FIRE RISK OF ENVIRONMENTALLY SENSITIVE SITES
MOUNT REVELSTOKE AND GLACIER NATIONAL PARKS - BC

Part I: Fire Regime Analysis of Greater MRGNP

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1.0 INTRODUCTION

This study was divided into two work phases. The first one - this document - is a fire regime assessment using already available fire record data, while the second part will involve an assessment of fire patterns in relation to spatial variables and how they apply to environmentally sensitive sites based on field data collection. This document contains the fire regime profile for both Mount Revelstoke and Glacier National Parks, as well as for a greater area well beyond the borders of the parks.

1.1 BACKGROUND INFORMATION

In May of 2000 a fire regime study for Mount Revelstoke National Park (MRNP) was completed by Rogeau (2000). This study demonstrated that the level of historical fire activity was moderate to high, with mean-fire-return-intervals ranging from 18 to 48 years and a mean fire cycle of 266 years. It was also found that a large number of fires occur at higher elevations, that they are generally small in size (less than 10 ha), and that lightning is the prevailing source of ignition (80%). A previous fire history study (Johnson *et al.* 1990), which took place in Glacier National Park (GNP) in the late 1980's, also identified a large number of fairly recent fires, and identified a fire cycle as short as 110 years since 1759.

In order to meet one of the goals of the Parks Management Plan, which is to allow natural processes to take their own course, the 2000 Fire Regime Study recommended that a fire reintroduction program be implemented as part of the forest and fire management practices of MRNP. The re-introduction of fire, whether planned or unplanned (wildfire), in both MRNP and GNP, poses a threat to locations that have been declared as Environmentally sensitive. Included in this, are the threatened (COSEWIC list as of 2000) woodland caribou population (*Rangifer tarandus caribou*), also known locally as the mountain caribou, old growth forests (OGF), as well as smaller, peculiar areas such as the Beaver Valley Fen, an ancient forest stand, and other Environmentally Sensitive Sites (ESS) (to be identified).

While MRGNP Management Plan advocates the management for a natural fire regime while protecting ESS, it does not address the protection of mountain caribou habitat from fire. A number of studies on caribou habitats have been carried out in the past for the Columbia Mountains. The Columbia Mountain Institute of Applied Ecology based out of Revelstoke, maintains web links to the Mountain Caribou Compendium (http://www.cmiae.org/mtn-caribou-compendium.htm) where a large number of abstracts related to caribou studies can be found. Overall, there is a common consensus that favourable caribou sites are diminishing from year to year. This causes great concern with regards to the future of the mountain caribou population of the Columbia Mountains, which makes use of both Mount Revelstoke and Glacier National Parks.

The potential occurrence of fire, planned or unplanned, is the object of much debate. No organizations, industry or Parks, have the logistical means and ability to guarantee that all fires in or near ESS can be extinguished. Should Parks Canada be fairly efficient at putting out all fires, as it has been in the past, the management of MRGNP under a long term, complete fire exclusion policy would be contrary to the Parks mandate, which is to maintain natural processes and ecological integrity. Further, the complete exclusion of fire would pose an even greater concern over the increased risk of catastrophic fire events due to fuel buildup and lack of fuel breaks, as we were experienced across North Western America in 2003. Mountain caribou favours arboreal lichen growing on old trees as its main food source during the winter months. A complete fire exclusion over a long period of time could actually be more devastating as extensive areas of old growth forests, and consequently mountain caribou habitats, could be lost due to unmanageable, extreme fire behaviour.

Prior to the implementation of a fire reintroduction program, the wildfire threat levels to ESS must be assessed, and a number of the issues raised by the Revelstoke Community Forest Corporation, the B.C. Ministry of Forests and Parks Canada alike, must be addressed. These issues are fully discussed in Section 1.2, as they affect the choice in methodology used to carry out this study.

1.2 ISSUES TO ADDRESS

1.2.1 Amount of old growth forest identified

Based on recent studies on the historical amount of OGF found in the Oregon Coast Range (Wimberly *et al.* 2000), and management by natural fire regime also in Oregon (Cissel *et al.* 1999), some argue that the extent of OGF in the Columbia Mountains must be greater than what fire history studies of this region indicate. This conflicting view is supported by The Revelstoke Community Forest Corporation and the B.C. Ministry of Forests based on the amount of OGF identified on forest inventory maps and from what is "seen" from forest harvesting in this region.

Some of this controversy could be due in part to the fact that people have different perceptions of what should be called old growth forests. The fast tree growth and rapid increase in wood volume due to high levels of precipitation and mild winters typical of the Columbia Mountains, may mislead one's perception of what is old. As part of this project, we would like to develop a definition of *old growth* in the Columbia Mountains based on fire regime characteristics, fire history and fire risk at the stand level, without focussing strictly on tree size and age. For example, fire can speed up the structural characteristics of old growth (multi age, large amounts of woody debris, canopy gaps, etc.) and can also change the species composition.

During the June 17th, 2002 workshop, which took place in MRNP, different views on age and extent of OGF in the Columbia Mountains were shared. Based on our accounts of historical fire events and stand age modelling, about 31% of the forest should be older than 300 years (Rogeau 2000). In response to views and issues that were brought up at the workshop, a letter was sent to Murray Peterson, Fire and Vegetation Specialist for Mount Revelstoke and Glacier National Parks, that addressed concerns over the amount of old growth forest from forest inventory data, as well as dating issues associated with that database. The letter is included in Appendix A. In summary, forest inventory data indicate that 24% of the forest is old growth. This is 7% less than what the fire history and stand origin modelling exercise claim. In retrospect, it is not clear if the concerns are actually related to discrepancies in the amount of OGF, or are more related to a common fear of allowing fire to return to national park lands. This brings us to the second issue.

1.2.2 Old growth forests - responsibility of National Parks?

Also during the June 17th, 2002 workshop, it was observed that there is a tangible pressure from the Revelstoke Community Forest Corporation and the B.C. Ministry of Forests to use National Parks as an island of protection to ensure biodiversity and preserve old growth forests. In practice, this policy would not allow any disturbances within the National Parks to offset the removal of larger amounts of commercial old growth forests in valleys surrounding the parks. This concept of old growth islands is highly unnatural and, due to the abnormal buildup of woody material, could lead to catastrophic consequences should a wildfire break out in MRNP or GNP and eradicate extensive amount of the "protected" old growth forests.

As per the closing comments of my June 29th letter (Appendix A), I believe that the MoF age-class data lacks the credibility to imply that much larger areas of old growth forests exist in the region. I also believe that a great number of inaccuracies exist with the inventory age data. Therefore, great caution should be exercised when MRNP and GNP are being asked to act as old growth forest and biodiversity pools. It was recommended that a better understanding of the amount and distribution of old growth forests in a "fire context" be acquired for a much larger landscape than the one used for the fire regime analysis of the Greater MRNP, which was about 1,000 km^2 (without MRNP). This is what this present study is attempting to achieve.

1.2.3 Stand origin map and the fire cycle

This Section deals with the shortcomings of using a stand origin map and negative exponential model to calculate the fire cycle[1] and justifies the alternate approach taken for this study. The fire cycle is one of the most popular fire regime parameters in forest management. It has been calculated for several other landscapes in British Columbia and provides a means to compare rates of burning between landscapes. The application of the negative exponential model to age-class data extracted from a stand origin map (Johnson and Gutsell 1994) has been highly debated in recent years for its weaknesses in estimating accurate fire cycles (Rogeau *et al.* 2001, Huggard and Arsenault 1999, Rogeau 1996, Rogeau *et al.* 1996, Finney 1995). It was this contested method that was used for Glacier National Park (Johnson *et al.* 1990).

Huggard and Arsenault (1999) comment on the misuse of the negative exponential model and use of log-transformed age distributions, which would lead to erroneous interpretation of the fire cycle and fire regime and thus, lead to inappropriate management recommendations. Finney (1995) comment on the "old age tail" of the negative exponential distribution, which is assumed to be present when in fact it is censored from sample distributions of forest age-classes. This censoring alters the shape of the distribution and can lead to misinterpretation of fire data.

Several problems associated with the study of fire cycles derived from stand origin maps have been identified as part of a fire history study in the southern Rocky Mountains of Alberta (Rogeau *et al.* 2001, Rogeau 1996, Rogeau *et al.* 1996). In general, the overlapping nature of fires on the landscape through time, limits our ability to use stand age-class distributions to predict fire cycles. At present, for most areas, the calculation of fire cycle is based on a single snapshot of the current stand age-class distribution. The negative exponential model (or Weibull model) is normally used to calculate the fire cycle, but it is inadequate for study areas that: 1) do not have a random fire distribution, 2) do not have a sufficiently large study area in comparison to the largest burn area, and, 3) lack a sufficiently long fire history time period in comparison to the expected fire cycle. In addition, this approach when applied to the entire study area does not allow for the calculation of natural, spatial and temporal variability in the fire cycle. As per the Fire Regime Analysis Report for MRNP (Rogeau 2000), it was identified that the Park was too small in size to consider using the negative exponential model and that most importantly, the fire regime and forest conditions are not homogeneous throughout MRNP. Similar conclusions would apply to Glacier National Park.

In light of the weaknesses associated with the use of this method to calculate the fire cycle, other approaches and tools had to be explored to assess the fire regime and cycle of the study area.

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[1] The fire cycle is the number of years it takes to burn an area equivalent to the size of the study area. Some areas may burn more than once, while others may not burn at all (NRC 1987, Romme 1980).

2.0 RESEARCH OBJECTIVES

1) To determine the fire regime and probability of a fire occurring in a specific biogeoclimatic zone (ICH and ESSF); (Part I)

2) To determine the fire regime of the Columbia Mountains outside of the main transportation corridors, which are believed to have influenced patterns of ignition, notably in the early 1900s; (Part I)

3) To determine causes (topography, source of ignition, proximity to water) that influence distribution of old growth forests and fire patterns in general; and (Part II)

4) To define the risk of destruction through burning to the Beaver Valley Fen, an ancient forest stand in the Beaver Valley of Glacier National Park, and other Environmentally Sensitive Sites to be identified including mountain caribou habitat. (Part II)

2.1 QUESTIONS TO ANSWER

- What is the wildfire threat to Environmentally Sensitive Sites? (Part II)
- How much old growth and where? (Part I and II)
- Is “big growth” confusing our perception of old growth? (Part II)
- When can a tree be called old growth? (By species and natural disturbance type (NDT)) (Part II)
- Is the fire regime different than the one identified for the Greater MRNP? * (Part I and II)

* MRNP fire regime study (Rogeau 2000) was done for a small area encompassing the headwaters of narrow valleys. The main valleys that were sampled had been affected by highly used transportation corridors. There is some scepticism among forest managers of the region that more old growth forests exist than what this previous study indicates, and that the fire distribution in the Columbia and Illecillewaet valleys, both with important transportation corridors, may have biassed our perception of fire distribution.

2.2 HYPOTHESIS TESTING

Hypotheses addressing the homogeneity of the landscape in terms of fire occurrence: (Part I)

H_{01}: The fire regime is homogeneous throughout the entire Study Area.
H_{02}: The probability of fire ignition is homogeneous throughout the entire Study Area.
H_{03}: The probability of fire ignition is homogeneous within biogeoclimatic zones.

Hypotheses addressing the homogeneity of the fire patterns in terms of topography: (Part II)

H_{04}: Fire patterns, expressed as stand ages or MFRI[2] are not significantly different by aspect.
H_{05}: Fire patterns, expressed as stand ages or MFRI are not significantly different by elevation strata.
H_{06}: Fire patterns, expressed as stand ages or MFRI are not significantly different by valley orientation.

