, 4) the percentage of island remnants and 5) the percentage of matrix remnants. To capture the patterns of disturbed patches within events, we calculated 6) the absolute number of patches in each even, 7) the shape of disturbed patches, and 8) the percentage of the largest disturbed patch relative to the total event area. We added to this list 9) a breakdown of the mortality classes for total remnants. An example of some of these metrics calculated for a single fire event is included Figure 4.

Table 1. Summary of the spatial fire pattern metrics used in this study.

Scale	**Indicator [unit]**	***Formula***	**Interpretation**
Event	Event area [ha]	*EA = Matrix remnants + disturbed patches*	The total area affected by the fire
	Shape index [no units]	*Ratio of event perimeter with that of a circle of the same size.*	Measures the complexity of the perimeter of an event
Within Event	Number of disturbed patches [patches]	*Count of dsiturbed patches per event*	Disturbed patch density, by event
	Shape index of disturbed patches	*Ratio of disturbed patch perimeter to that of a circle of the same size*	Measures the complexity of the perimeter of disturbed patches
	Percentage of largest disturbed patch [%]	*(Area of the largest disturbed patch / EA) * 100*	Size dominance of the largest disturbed patch
	Percentage of matrix remnants [%]	*(Total area of islan remnants / EA) * 100*	Percentage of area in residuals physically attached to the surrounding matrix of intact forest
	Percentage of island remnants [%]	*(Total area of island remnants / EA) * 100*	Percentage of area in residuals lying entirely within disturbed patches
	Percentage of total remnants [%]	*(Total area of island remnants + total area of matrix remnants) / EA) * 100*	Percentage of area in vegetation that survives in some form
	Percentage of partially disturbed remnants (%)	*(Total area of all remnants in each remnant mortality class/ total remnant area) * 100*	Breakdown of remnant area by survival class



Calculated patch metrics

Event area = 300 ha
Shape index = 8
% of island remnants = 40%
% of matrix remnants = 8%
% of total remnants = 48%
Number of disturbed patches = 2
% of largest disturbed patch = 15%

Figure 4. Example of fire pattern metrics for a wildfire event.

4.0 RESULTS AND DISCUSSION

How to read a violin plot: ‘Violin plots’ are a good way of presenting data from small sample sizes with non-normal distributions. They include the standard statistical ***box and whiskers*** diagram identifying useful median and quartile boundaries. But the shape of the violin itself also represents the relative sample density. For example, a violin shaped like a vase - narrow at the top and fat at the bottom – describes a positively skewed distribution (i.e., towards lower numbers) distribution.

4.1 HOW LARGE ARE DISTURBED EVENTS?

The total area of all fire events was 91,942 ha. The median event size was 1,863 ha with a mean of 8,358 ha, which implies that the distribution was heavily skewed towards smaller fires. In fact, the two largest fires larger than 30,000 ha accounted for 74% of the area disturbed or 67,819 ha. Those two fires also corresponded with the events that were not completely mapped out (see section 2), which means their actual size was even larger. The size of the remaining nine fires ranged between 22 and 10,578 ha (Figure 5).

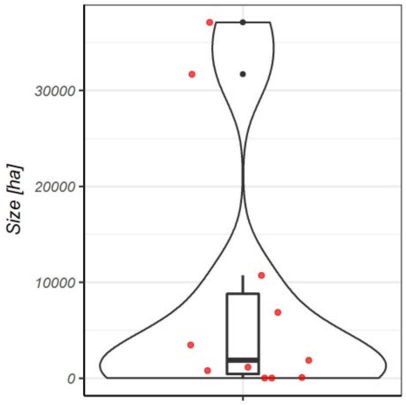


Figure 5. Violin plot of event size (ha). Individual fires are represented as red dots.

4.2 WHAT SHAPE ARE DISTURBANCE EVENTS?

A shape index is the ratio of the actual outside perimeter of a polygon, to the outside perimeter of that area if it were a perfect circle. A circle represents the least possible amount perimeter for a given area, represented by a shape index of one. A shape index of two means that the length of a polygon perimeter is exactly twice as long as it would be for a circular polygon of the same area.