Hypotheses addressing old growth occurrence and distribution: (Part II)

H_{07}: Old growth distribution is homogeneous.
H_{08}: Old growth distribution is not affected by topography.
H_{09}: Old growth distribution is not affected by distance from water bodies.

Hypothesis addressing the wildfire threat to Environmentally Sensitive Sites (ESS): (Part II)

H_{10}: ESS do not have greater chances of burning than the rest of the landscape.

3.0 STUDY AREA

The choice of the study area was driven by a number of factors. The study area had to be spatially connected (continuous landscape) and large enough to include both MRNP and GNP, as well as adjacent valleys that would have experienced less human disturbance activity since the turn of the century. The area also had to be representative of climatic patterns found in the Columbia Mountains. This was broadly determined by using the "wet" and "dry" subvariants of the biogeoclimatic zones (MoF 1995). Lastly, the extent of the study area was dictated by the amount of resources available to undertake such research.

To offset the limitations associated with cost, three work scales were used in this research. The coarser scale is the largest landscape and is referred to as the "Greater Area of Mount Revelstoke and Glacier National Parks" as shown in Figure 1. It was used to carry out a fire regime assessment using provincial fire records (Section 5) due to its low-cost process, which is irrelevant of scale. The longitude and latitude coordinates of the lower left and upper right corners of the study area are: 50° 45' - 118° 45' and 51° 45' - 116° 45'. This area is roughly bound to the west by the east slopes of the Monashee Mountains, to the south by Blanket Mountain and Mount Sproat (on either side of the Columbia River), to the north by the upper drainages of the Goldstream River, and to the east by Yoho National Park. It covers a total area of 1,544,741 ha, or 15,447 km^2.

The second study area, of a lesser extent (408,864 ha or 4,089 km^2), is bound to the west by the Columbia River, by the height of land of the Downie watershed and GNP to the north, GNP and the Spillimacheen Valley to the east, and GNP and Greeley watershed to the south. This area was used to assess the historical fire occurrence and type of burning by using old aerial photography (Section 6). Within that study area, watersheds showing a representative fire regime were chosen to carry out detailed fire history through field data collection (Part II of this research) and were designated as study units. The choice in study unit

[2] Mean-fire-return-intervals: the average number of years between consecutive fires (Romme 1980).

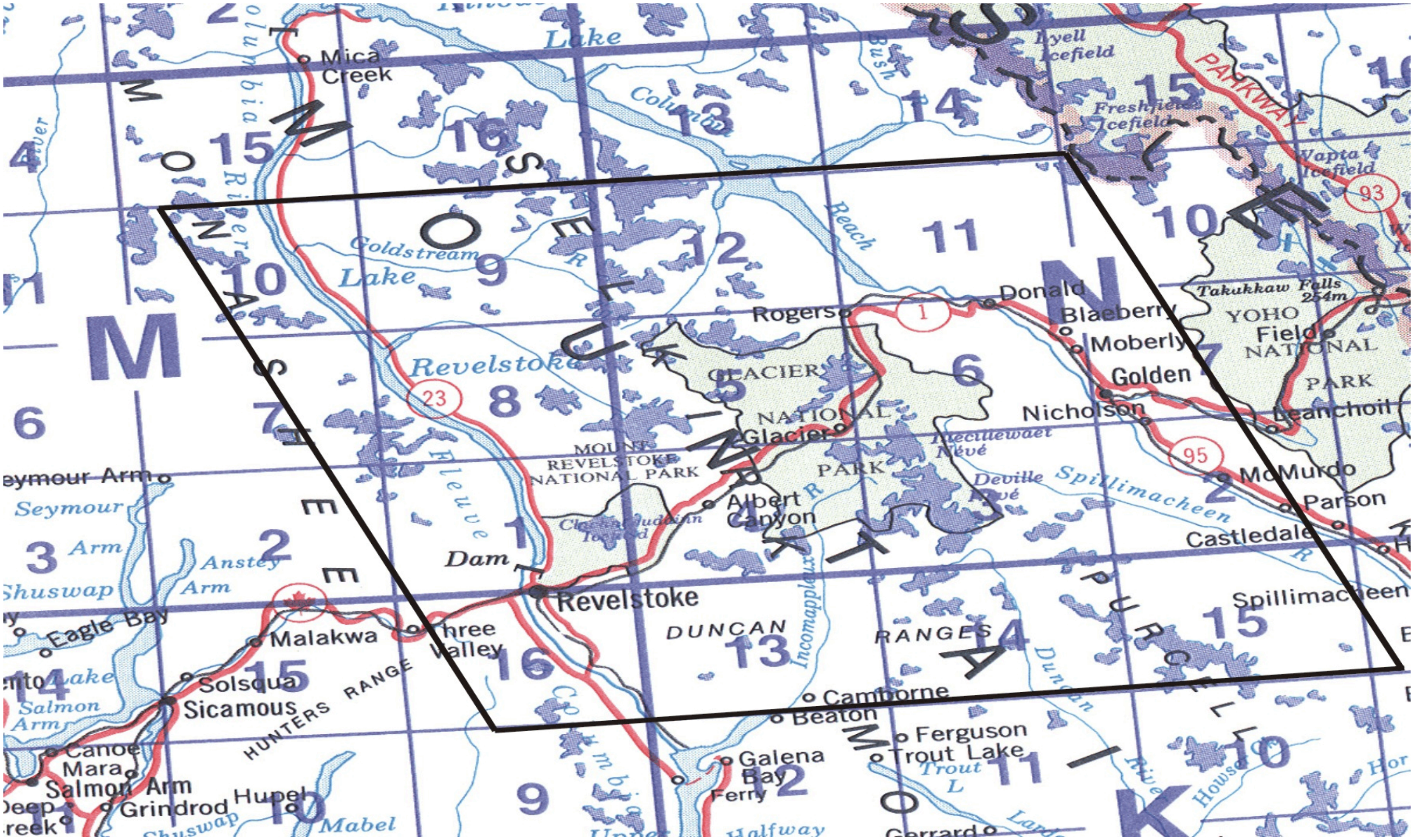

Figure 1 Greater Area of Mount Revelstoke and Glacier National Parks covers an area of 15,447 km^2.

will be detailed in Part II.

4.0 DATA LAYERS AND DATA LIMITATIONS

A number of maps and data sets were used in the assessment of the fire regime. A description of the source of the data and its use are presented below. Data limitations, if any, are also discussed to advise caution when there is a concern with the reliability of the data and its results.

All maps acquired for this project were imported into Idrisi Kilimanjaro GIS and were rasterised at a 20 m^2 resolution. Considering the generality of some data layers used and the large size of the study area (~15,000 km^2 area), this level of resolution was considered appropriate for the level of detail required. The projection used was UTM Zone 11, NAD83.

4.1 WATERSHED MAP

Data uses: - Help in the identification of fire regimes (Section 6)
- Study the effect of topography (Part II)

This map layer was created by the author and digitized by staff from MRNP. The watershed map was created from 1:50,000 topographic maps by outlining the height of land as watershed boundaries. Watersheds identified were as a minimum, 6 to 8 km long. The watershed map was also built with the purpose of representing valley orientation, which is an important topographic variable affecting fire behaviour. Valley orientation was found to be one of the most important factors of fire distribution on the east slopes of the Canadian Rockies (Rogeau *et. al*. 2001). Because of this, some watersheds had to be parted in their middle to capture the changes in valley orientation. As a result, 51 polygons were created.

4.2 FIRE OCCURRENCE DATABASE

Data use: - Assessment of several fire regime parameters (Section 5)

The BC Ministry of Forest fire occurrence statistics, provided by Eric Meyer, Fire Weather Specialist for the MoF in Victoria, were used to determine the number of fires by cause, size and seasonality (Section 5). The data set covers a period of 64 years: 1950 to 2003. The limitations associated with this data set is that most fires, especially those that occurred in the last 30 years, have been subjected to different degrees of fire suppression. This has the effect of reducing the size of the burn area. Fire occurrence records from the 1950s and 1960s may also be incomplete, especially for fires that were small and remote. There were also missing fire attributes for 122 fires dating from 1999 to 2003. Most attributes of size and cause were missing for the 2003 fire season as the information had not been completely compiled at the time this analysis took place.

MRGNP provided a similar fire record data set for the period of 1960 to 2003 (54 years). It suffers from the same limitations and also had some missing fire attributes for a small number of fires: 4 or 5 fires for each kind of missing attributes, but not always the same fires. The amount of missing data, less than 2% of each data set, should not bias any results from the fire regime assessment.

4.3 LIGHTNING STRIKE DATABASE

Data use: - Evaluation of probabilities of ignition (Section 5)

The lightning strike database was provided by Eric Meyer, Fire Weather Specialist with the BC Forest Management Branch in Victoria. This database consists of a list of geographical coordinates for every strike recorded by lightning strike detection systems between 1981 and 2003. The polarity of strikes is also recorded (positive or negative). The technology for direction finders has improved in the last decade and it is assumed that locations of strikes that occurred in the 1990's are more accurate than those of the 1980's. Also, due to the broad separation of direction finders and high mountain ranges, the mean location error of lightning strike distribution can be as much as 10 km (Nimchuck 1989).

4.4 ELEVATION MAP

Data use: - Evaluation of probabilities of ignition (Section 5)
- Effect of topography study (Part II))

The digital elevation model was obtained from Greg MacMillan, Data Management Specialist for Parks Canada in Vancouver. The file was already in a raster format at a 50 m resolution. The original DEM was created from Terrain Resource Information Management (TRIM) files at a scale of 1:20,000, available from Geographic Data BC. The file was resampled with a cubic convolution to 20 m resolution.

The extent of the DEM coverage available is slightly smaller than the largest study area used to assess fire occurrences using the provincial fire records. The size of the DEM map is 1,260,521 ha or 12,605 km^2. This landscape is sufficiently large enough to assess fire occurrence by aspect and elevation. It also entirely covers the area of the watershed map.

4.5 BIOGEOCLIMATIC ZONE MAP

Data uses: - Evaluation of probabilities of ignition (Section 5)
- Creation of “wet” and “dry zones” (Section 5)

The Biogeoclimatic zone map from the MoF was used to identify the general fuel types on the landscape. This map was obtained from their web site at the following address:
http://www.for.gov.bc.ca/hre/becmaps/becmaps.htm

The biogeoclimatic zone map for this area has not yet been updated using the 1:20,000 TRIM data, which means that the information presented was mapped at a scale of 1:100,000 to 1:500,000 (unknown) and is very coarse.

5.0 RECENT FIRE REGIME

The assessment of the "recent" fire regime targets the time period covered by the MoF and MRGNP fire records, which is 1950 to 2003 and 1960 to 2003, respectively. For this period, a number of fire parameters were evaluated:

- fire occurrences by year and decades
- fire size distribution
- burn area by decade
- rate of disturbance and fire cycle
- fire occurrence and burn area by month and cause
- spatial distribution of fire by cause
- spatial distribution of lightning strikes and relationship to lightning-caused fires
- spatial probabilities of ignition from lightning

All of these evaluations were performed for the Greater Area of Mount Revelstoke and Glacier National Parks, as well as for the combined national parks. Some were also compiled by biogeoclimatic zones and for the biogeoclimatic zone subvariants (wet versus dry). Using the results from the spatial probabilities of ignition, a probability model of ignition was also developed. The information gained from these analyses will make it possible to draw a fire regime profile for the Columbia Mountains and assess if more than one fire regime co-exist on the same landscape. Forest and fire managers, and planners alike, will benefit from this increased knowledge about the occurrence, size and distribution of fire on the landscape.

5.1 TEMPORAL FIRE OCCURRENCE

The provincial forest protection branch does not keep track of fire occurrences on federal land. This is largely the main reason why fire statistics from the National Parks are presented separately from the Greater Area. However, this provides a good opportunity to compare the similarities of the parks' fire regime to the surrounding environment.

In a 64-year period a total of 4,584 fires occurred on the Greater Area, not including the federal land, and 275 fires occurred in both MRGNP between 1950 and 2003. When comparing the total fire counts for an equal period of time over an equal size landbase, the national parks see 44% less fire ignitions than the surrounding landscape. When repeating the exercise for lightning fires alone, the national parks see even less (45%) fire ignitions.

Table 1 shows some variation in fire occurrences by decade, but overall the percent of fire occurrence by decade has not varied greatly: 18% to 24% for the Greater Area and 23% to 25% for MRGNP. The earliest period was ignored for both areas as the fire tracking system was not as rigorous in those days. The 2000 decade was also left out due to its incompleteness. The yearly fire statistics also demonstrate the wide variation in the number of fires each year. For MRGNP, 2003 saw the most fires (21) followed closely by the years 1970 and 1998 when 20 fires were recorded during those seasons.

Table 1 Temporal fire distribution by decade and yearly fire statistics.

	Greater Area		Parks	
Period	**Counts**	**% Fire**	**Counts**	**% Fire**
2000 to 2003	412	8.99	38	13.82
1990 to 1999	837	18.26	62	22.55
1980 to 1989	1100	24.00	69	25.09
1970 to 1979	1007	21.97	67	24.36
1960 to 1969	843	18.39	39	14.18
1950 to 1959	385	8.40		
Total:	4584	100	275	100
Fires per year				
Minimum	14		0	
Maximum	245		21	
Average	85		6	

5.2 Fire Size Distribution

All fire sizes were grouped into size categories (Table 2). Fires greater than 200 ha are considered large size fires. Only 1.03% of fires are greater than 200 ha for the Greater Area (MoF fire records), but they account for 79% of the area burned. Significantly more fires become large in MRGNP; 3.27% of fires account for 83% of the area burned. Despite that, the maximum fire sizes experienced in the national parks are much smaller than those recorded for the Greater Area. In the Greater Area, a fire burned 21,071 ha in 1971 and 4,597 ha in 1951. The Copperstain Valley of Glacier National Park also experienced it's largest fire on record in 1971, but it was only 1,600 ha. 2003 produced the second largest fire on record when 800 ha of land burned in Ursus Valley, also in Glacier National Park. Unfortunately, the fire size data from the MoF was not complete for 2003. Overall, there were 122 fire size records missing in that data set.

Table 2 Fire size distribution.

	Greater Area		Parks	
Size class	**Count**	**% fire**	**Count**	**% fire**
0.99	3907	87.56	224	81.45
10	327	7.33	29	10.55
100	142	3.18	11	4.00
200	40	0.90	2	0.73
1000	42	0.94	8	2.91
2000	2	0.04	1	0.36
5000	1	0.02	275	
25000	1	0.02		
	4462			

The number of large size fires was also examined by decade and by cause (Table 3). A greater number of large size fires occurred during the 1960's and 1970's. This was likely due to a larger number of dry summers coupled to the fact that fire suppression capabilities and response time were not as effective in those days. It is interesting to see that the vast majority of large size fires are caused by lightning. Lightning-caused fires tend to occur at higher elevations and in poorly accessible areas, making it even more difficult to combat, especially in the early days of fire suppression.

Table 3 Number of large size fires by decade and cause.

	Greater Area	Parks
Period	**Count**	**Count**
2000 to 2003	0*	3
1990 to 1999	7	1
1980 to 1989	5	0
1970 to 1979	15	4
1960 to 1969	13	1
1950 to 1959	6	
Total:	46	9
% lightning-caused	89	100

* no size records available for 2003 (MoF data)

5.3 Burn Area and Fire Cycle

The total area burned for both Mount Revelstoke and Glacier National Parks since 1960 amounts to 6,151 ha. This represents a burn rate of 140 ha / year, or 0.19% of the forested area. The Ecological Land Classification of the Parks (Achuff et al. 1984) estimate that 54% of the land is composed of rock and ice, 19% of ICH forest type and 27% of ESSF forest type. This rate of disturbance, for a forested area estimated to be 74,014 ha, is equivalent to a 529 year fire cycle. Since 80% of fires are caused by lightning (Section 5.4), it is believed that this fire cycle is much longer than the historical one when no fire suppression was taking place.

Interestingly, despite the fact that the Greater Area sees 55% more fires than the parks, its fire cycle is longer. The total area burned for the Greater Area since 1950 amounts to 58,130 ha. This represents 1,077 ha burned per year or a rate of disturbance of 0.16% of the forested area. This is equivalent to a 643 year fire cycle. The forested area of the Greater Area was estimated to represent 50% of the landscape based on information from the Timber Supply Analysis of Revelstoke Community Forest Corporation (Sylvatech 2000). It was found that the biogeoclimatic zone map was not accurate in its representation of forested areas. By removing the combined areas from the Alpine Tundra (AT) and lakes, non-forested areas represented only 12% of the landscape.

5.4 Monthly Distribution of Fires

The assessment of fire distribution on a monthly basis (Table 4) revealed that over 76% of fires occur during the months of July and August, most fires being lightning-caused. People-caused fires tend to occur in June and July in the parks, but prevail for a longer period of time in the Greater Area, from May to August. The greatest amount of area burned also occur in July and August for the Greater Area and MRGNP. However, the national parks see a significant amount of burning in August with 87% of the total area burned since 1960.

Table 4 Percent of fire occurrence by month and fire cause since 1950 for the Greater Area, and since 1960 for MRGNP.

	Greater Area			Parks		
Month	**% Light.**	**% People**	**% Total**	**% Light.**	**% People**	**% Total**
January	0.00	0.23	0.04	0.00	0.00	0.00
February	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	1.02	0.20	0.00	0.00	0.00
April	0.00	6.46	1.26	0.00	6.78	1.45
May	1.35	**20.84**	5.15	0.46	11.86	2.91
June	9.47	15.63	10.67	6.94	**25.42**	10.91
July	**33.05**	**22.08**	**30.91**	**29.63**	**28.81**	**29.45**
August	**52.02**	17.33	**45.25**	**56.02**	22.03	**48.73**
September	4.06	11.33	5.48	6.94	5.08	6.55
October	0.05	4.53	0.93	0.00	0.00	0.00
November	0.00	0.34	0.07	0.00	0.00	0.00
December	0.00	0.23	0.04	0.00	0.00	0.00

Table 5 Percent of total burn area by month since 1950 for the Greater Area, and since 1960 for MRGNP.

	Greater Area		Parks	
Month	**Area (ha)**	**% Area**	**Area (ha)**	**% Area**
January	59.30	0.10	0	0.00
February	0.00	0.00	0	0.00
March	24.50	0.04	0	0.00
April	583.50	1.00	0.4	0.01
May	782.84	1.35	1.9	0.03
June	7,275.61	12.52	330.56	5.37
July	33,520.04	**57.66**	672.9	**10.94**
August	13,838.95	**23.81**	5136.05	**83.50**
September	1,781.85	3.07	9.45	0.15
October	263.30	0.45	0	0.00
November	0.11	0.00	0	0.00
December	0.11	0.00	0	0.00
Total	58,130.11	100	6151.26	100

5.5 FIRE CAUSES AND THEIR SPATIAL DISTRIBUTION

The leading cause of fire for both the Greater Area and MRGNP is lightning, which is responsible for 80% of the fire occurrences of this region. This is the complete opposite of the East Slopes of the Canadian Rockies (Banff and Jasper National Parks), where only 20% of fires are caused by lightning. Anthropogenic fires are sub-classified by sources of origin and allow fire managers to directly address the lead fire agents by either education or strategic planning of deployment of fire fighting resources. The leading causes of people fire within the Greater Area are attributed to miscellaneous causes, to fire use and then to campfires/recreation. In the national parks, due to their wilderness settings, the leading fire agent by far, is the railroad, followed by the recreational park users.

Table 6 Classification of fire occurrences by cause.

	Greater Area		Parks	
Cause	**Count**	**% fire**	**Count**	**% fire**
Lightning	3647	80.44	216	78.83
People	887	19.56	58	21.17
Total	4534	100.00	274	100
Missing data	*50*		*1*	
Detailed causes* (people)	**Fire count**	**% fire**	**Fire count**	**% fire**
Campfire / Recreation	133	14.99	7	12.07
Equip. use / Other Industry	78	8.79	2	3.45
Fire use / Residential & Slash	200	22.55	2	3.45
Incendiary	64	7.22	3	5.17
Misc.	222	25.03	1	1.72
Railroads	73	8.23	43	74.14
Smoker	117	13.19	0	0
	887	100	58	100

* The MoF and Parks Canada use different categories to classify their people fires.

The spatial distribution of people-caused fires is rather predictable based on the documented sources of fire origin. Lightning-caused fires are not as predictable but are certainly not distributed randomly either. Figure 2 shows the lightning-caused fire density recorded for 5 km x 5 km grid cells. This resolution was chosen to match that of the lightning strike density distribution (see Section 5.6). The total number of lightning-caused fires since 1950 ranged from 0 to 41 per 25 km^2. This information was classified into very low to very high fire density zones, and showed that chances of lightning-caused fires over a 54 year period can vary spatially from 4% to as much as 76% (Table 7). However, close to half of the land base displays very low chances of burning and overall, 79% of the area has less than 20% chance of fire. The greatest chances of fire occur west of Revelstoke, along the Columbia River basin as well as in the Monashee Mountains.

It is also interesting to examine more closely the kind of factors that drive the distribution of lightning-caused fires on the landscape. Terrain and vegetation types are the two environmental variables that could affect lightning-caused fire distribution. Different classes of aspect and elevation were assessed, as well as the biogeoclimatic zones and subvariants (wet and dry) pertaining to this region. Because of the wide variation in land base associated with each variable class, the fire counts were recalculated for a normalized area of 100,000 ha. This is done to remove any interpretation bias as larger areas have a greater opportunity to