Event shapes were simple, ranging from 1.2 to 3.5 with an average of 2.0. Shape index significantly increased as events become larger as suggested by the equation below. For example, the shape of a 1,000 ha event averaged 1.6, 1.7 for a 4,000 ha event, and 2.0 for a 10,000 ha event (Figure 6).

$$Event\ Shape = 1.54 + 0.0000547(Event\ size)$$

$$n = 11, \qquad Adjusted\ R2 = 0.68, \qquad P =< 0.01, \qquad F = 22.0$$

It is notable that the largest event had the most complex shape. Recall that this event was artificially truncated (see Figure 1) and represented by a straight line for part of its perimeter. This suggests that its actual shape of the full event is more complex than observed.

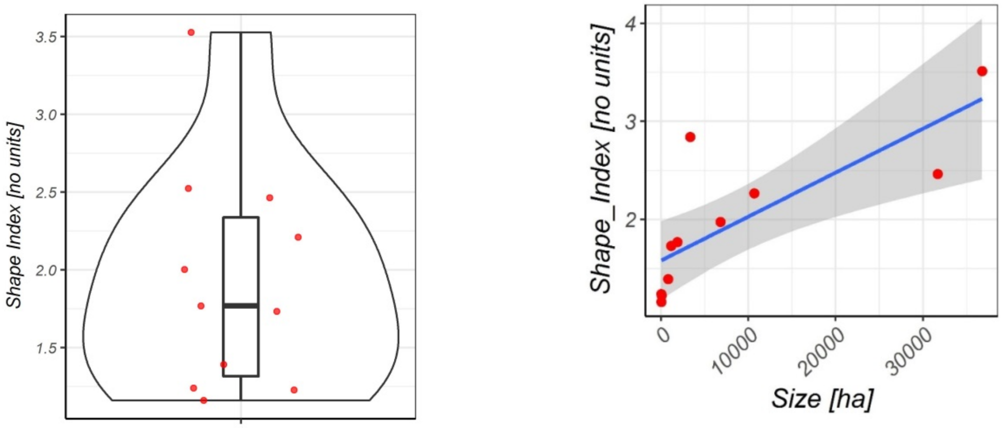


Figure 6. Violin plot of event shape (left) and the relationship between event shape and size (right). Individual fires are represented as red dots, the blue line as the equation given above, and the shaded area the confidence interval associated with the equation.

4.3 HOW MANY DISTURBED PATCHES ARE IN AN EVENT?

Of the 11 disturbance events in the sample, two (18%) had only one patch, six (55%) had 2-4 patches, four (36%) between 5-35 disturbed patches, and one fire had 119 patches (Figure 7). There was a significant linear relationship between event size and the number of disturbance patches:

$$No.of\ Disturbed\ Patches = 4.33 + 0.0018(Event\ size)$$

$$n = 11,\ Adjusted\ R^2 = 0.44,\ P = 0.015,\ F = 8.9$$

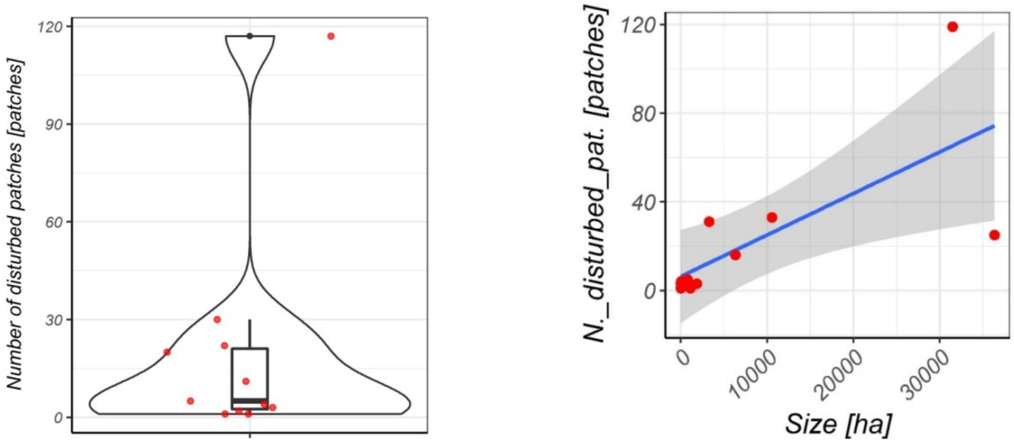


Figure 7. Violin plot of disturbed patch density per event (left) and relationship between disturbed patch density and event size (right). Individual fires are represented as red dots, the blue line the equation from above, and the shaded area the confidence interval associated with the equation..