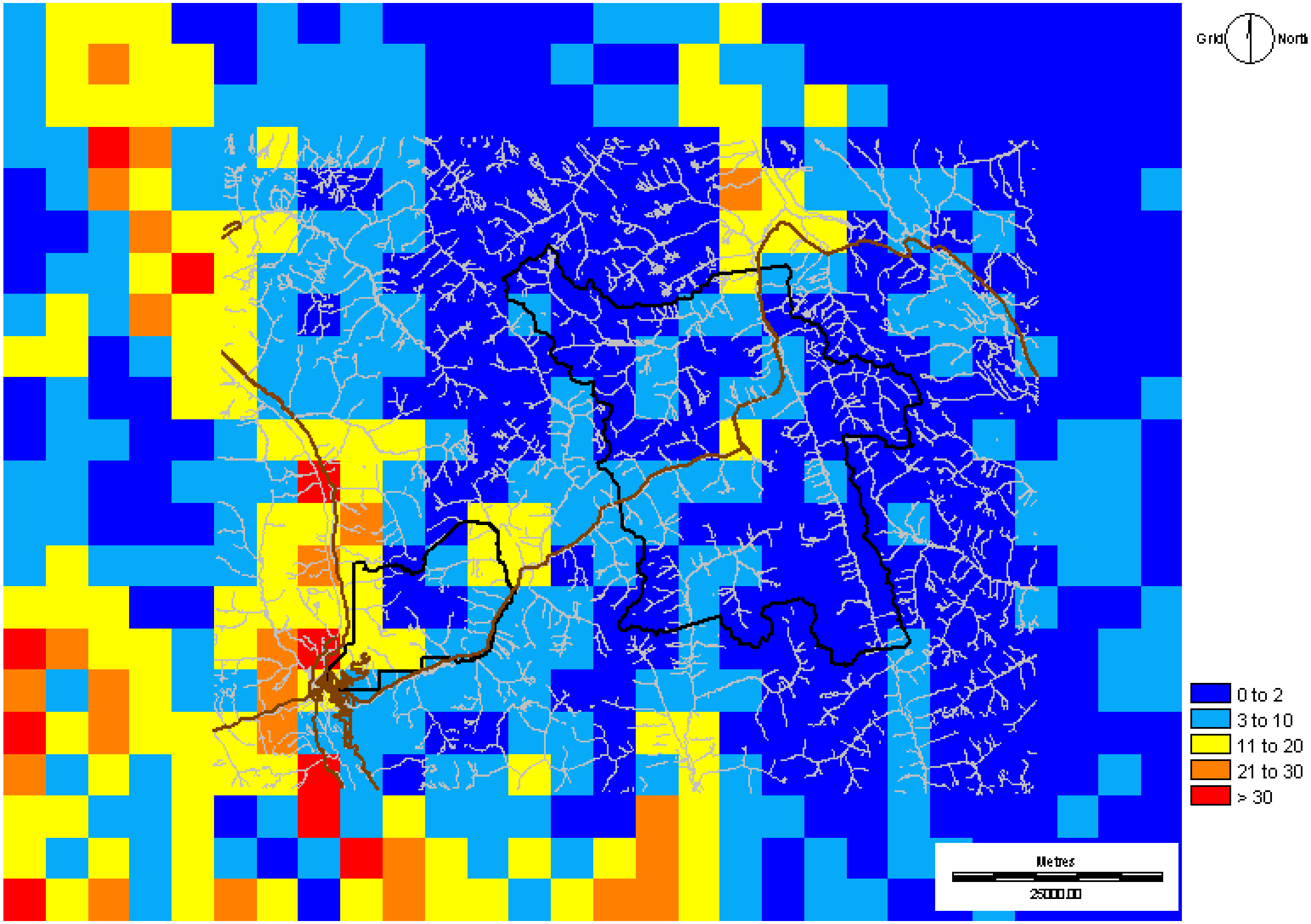

Figure 2 Density of lightning-caused fires for 5 km x 5 km grid cells. Greater Area, 1950 to 2003 fire records.

capture a larger number of fires. Table 8 presents the percent of lightning fire occurrence associated with each variable class. It can be observed that the effect of aspect is not very strong, but it would appear that N and NE facing slopes have more lightning fire ignitions than any other aspects, and that NW facing slopes would have the least with only 10% fire occurrence. Percent of lightning fire occurrence by elevation strata also does not vary exceptionally but there are more ignitions (39%)between 1250 m and 1750m. This corroborates the findings from the 2000 Fire Regime Study of Mount Revelstoke (Rogeau 2000), where fire-return-intervals were found to be shorter at that elevation band. The thermo-belt effect that occurs in August, which is also the month of greatest number of fires and area burned, (Section 5.4) could also be responsible for the fact that a greater number of fires can ignite due to drier fuel conditions found at those elevations. It was also observed that ICH forests receive the greatest number of lightning fire ignitions. Based on the fire ignition information retrieved by elevation, it would appear that the ignitions in the ICH would occur at the upper limit of that biogeoclimatic zone, which is near the transitional zone with the ESSF. Because fires move upslope, this would have a direct impact on the amount of area burned in the ESSF despite the fact that it sees less ignitions. The vegetation composition and structure of the ICH, with often contains high, dead tree tops may be more conducive to lightning fire ignitions than the nearby ESSF forest. Lastly, 68% of fires occur in the wet subvariant zone of the biogeoclimatic zones. Despite the fact that the information was normalized, very little land (4% or 60,000 ha) in the Greater Area fell in the dry subvariant zone. This land base may be too small to be representative of the lightning fire distribution in the dry zone. Similar conclusions can be drawn from the IDF and MS biogeoclimatic zones, which cover an equivalent land base as the dry zone.

Table 7 Lightning-caused fire density per 25 km^2 and percent chance of fire, area and percent area associated with each fire density zone. Greater Area, including MRGNP.

Fire Density	# fires	% chance of fire	Area (ha)	% Area
Very Low	0 to 2	4 %	704663	45.62
Low	3 to 10	19 %	509062	32.95
Moderate	11 to 20	37 %	245754	15.91
High	21 to 30	56%	60185	3.9
Very High	30 +	76%	25077	1.62
Maximum	41		1544741	100

Table 8 Percent of lightning-caused fires associated with aspect and elevation classes, and biogeoclimatic zones and their subvariants. Greater Area, including MRGNP. Calculated for normalized areas of 100,000 ha.

Aspect	% Fire	Elevation	% Fire	Biogeozone	% Fire	Subvariant zone	% Fire
N: 337.5-360, 1 - 22.5	12	400 - 750 m	13	ESSF	24	Wet	67.53
NE: 22.5 - 67.5	15	750 - 1000 m	15	ICH	54	Dry	24.55
E: 67.5 - 112.5	16	1000 - 1250 m	15	IDF	18	Non-forested	7.92
SE: 112.5 - 157.5	11	1250 - 1500 m	19	MS	0		
S: 157.5 - 202.5	12	1500 - 1750 m	20	AT	4		
SW: 202.5 - 247.5	12	1750 - 2000 m	13				
W: 247.5 - 292.5	12	2000 + m	5				
NW: 292.5 - 337.5	10						

5.6 SPATIAL DISTRIBUTION OF LIGHTNING STRIKE DENSITY

Lightning strike data, obtained from the MoF Protection Branch, was used to determine if clusters of lightning strikes yield more lighting-caused fires. The data set covers a 23-year period, from 1981 to 2003. 65,218 strikes have been recorded during that time, 20% of which are positive. The density of strikes on 5 km x 5 km grid cells was recorded and classified in increments of 25 (Figure 3). That resolution was chosen due to positioning errors of strikes, which can be as large as 16 km in mountainous terrain (Nimchuk 1989). The density of strikes ranged from 44 to 194 strikes, with the highest strike density found west of Revelstoke, in the Columbia River Basin and in the Monashees. Although this is also where the highest density of lightning-caused fires is recorded, the Chi-square test ($\alpha = 0.05$) defines these two populations as independent and Cramer's V measure of association also rates it as poor (0.22). Despite the weak relation determined by statistical tests, the percentage of lightning fire occurrence in each strike density zone (Table 9) shows that there is a strong tendency to find the majority of lightning fire density zones where strike densities are greater than 100. The lowest and highest strike density zones also coincide with the lowest and highest lightning fire starts, respectively. It is often suggested that fire starts tend to come from strikes that have a positive polarity. The exercise was repeated using positive strikes only, but the correlation between positive strikes and lightning fire ignitions was even weaker.

Table 9 Percent area of strike density in relation to lightning fire density zones for the Greater Area.

	Lightning Fire Density				
Strike Density	**Very Low (0 - 2)**	**Low (3 - 10)**	**Moderate (11 - 20)**	**High (21 - 30)**	**Very High (31 +)**
26-50	0.00	100.00	0.00	0.00	0.00
51-75	62.96	27.16	9.88	0.00	0.00
76-100	59.73	32.13	7.24	0.90	0.00
101-125	22.19	18.34	11.24	3.85	44.38
126-150	13.75	21.88	14.37	3.13	46.88
151-175	3.70	40.74	40.74	14.81	0.00
176-200	0.00	3.57	7.14	0.00	89.29

5.7 PROBABILITY OF IGNITION MODEL

The probability of ignition model takes into account the spatial distribution of fire ignitions. Since the fire regime is driven by lightning-caused fires, and that the distribution of people-caused fires is more predictable, the model only includes probabilities of ignition from lightning. Results from the lightning strike density distribution (Section 5.6), lightning-caused fire density distribution (Section 5.5), and occurrence of lightning-caused fires by aspect, elevation and biogeoclimatic zones were used in a GIS weighing and ranking system to estimate probabilities of ignition on the landscape. Because the DEM available does not extend as far as the Greater Area, the probability of ignition map covers only the DEM area. The extent of that region is slightly larger than the watershed study area as described in Section 3.

The weighing process consisted of rating, in percentage value, the importance of each variable (GIS layer) used, while the ranking process ranked the variable classes on a scale of 1 to 5, 5 representing the highest likelihood of getting an ignition. The weighing and ranking of the information was done as follow:

40% **Density of lightning-caused fires**

1 - Very low density (< 4% chance of fire / yr)
2 - Low density (5 to 19%)
3 - Moderate density (20 to 37%)
4 - High density (38 to 56%)
5 - Very high density (57 to 76%)

20% **Density of lightning strikes**

2 - Very low and low density (0 to 75)
3 - High and very high density (150 to 200)
5 - Moderate density (75 to 150)

15% **Biogeoclimatic zones**

1 - MS, AT
3 - ESSF, IDF
5 - ICH

15% **Elevation**

1 - 2000 + m
3 - 400 - 750 m, 1750 - 2000 m
4 - 750 - 1250 m
5 - 1250 - 1750 m

10% **Aspect**

2 - NW
3 - N, SE, S, SW, W
4 - NE, E

p_ignition = ([lgt_fire_distribution*40] + [strike_distribution*20] + [lgt_biogeo*15] + [lgt_elev*15] + [lgt_aspect*10]) / 5

This map manipulation process resulted in obtaining a range of probabilities of ignition that vary spatially over the landscape. The range extends from 22 to 98%. The probability of ignition map is shown in Figure 4.

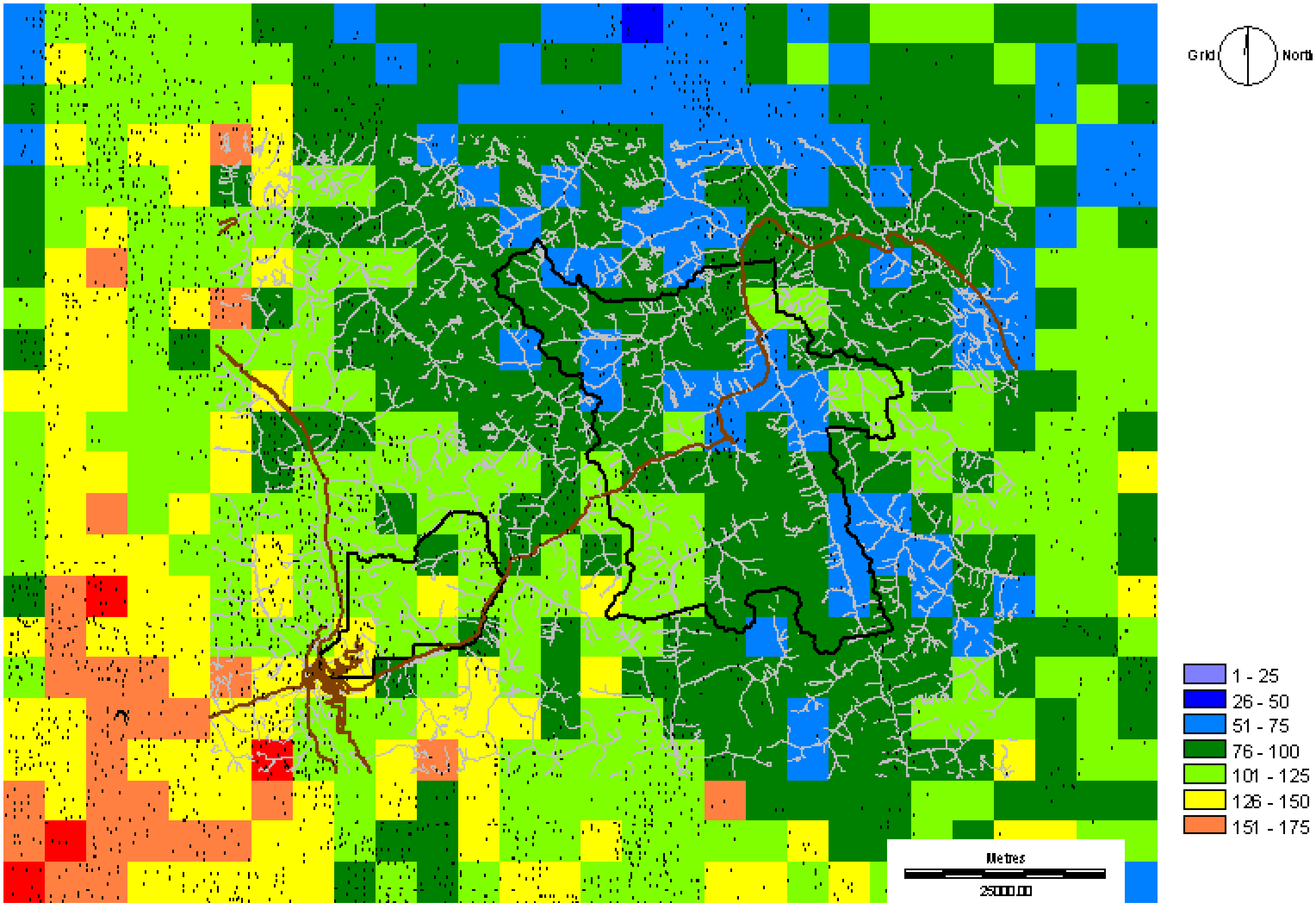

Figure 3 Density of lightning strikes for 5 km x 5 km grid cells. Lightning-caused fires are overlaid onto the map. Greater Area, strike data: 1981 to 2003, fire data: 1950 to 2003.