However, note the strong influence of the largest fire, and the large amount of variation in disturbed patch density for the other fires (Figure 7). If the largest fire was not included in the data, there would have been no significant relationship between event size and number of disturbed patches (thus the reason why both the violin plot and the relationship with event size are given in Figure 7).

4.4 HOW BIG IS THE LARGEST DISTURBED PATCH?

The data suggests that most natural fire events in the sample were dominated by a single large disturbance patch. As previously mentioned, two of the events in our sample only had one disturbed patch. Overall, on average the largest accounted for 76% of the event area, with a median of 79%, and a range of 50-93% (Figure 8). The middle two quartiles (i.e., the middle 50% of the data) were relatively tightly grouped between 73-88%.

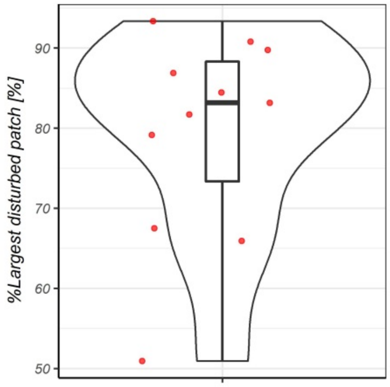


Figure 8. Violin plot of the % of the event accounted for by the largest disturbed patch.

There is no significant relationship between the proportional area of the largest patch, and the total size of the disturbance. In other words, it is just as likely that a 1,000 ha event had a 800 ha disturbed patch than it was a 10,000 ha event had a largest disturbed patch of 8,000 ha.

4.5 WHAT IS THE SHAPE OF DISTURBED PATCHES?

Disturbance patch shape was defined as was event shapes from section 4.2 using a circle as the reference point for a minimum shape of 1.0. As noted with event sizes, larger disturbed patches have more convoluted shapes. This relationship is statistically significant, as follows:

$$Disturbed\ Patch\ Shape = 1.75 + 0.000237(Disturbed\ Patch\ size)$$
$$n = 432, \qquad Adjusted\ R^2 = 0.29, \qquad P =< 0.001, \qquad F = 180.4$$

The shape of disturbed patches is far more complex than that of events, which is understandable given that events are created using a GIS smoothing algorithm. For example, using the two shape equations, the shape of a 1,000 ha event will be about 1.6, while a disturbed patch of the same size will have a shape of almost 2.0. Similarly, the shape of a 10,000 ha event will be about 2.0, while that of a 10,000 ha disturbed patch will be 4.3.

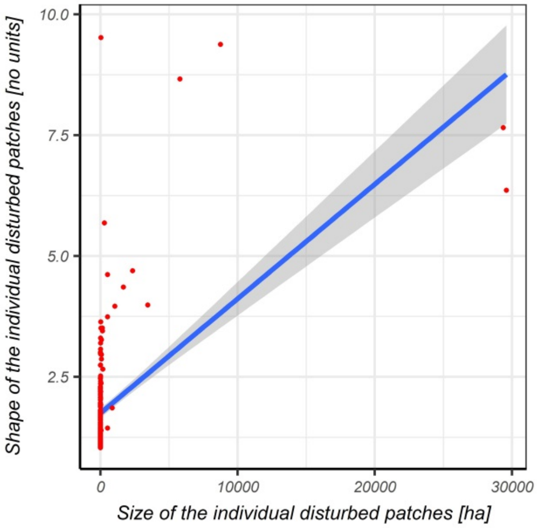


Figure 9. Relationship between disturbed patch shape and disturbed patch size. Individual fires are represented as red dots, the blue line the equation from above, and the shaded area the confidence interval associated with the equation.

4.6 HOW MUCH AND WHAT TYPES OF REMNANT AREA IS THERE WITHIN EVENTS?

The overall percent of disturbance event area in total remnants ranged between 11-68%, averaging 29% with a median of 25% (Figure 10). However, there are many different ways of summarizing the different types of fire remnants. We present two possibilities here. First, island vs. matrix, as defined by our spatial language. On average, the total remnant area was almost equally split between islands and matrix. The amount of matrix remnants averaged 14%, ranging between 6-42%. Island remnants account for the remaining remnant area, averaging 15%, and ranging between 5-32% (Figure 10). There was no significant relationship between event size and any of these three different versions of remnant areas.

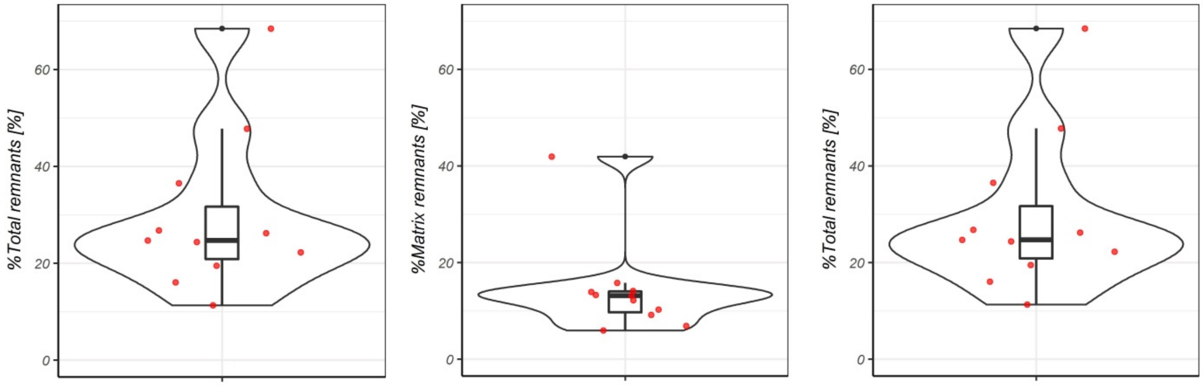


Figure 10. Percentage of event area in total remnants (left), matrix remnants (center), and island remnants (right).

The second breakdown of remnant area presented here is by mortality level, using the five remnant mortality classes described in the methods section, and presented in Figure 11. Of the average of 15% area in island remnants, most of it (12%) was partially disturbed. Moreover, *partially disturbed* vegetation in these fires was evenly represented across all five remnant mortality classes (Figure 11). When matrix remnants (which by definition experience 0% mortality) are included in the overall event estimate of remnants (i.e., islands + matrix), an average of 46% of all remnants were partially disturbed, and 54% completely undisturbed (Figure 11).

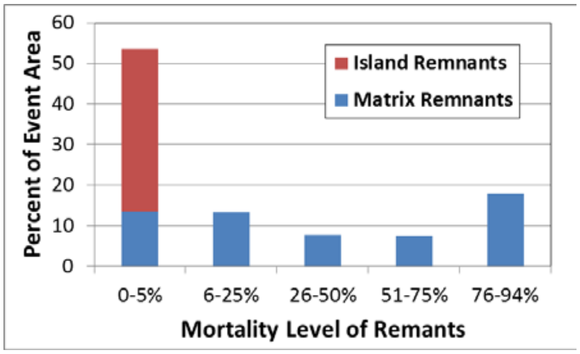


Figure 11. Frequency distribution of the average mortality levels of total wildfire remnants. Red bars represents matrix remnants (which are always 0% mortality), and the blue bars represent the various island remnant mortality levels.

5.0 DISCUSSION

As discussed in the introduction, comparing fire patterns across different areas and different studies is challenging because of the differences in spatial definitions (*sensu* Andison 2012). However, the patterns noted from Andison (2012), Andison (2013), and Andison and McCleary (2014) use exactly the same spatial language, and thus direct comparisons of the patterns noted in this study to those from the southern western boreal forest are possible, and informative.

The fire patterns from NWT are similar to those from the boreal plains-shield and Rocky Mountain foothills in many ways. First, in both cases, event shapes were generally simple, and become more complex as they got larger (Andison 2013, Andison and McCleary, 2014). Fire shape indicies found here also align with fire shapes noted by other northern boreal wildfire studies (e.g. Burton et al. 2008). Second, in both cases most fire events had multiple disturbed patches, the number of which increased as events got larger. Interestingly, the disturbed patch density of the fire events in this study were almost perfectly intermediate between the very patchy foothills fires, and the more contiguous fires of the boreal plains-shield. Third, in both cases all fire events tended to have one large patch. The average size of the largest disturbed patch in an event noted in this study (76%) was again almost midway between the 84% noted for the boreal plains-shield and the 67% average for the foothills. Fourth, the shapes of disturbed patches noted here was almost identical to those found in both the boreal-shield and foothills (Andison 2013). And finally, as with fires south of the 60th parallel, most of the area in island remnants was partially disturbed (Andison 2013).