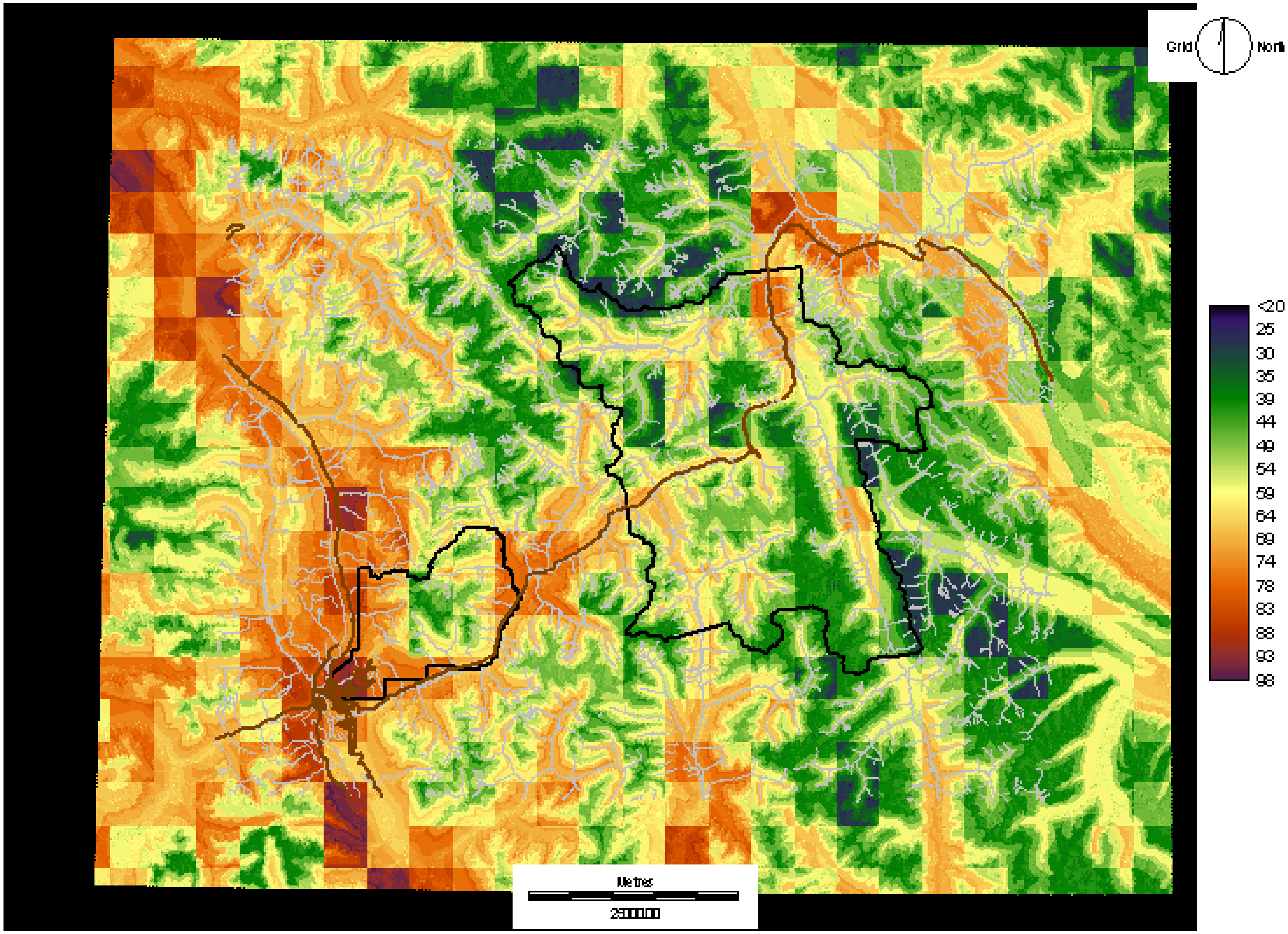

Figure 4 Probability of lightning fire ignition model for a 12,605 km^2 area within the Greater Area of Mount Revelstoke and Glacier National Parks.

6.0 HISTORICAL FIRE REGIME

The previous chapter assessed some fire regime parameters from fire records dating since 1961. On a fire history scale, this is a relatively short period of time. It is also a period that has been influenced the most by human disturbance by the increased use of the landscape by people, which could lead to more fires, and by fire suppression efforts that could have reduced the amount of area burned. Two key variables, frequency and area burned, that are used in the calculation of the fire cycle and yearly rate of forest disturbance.

To gain an even better understanding of the fire regime, and for an increased length of time, the use of historical aerial photography is an excellent tool. Most of the country was flown at a scale of 1:40,000 between the years of 1948 and 1952. These older photographs are perfect for uncovering historical fire boundaries that are no longer visible on today's landscape. Aerial photographs can also inform us of the number of fires, their size (before being overlapped by subsequent burns), relative age of the forest, and the intensity of burning, which is another important fire regime parameter. Intensity refers to the kind of fire encountered: surface, intermittent or crown. Fire intensity is directly linked to the level of patchiness (amount and size of forest patch residuals after a fire) found on the landscape, which is easily assessed from a visual screening of aerial photography. An air photo screening process was undertaken on a watershed basis to capture these additional fire parameters from the turn of the century. The accuracy of this information is best from circa 1900 to 1950, but deteriorates for forests originating prior to the 1900's. Fire boundaries from the mid 1800's are for the most part still visible, but the rapid forest growth seen in the Columbia Mountains prevents the air photo interpreter from making confident assessments for disturbances dating prior to the mid-1800's.

The screening process consisted of a visual analysis of the vegetation complexity in terms of the number of visible fires, burning patterns and level of patchiness. Differences in tones and textures of the forest cover were the key elements for assessing the number of visible fires and vegetation complexity. For each watershed, a series of fire related parameters were recorded. The number of potential fires was estimated, as well as the number of recent fires (1900 - 1950). The complexity of the burning patterns observed was rated as low, moderate and high. A high complexity most often reflects a greater number of fires that overlap one another, or lower burning intensities, generally on more gentle to flat terrain, that leave a large number of residual trees or small patches. Other attributes recorded include: the watershed ID number, which was used in the digitizing process; name of creek or river draining the watershed; the name of the main watershed basin; the estimated age of the most recent burn; and the valley orientation code. Valley orientation is the topographic variable that shows the greatest effect on fire distribution in the East Slopes of the Rockies (Rogeau et al. 2001) and it is suspected that it plays a similar role in the fire behaviour of the Columbia Mountains. The valley orientation coding reflects how two valleys (watersheds) intersect at their confluence. Some watersheds will contain more than one valley orientation when there is a significant change in the direction of valley flow.

As shown in Table 10 and Figure 5, a total of 51 watersheds were identified (see Section 3 for details of the map creation). Each fire attribute recorded from the photo screening process was attached to the digitized watersheds. A series of maps were created and are presented in their respective sub-section. Figure 5 presents the watershed outlines over the biogeoclimatic zone map to show the proportion of forest type of each watershed.

Table 10 Results of the screening process from 1948-49 aerial photography, 1:40,000.

Poly ID	Valley	Watershed	Orientation	Complexity	Total fires	Recent fires	Min age
1	Granite	Downie	31	L	3	0	75
2	Boulder	Downie	31	L	4	1	50
3	U. Downie	Downie	2	M	24	4	20
4	Sorcerer	Downie	12	L	12	0	100
5	L. Downie	Downie	1	M	13	3	20
6	Sorcerer	Downie	21	L	9	1	40
7	U. Mountain	Mountain	24	M	13	6	15
8	Standard	Downie	12	L	5	1	15
9	U. Columbia	Columbia	2	M	14	2	10
10	L. Beaver	Beaver	3	H	37	5	20
11	L. Mountain	Mountain	1	M	26	2	20
12	Tangier	Tangier	23	M	8	1	30
13	M. Mountain	Mountain	4	L	12	3	15
14	Kelly & Burke	Tangier	14	L	9	3	10
15	Grizzly	Beaver	43	M	6	2	15
16	Casualty	Mountain	31	L	11	1	15
17	Ursus	Mountain	31	L	16	1	15
18	Connaught	Beaver	12	L	14	2	15
19	McKonnon	Tangier	12	L	4	1	15
20	U. Beaver	Beaver	3	M	31	6	20
21	East Grizzly	Beaver	34	L	4	0	200
22	Copperstain	Beaver	24	M	9	2	15
23	Carnes	Columbia	21	L	21	3	15
24	Tangier	Tangier	3	L	29	3	15
25	L. Columbia	Columbia	3	H	26	5	15
26	Fang	Tangier	23	L	5	1	15
27	U. Illecillewaet	Illecillewaet	21	L	6	0	250
28	Illecillewaet	Illecillewaet	1	H	39	9	20
29	U. Spillimacheen	Spillimacheen	32	L	5	1	40
30	Baird Brook	Spillimacheen	13	L	5	1	40
31	Woolsey	Illecillewaet	31	L	8	1	20
32	U. Spillimacheen	Spillimacheen	2	H	17	2	15
33	Illecillewaet	Illecillewaet	1	H	52	6	15
34	La Forme	Columbia	24	L	10	2	10
35	Flat	Illecillewaet	21	L	8	2	15
36	U. Incomappleux	Incomappleux	13	L	11	0	200
37	Maunder	Illecillewaet	43	L	6	2	20
38	L. Spillimacheen	Spillimacheen	2	VH	47	1	40
39	Jumping	Illecillewaet	21	L	6	1	15
40	West Woolsey	Illecillewaet	43	M	4	1	20
41	Caribou	Spillimacheen	32	L	8	0	200
42	L. Incomappleux	Incomappleux	3	L	5	0	200
43	Van Horne Brook	Incomappleux	31	L	8	1	15
44	St-Cyr	Columbia	43	L	3	0	200
45	McMurdo	Spillimacheen	12	L	11	0	200
46	Bain Brook	Incomappleux	13	L	3	0	250
47	Coursier	Columbia	43	L	8	1	15
48	Clachnacudainn	Illecillewaet	21	L	6	1	30
49	Albert	Illecillewaet	21	M	15	3	15
50	Twin	Illecillewaet	21	L	12	2	20
51	Greeley	Illecillewaet	21	L	5	1	15