The only differences between the burning patterns noted here and those further south were related to remnant area and type. First, the overall remnant levels from this study (29%) was significantly lower than the 41% average noted in both the foothills and boreal plains-shield (Andison 2013). Second, the even split between island and matrix remnants noted in this study was not consistent with either the foothills or the boreal plains-shield. In the boreal plains-shield, most of the remnants were in the form is islands, while in the foothills, most remnants were matrix (Andison 2013). This suggests that fires in the foothills were historically more “patchy” than those in the boreal plains, suggesting the NWT fires were intermediate in terms of patchiness.

The similarities in burning patterns between the fires from NWT in this study, and those of both the boreal plains-shield and foothills areas, are surprising. From a fire behaviour perspective, the fuel-types north of the 60th parallel change in several important ways. First, the percentage of dense forest declines significantly. Our own estimates from the underlying forest inventory suggest that only 1% of the total area of our fire sample is dense forest. Second, the proportion of wetland areas, and/or areas with “wet” soil moisture increases. And third, areas of intermittent permafrost become increasingly prevalent. Environmentally, the fire season is significantly shorter north of the 60th parallel, providing less opportunity for heavy and deep fuels to dry out sufficiently to burn. Logically, these differences all suggest that wildfires in NWT would burn more preferentially (in terms of available fuel) over space, and thus be less compact and more convoluted as regards event shape, have a higher density of patches, a less prominent largest disturbed patch, and leave behind a higher proportion of internal residuals. If anything, the opposite was true.

This suggests that available fuel-types for our sample were in fact relatively spatially contiguous. In other words, fires did not a problem finding available fuel to burn. This begs the question of how the following fuel-types are arranged on the NWT landscape; for example, a) dense vs. open forest, and b) wetlands vs uplands. A simple GIS exercise evaluating some key spatial metrics of these vegetation types may reveal an explanation for our findings – and a key to help understand how wildfires burn in NWT. For example, to what degree are the different fuel-types spatially contiguous vs. patchy?

Another possible explanation for our findings is the influence of fire weather. Eight of out 11 fires were from 2014, which had extremely high drought codes, suggesting that the water table was lower than normal, and created dry deep fuels – even in wetlands. Thus, wetlands may be more likely to be fire remnants in “normal” fire weather years, and act as wicks in extreme fire years. This would potentially create two very different burning patterns. We in fact had this question in mind when we started, but with our small sample we were unable to detect a difference in burning patterns between the 2014 fires, and those from other years. This is another new question that could be explored with a larger sample size – which is relatively easy and inexpensive to generate now that there is now a fully calibrated landsat-based predictive model for fire mortality for NWT (San Miguel et al. 2017). The challenge would be finding enough fires with pre-fire vegetation types from forest inventory or other sources – which was exactly the reason for our small sample size. As a last resort, one could simple adopt very broad vegetation types that are unlikely to change after wildfire, and most likely to be influenced by changes in fire weather indices. For example, wetland, dense forest, sparse forest, and lower vegetation as measured after the fire are likely to be the same types as before the fire.

It is also possible that the method of capturing fire mortality patterns created and used widely in the southern boreal are less appropriate for fires in the NWT. The focus of the fire mapping methods is on vegetation mortality. This works well in areas where there is obvious mortality to trees and shrubs, but less so in areas dominated by mosses, lichen, broyphytes and other lower vegetation. Aerial interpretation – whether it is by photos or satellite imagery, will classify any blackened surface (of moss for example) as 100% burned, regardless of whether it scorched the top 2-3 centimeters of duff, or consumed 50cm. Perhaps both the mapping methods and spatial language need to be modified to suit the unique NWT fuel-types.

6.0 CONCLUSIONS

This report offers a first glance at the burning patterns of wildfires in NWT relative to those in other parts of the boreal. Such a direct comparison was only possible because we used a common, well-documented sampling and mapping method and spatial language that created wildfire "events" from mortality maps. The value of adopting a common spatial language cannot be stressed enough: Without it, comparisons of even the simplest of metrics are misleading at best, and invalid at worst. The methods and spatial language created by the Healthy Landscapes Program 15 years ago have become the standard in many parts of the western boreal, the foundation for more than ten publications so far, and an automated GIS-based decision-support-tool called NEPTUNE (Natural Event Pattern Tool for Understanding Natural Events).

While many questions remain unanswered, this study provided some valuable new insights, tools, and questions for NWT regulator and managers.

In terms of new insights, the convergence of so many burning pattern metrics found in this study with those in vast parts of the western boreal south of the 60th parallel was surprising given the significantly different fuel types and fire weather conditions. However, we are only beginning to explore and understand these patterns, let alone the processes involved. San Miguel et al. (2018) was the first to test for differences in fine-scale mortality patterns across multiple ecozones of the boreal, and found several significant burn pattern "signatures". The degree to which these same ecozones align with the signatures of other fire regime attributes such as fire size, frequency, or periodicity is unknown. At this point, thanks largely to the focused effort of the HL Program, our understanding of fine-scale fire mortality patterns is far more advanced than that of any other fire regime attribute.

In terms of new tools, these results provide entirely new knowledge at a level of detail of fire patterns not previously possible. Moreover, the spatial language used here introduces some innovative and powerful new spatial concepts that are well-suited to forest management. The "event" as described in this report and by many others roughly equates to a *harvest compartment*, while the "disturbed patch" aligns with a *harvest block*. Integrating these two concepts into a single spatial language is a new, powerful way of planning and regulating how and where harvesting occurs. Conceptually, we now have a (science-based) vision of what an emulation strategy looks like. In general, wildfire events in NWT are spatially compact, have multiple disturbed patches including one very large one, and have about 1/3 of their area in remnants.

In terms of the details, the graphs and equations in this report were designed specifically to function as decision-support-tools, offering specifics in terms of not only statistical measurements, but the associated NRV for each one. Note also that the detailed graphs and equations presented in the results section of this report also represent robust, SMART (Specific, Measurable, Assignable, Realistic, and Time-bound) indicators. True, the number of different fire pattern metrics offered in the results is a lot of new information to digest. But the indicators shown in the results section should be considered a shopping list, not a "to do" list. The adoption of an NRV-based management strategy is almost always an evolution, not a revolution. The number and specifics of which metrics the NWT government chooses to adopt should be based on capacity, need, and effectiveness. Begin with the simple and basic, and move on from there. If and when the bar is raised to include more metrics, this report will provide some foundational guidance. By definition, adopting a "science-based" framework implies using the best available knowledge – which is now represented by this preliminary study.

In terms of new questions, we are well positioned in terms of furthering our understanding of fire-scale burn patterns in the western boreal overall. The HLP now has 140 natural fire samples from across the western boreal created from aerial photos, 94 of them with pre-fire information, and all of them with climate data. We also have another 507 natural fire samples from across the western boreal generated from our new Landsat predictive model, which has been calibrated for the NWT as another part of this project. New questions this study raised include:

1) How are the major fuel-types in the NWT arranged spatially?
2) Do we have enough information on the relative fire behaviour attributes of the available fuels in NWT? The Canadian FBP system is biased towards dense forest types, which means there are potentially some significant knowledge gaps in the NWT.
3) Are there significantly different mortality patterns from fires that burn during extreme fire weather conditions versus those during average or high conditions? Note that this question could easily be re-worded to reflect the likely changes to fire patterns as a result of climate change.
4) Do we need to adapt the fire mapping and spatial language standards developed south of the 60th parallel to capture fire patterns in NWT in a more robust way? What does that look like?
5) If/how to other fire regime parameters (i.e., size, frequency, periodicity, seasonality, etc) change north of 60?

In summary, this small project represents the beginning of a deeper understanding of wildfire patterns in the NWT – not the end. Clearly, many critical questions remain unanswered. However, there is more than enough new knowledge in this report to allow the government of the NWT to a) identify key pattern metrics, and b) begin exploring the veracity and logistics of some natural thresholds for key metrics of future harvesting activities. In the end, this study will allow the NWT to meet or exceed national and international requirements for sustainability based on coarse-filter indicators at fine scales.

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