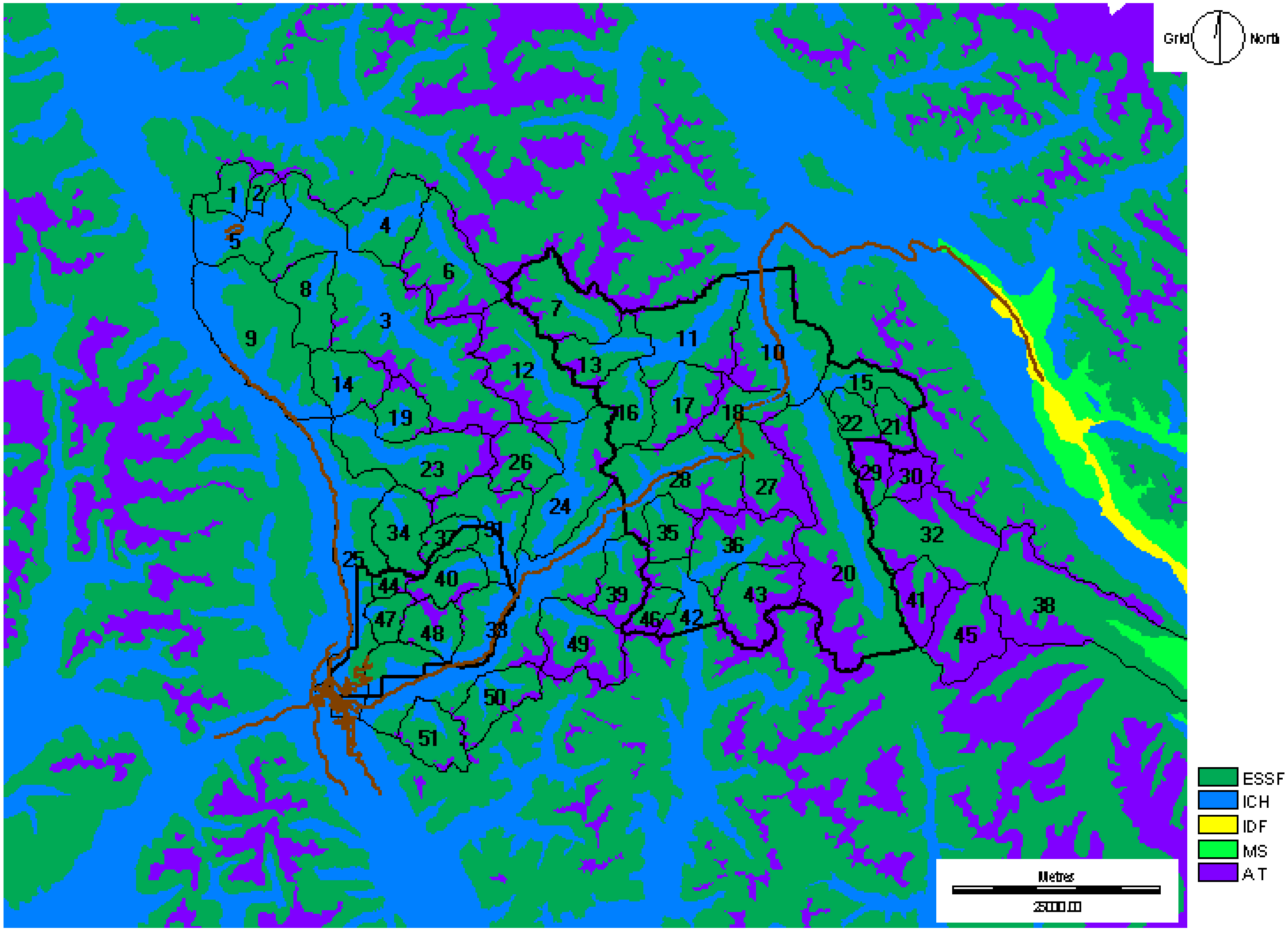

Figure 5 Watersheds used for the screening process of historical aerial photography overlaid onto the biogeoclimatic zone map. Numbers refer to Table 10.

6.1 Vegetation Complexity

The vegetation complexity ranks the level of patchiness of the forest caused by burning patterns. Clean burning with very few patches of remnant trees was rated as low. This usually occurs with more intense burning on steeper terrain or in watersheds encompassing a large cover of homogeneous looking forest. A forest that was subjected to frequent passive crown fire activity will show numerous individual or patches of unburnt trees and was rated as high. A mixture of low and high vegetation complexity, or a complexity that is not low or high, was rated as moderate. As a general rule, the level of patchiness tends to increase with greater fire frequency.

Figure 6 shows the distribution of vegetation complexity rating across the landscape. The highest vegetation complexities were found exclusively in the lower portions of main and widest valleys, such as the Beaver, Illecillewaet, Columbia and Spillimacheen. The Spillimacheen valley was by far the most complex and its lower portion had to be given the unique identifier of "very high" complexity. The Spillimacheen falls in the dry sub-variant zone, and is one of the few watersheds that has IDF (Figure 5).

6.2 Number of Fires

The number of fires was estimated based on the different tones and textures of the forest cover. This means that any forest patches that looked different were counted as a different fire. Because the size of watersheds vary greatly, the number of fires estimated from photos varied accordingly. This provides a bias perception of the fire frequency in each watershed. To correct this problem, the number of fires recorded in each watershed was normalized over an equal area of land, arbitrarily chosen to be 25 km^2, so that the number of fires could be compared across the landscape. For example, a greater number of fires are usually recorded in large watersheds than in small ones. This leads us to believe that the fire frequency would be greater in larger watersheds. But if one looks at the same information recalculated for 25 km^2 of land, we may find that the number of fires on a 25 km^2 basis could actually be similar. Figure 7 shows the spatial distribution of the number of fires per watershed, normalised over 25 km^2.

The greatest total number of fires recorded fall in the following watersheds: Coursier, Copperstain, Connaught, Illecillewaet, Beaver and Boulder. With the exception of the Boulder waterhsed, which drains into the main Downie watershed, all other watersheds are in MRGNP. The watersheds that saw the least number of fires in the last few centuries are Tangier and the Upper Downie.

6.3 Number of Recent Fires

The number of recent fires estimated to have occurred after 1900 was recorded for each watershed. This value was recorded to determine if there were regions that were more prone to fire. Because recent fires can be better detected, and there is less chance of overlap among fires, this value should be more accurate than the total number of fires from Section 6.3.2. However, it provides a much narrower view of fire occurrence, especially for regions under long fire cycles that see no or very few fires over a 50 year period. In this case, values were not normalised.

Figure 8 presents the number of recent fires per watershed grouped into three frequency classes: low, moderate and high. The number of recent fires (~1900 to 1950) per watershed varied from 0 to 9. Watersheds with the most recent fires are the Beaver, Upper Mountain, and the Upper and Lower Illecillewaet. All of these are located in Glacier National Park, with the exception of the Lower Illecillewaet, which extends from GNP onto provincial lands and onto MRNP. Only the Illecillewaet watershed was affected by human use, which was in those days the railroad.

6.4 Minimum Estimated Forest Age

The minimum age of the forest was visually estimated based on the most recent fire that occurred in the watershed. This exercise was carried out simply to get a feel for the time-since-fire as of 1950. Originally the maximum age of the forest was to be estimated as well, but due to the rapid growth of the forest, all forests older than 150 years look roughly the same age. Regardless, it was observed from the air photo screening that old growth forest is found in all watersheds in variable extents. Figure 9 shows the minimum forest age expected to be found per watershed. The watersheds that have the longest time-since-fire are St-Cyr (MRNP), Bain Brook (off the Incomappleux), Lower and Upper Incomappleux (GNP), East Grizzly (GNP), as well as the Caribou and McMurdo, both off the headwaters of the Spillimacheen. It is interesting to see that areas with little fire or with the longest time-sine-fire tend to be located directly next to watersheds that have experienced a greater number of fires and recent fires. In that regard it would appear that the fire regime experiences local variations and that these variations are not attributed to factors of regional significance such as precipitation patterns (wet versus dry zones).

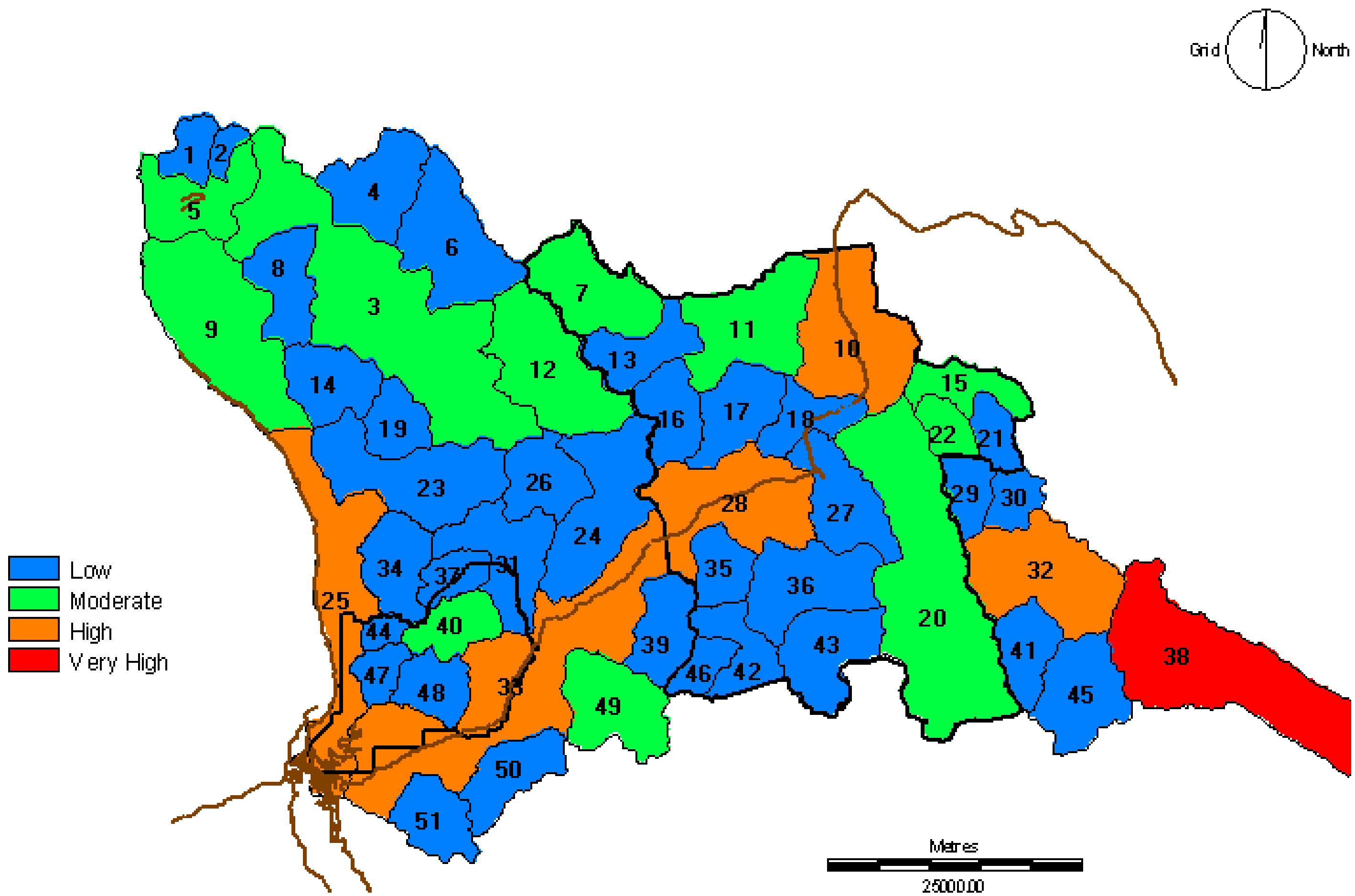

Figure 6 Vegetation complexity per watershed.

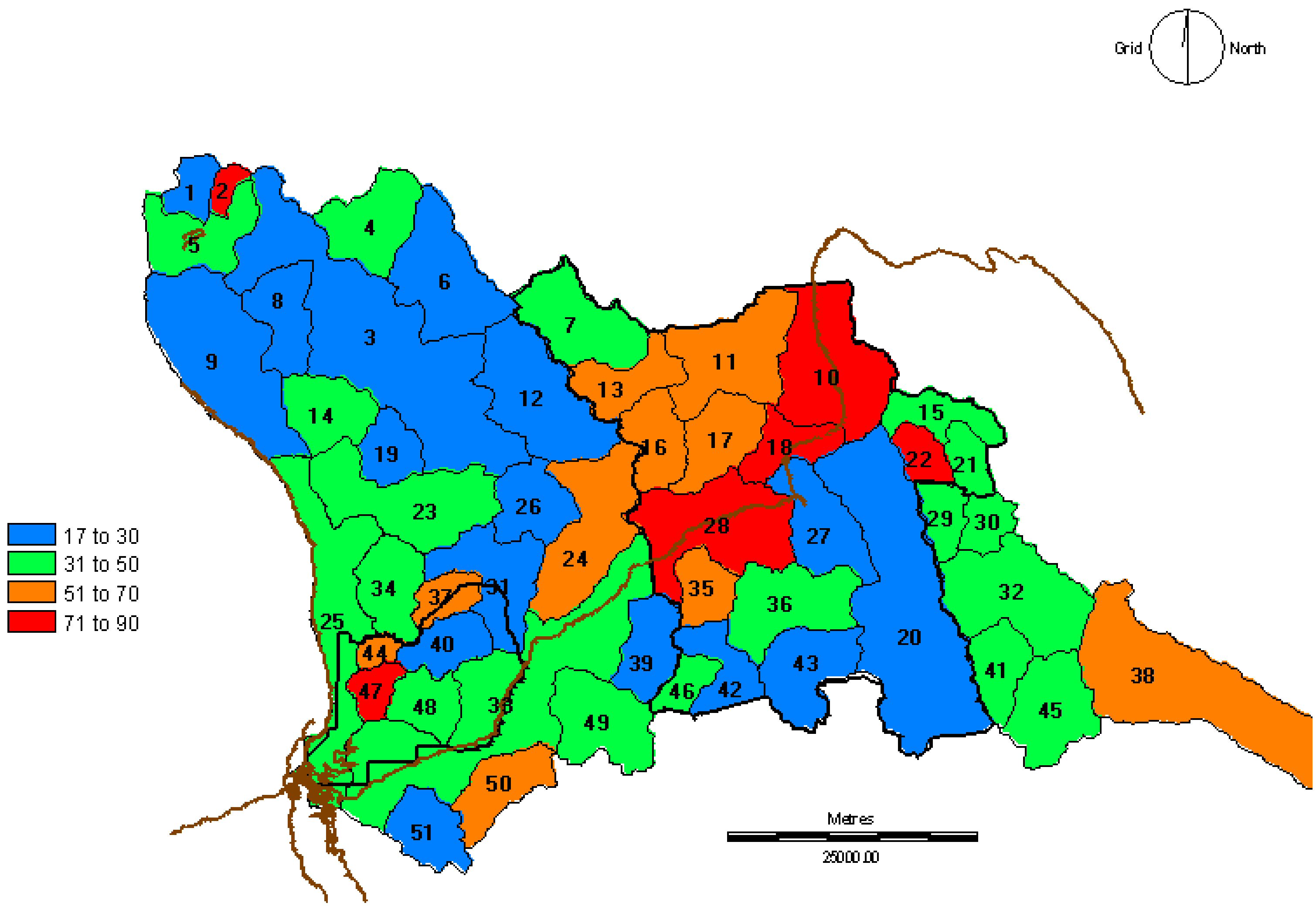

Figure 7 Total number of fires recorded by watershed and normalized for an equal land base of 25 km^2.

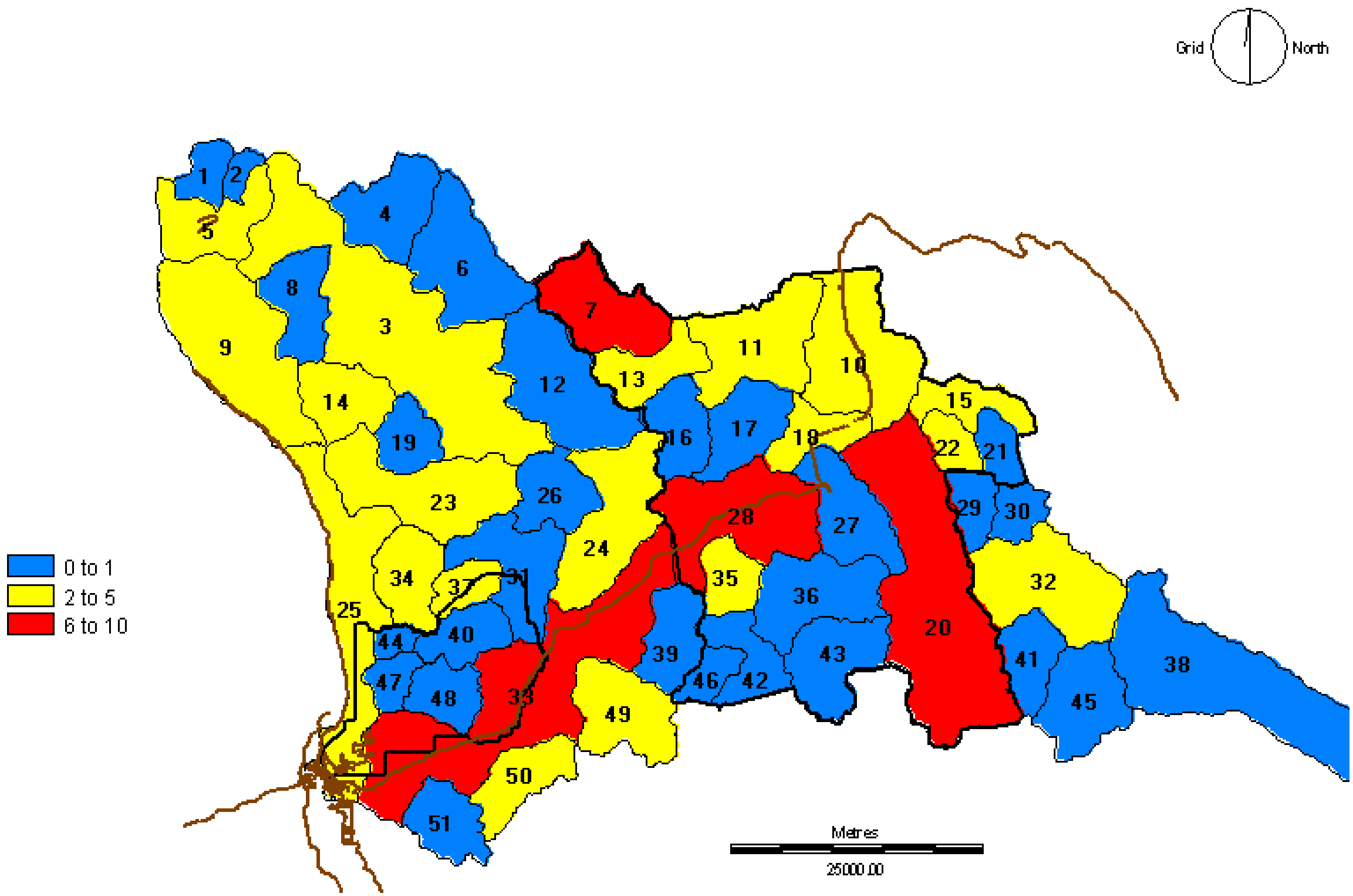

Figure 8 Number of recent fires (circa 1900 to 1950) recorded by watershed.

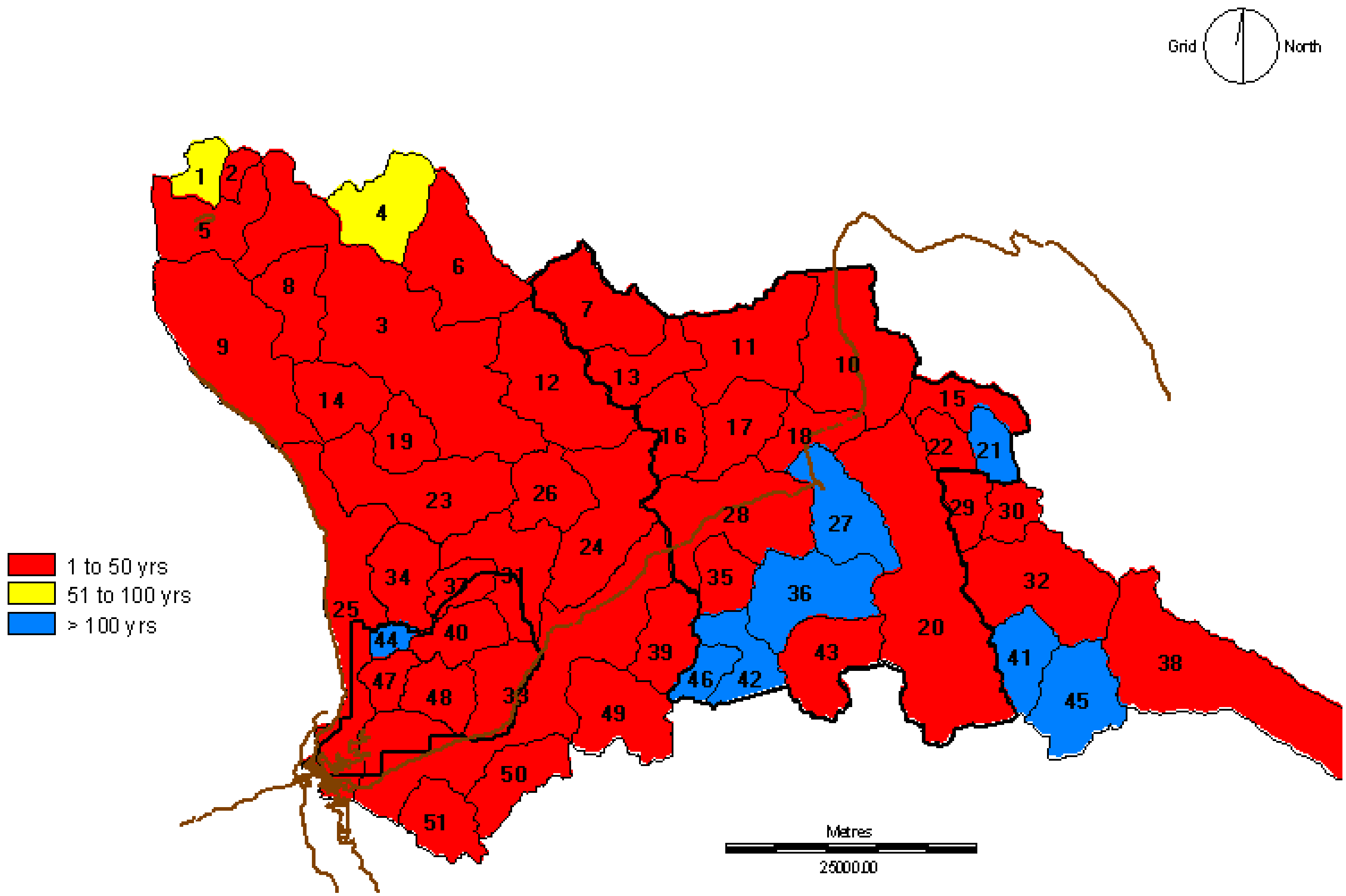

Figure 9 Time-since-last fire by watershed, based on estimates of minimum forest ages.

7.0 CONCLUSION

Hypotheses addressing the homogeneity of the landscape in terms of fire occurrence were all rejected based on the results from the assessment of fire records covering the period from 1950 (1960 for MRGNP data) to 2003, and screening of historical aerial photography. The fire regime was found not to be homogeneous, largely because of variable probabilities of ignition across the landscape. Below is a summary of the findings for MRGNP, which are put in perspective against the findings of the Greater Area.

It was found that the proportion of fire occurrence by decade for the national parks is comparable to the region, but the overall frequency of fire is about 45% less. However, the parks see more large size fires than the Greater Area and this would explain the shorter fire cycle estimated at 529 years for MRGNP against a 643 year fire cycle for the Greater area. Since 1960, MRGNP has an average annual rate of forest disturbance by fire of 140 ha, or 0.19% of its forested area. Whereas an average of 1,077 ha, or 0.16% of the forested portion of the Greater Area, has burned each year since 1950. In both landscapes, very few fires become larger than 200 ha but they account for most of the area burned. For MRGNP, 3.27% of fires account for 83% of the area burned, while only 1.03% of fires account for 79% of the area burned in the Greater Area. The largest fire on record in MRGNP is 1,600 ha and dates from 1971, but much larger fires have been recorded in the Greater Area: 21,071 ha (1971) and 4,597 ha in 1951. The majority of large size fires were found to have been caused by lightning: 89% in the Greater Area, and 100 % in MRGNP.

The fire regime of this region, both the Greater Area and MRGNP, is dominated by lightning-caused fires as 80% of ignitions are from lightning. The largest contributor of people-caused fire in MRGNP is the railroad (74% of fires). Because the Greater Area encompasses the Town of Revelstoke, many roads and commercial forest use, the leading sources of people fires have been attributed to miscellaneous causes (not specified in the data set), fire use, campfire and smokers.

July and August are the prevailing fire season of this region. 76% of fires occur during these two months and 82% of the area is burned during that same period of time. However, for MRGNP, the area burned largely occurs in August with 84% of the area burned during that month.

Variability of lightning ignitions across the landscape was assessed by aspect, elevation, biogeoclimatic zones and the wet/dry subvariants of the biogeoclimatic zones. Variations in ignitions were found among all classes of each variable tested. Areas with more lightning ignitions are N and NE facing slopes, between 1250 m and 1750 m, and at the upper limit of the ICH forests, which also corresponds to the "wet" subvariant. The number of lightning ignitions also appeared to be linked to 25 km^2 grid cells that had recorded more than 100 lightning strikes between 1981 and 2003. Despite the fact that the number of lightning-caused fires were found to be significantly different between biogeoclimatic zones, there is no indication that the fire regime is homogeneous within each zone as probabilities of lightning ignition do vary based on other factors such as topography and lightning strike density.

Results from the historical aerial photography screening process revealed that the number of fires per watershed, using normalized areas, varied greatly. The number of recent fires also varied from none to 9 over a 50-year period (1900 to 1950). The vegetation complexity across the landscape ranged from low to very high. The higher complexities seemed to be associated with the main drainage basins but, with the exception of the Illecillewaet and Beaver Valleys, the total number of fires were not. Watersheds that had the longest time-since-fire were often located next to watersheds of high fire frequency (total and / or recent). This indicates that there are micro-scale variations in the fire regime that can vary widely from one watershed to another over a very short distance. What causes this phenomenon is unknown at this time. The detailed fire history mapping to be undertaken for representative watersheds may help shed some light on the cause of these variations.

8.0 LITERATURE CITED

B.C. Ministry of Forest. 1995. Forest Practices Code of British Columbia - Biodiversity Guidebook. Ministry of Forests. 99 p.

Cissel et al. 1999. Landscape management using historical fire regimes: Blue River, Oregon. Ecol. Apl. 94(4)1217-1231).

Finney, M.A. 1995. The missing tail and other considerations for the use of fire history models. Int. J. Wildland Fire 5(4):197-202.

Huggard, D.J. and A. Arsenault. 1999. Comment - Reverse cumulative standing age distributions in fire-frequency analysis. Can. J. Forest Research. 29:1449-1456.

Johnson, E.A. and Gutsell, S.L. 1994. Fire frequency models, methods and interpretations. Advances in Ecological Research 25: 239-283.

Johnson, E.A., Fryer, G.I. and Heathcott, M. J. 1990. The influence of man and climate on the fire frequency in the interior Wet Belt Forest, British- Columbia. Journal of Ecology 78: 403-412.

National Research Council of Canada. 1987. Glossary of forest fire management terms. Fourth edition. Canadian Committee on Forest Fire Management, Ottawa, Ontario. Publication NRCC No. 26516.

Nimchuk, N. 1989. Ground-truthing of LLP lightning location data in Alberta. *In* Proceedings of the 10th Conference on Fire and Forest Meteorology, April 17-21, Ottawa, Canada. pp. 33-40.

Rogeau, M-P. 2000. Fire Regime Analysis of Mount Revelstoke National Park. Mount Revelstoke National Park, Box 350, Revelstoke, BC. V0E 2S0. 62 p.

Rogeau, M-P. 1996. Understanding age-class distributions in the Southern Canadian Rockies. M.Sc. Thesis, Dept. of Renewable Resources, University of Alberta, Edmonton, Alberta. 139 p.

Rogeau, M-P., I. Pengelly, and M-J.Fortin. 2001. Using a topography model to map historical fire cycles and monitor current fire cycles in Banff National Park. *In* R.T. Engstrom and W.J. de Groot, (eds.). Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in Temperate, Boreal, and Montane Ecosystems. Tall Timbers Research Station, Tallahassee, FL.

Rogeau, M-P, P.M. Woodard, and U. Feunekes. 1996. Landscape disturbance modelling. *In* R. Weber (Chair). Proceedings of the13th Conference on Fire and Forest Meteorology, Lorne, Australia, 27 - 31 October. pp. 461-466.

Romme, W.H. 1980. Fire history terminology: Report of the adhoc committee. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-81. pp 135-137.

Sylvatech Consulting Ltd. 2000. Timber Supply Analysis Report TFL56, Management Plan #3. Prepared for Revelstoke Community Forest Corporation, Revelstoke, BC. 77 p.

Wimberly et al. 2000. Simulating Historical Variability in the Amount of Old Forests in the Oregon Coast Range. Cons. Biol. 14(1)167-180.

Appendix A: Feedback June 17th, 2002 Old Growth Workshop

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June 29th, 2002

Re: Discrepancies between stand origin ages and MoF ages

Dear Murray.

To follow up on some of the issues that were discussed at the June 17 - Old Growth workshop, I have done some analyses using our stand origin data from 1998-99 and the MoF age-class map.

Some of the issues raised at the workshop were about the amount of old growth (age-class 8 and 9) and their distribution in the Greater MRNP Area. The MoF and the forest industry claim that there are many more old growth forests than what the results of the fire history/regime analysis demonstrated. The "fire people" were somewhat sceptical about this claim and this is why I wanted to take a closer look at the MoF age data.

I looked at the age-class distribution of the inventory data for the entire area (Table 1). Note that for the analysis, I lumped age-class 1 and 9 together, assuming that most of age-class 1 would represent cutblocks and that the oldest age-class (9) would have been targeted for logging. Table 1 shows that 31% and 24% of the forest belongs in age-class 8 and 9, respectively. However, based on the biogeoclimatic zones and the natural disturbance types identified for the Selkirks, "old-growth" forest should really only include age-class 9. The stand origin modelling exercise, that I did as part of the fire regime analysis for the Greater MRNP Area, showed that on average 31% of the forest was older than 300 years and was referred to as "old-growth". Like the Shakespearean play, the workshop discussion could have been entitled "Much a do about nothing".

In order to evaluate the distribution of older aged forests, I assessed the age-class data by 500 m elevation increments (Table 2). This is where a red flag was raised. Based on the fire regime analysis, the distribution of historical and present-day fires occur from lightning sources at elevations greater than 1000 m. Fires also burn during July and August and many of them during the thermo-belt effect, which is a belt of warm air and low relative humidity that occur roughly between 1200 m and 1750 m. Thus, forests at higher elevations should be younger than at lower elevations. The MoF inventory age data shows the exact opposite.

Table 1 Age-class distribution of forest inventory age-class data from the MoF, Greater MRNP Area.

Age-class	Area (ha)	% area)	Legend
1	7001	10.65	0 - 20 yrs
2	3317	5.04	21-40
3	3429	5.21	41-60
4	5083	7.73	61-80
5	7836	11.91	81-100
6	6955	10.57	101-120
7	2081	3.16	121-140
8	20921	31.81	141-250
9	9143	13.90	251 +
	65766	100	

Table 2 Age-class distribution of forest inventory age-class data by 500 m elevation interval.

	1	2	3	4	5	6	7	8	9
DEM	% area	% area	% area	% area	% area	% area	% area	% area	% area
< 500	1.53	1.50	3.02	3.08	3.78	3.18	1.98	0.38	0.14
501 - 1000	37.02	44.52	36.36	46.12	55.31	33.78	41.67	9.03	22.22
1001 - 1500	39.80	34.12	42.86	36.49	27.10	18.13	22.38	26.23	55.99
1501 - 2000	20.63	18.80	15.95	12.90	10.37	34.36	27.81	59.81	21.52
2001 - 2500	1.02	1.06	1.81	1.41	3.44	10.55	6.18	4.55	0.13
	100	100	100	100	100	100	100	100	100

During the field sampling of the fire regime study, which took place in 1998-99, 28 plots were actually collected on Provincial Land. This allowed me to assess the stand origin dating ability of the MoF stand age classification map. I overlaid the sampling sites onto the MoF age-class map and wrote down the age-class id. Because it is possible that stand boundary lines be offset by a few hundred metres, I also wrote down the age-class id number of nearby classes. Note that I was fairly loose in my assessment and made note of all age-classes falling within about 500 m of each plot site. The age-class ids were translated into a range of stand origin dates "as of 1999", the year of the sampling, as shown in Table 3.

Table 4 shows the results of the age validation process. The *Plot id* is the GIS point identification number, while the *Plot number* refers to the plot label on the tally sheet. Multiple fires were often detected, but the date of *fire origin* represents the dominant stand replacing fire. The *other fires* column indicates that evidence of other fires was also found, either in the form of scars, releases or post-fire regeneration trees (what I believe was often referred to as "second growth" during the workshop). The *MoF age-class* and its associated *MoF mean age* represent the age-class at the sampling site, whereas the *nearby classes* are the age-class ids that were identified within about 500 m of the sampling site. The *age difference* was calculated by subtracting the *fire origin* from the *MoF mean age*. The age difference was then recalculated using the nearby classes (*age difference (nearby classes)*).

Table 3 Interpretation of the MoF age-classes.

Age-class	Description	Dates as of 1999	Mean date
1	1-20 yrs	1979 to 1999	1989
2	21-40	1959 to 1978	1969
3	41-60	1939 to 1958	1949
4	61-80	1919 to 1938	1929
5	81-100	1899 to 1918	1909
6	101-120	1879 to 1898	1889
7	121-140	1859 to 1878	1869
8	141-250	1749 to 1858	1803
9	250+	older than 1858	1699

Results show that the MoF age-class map properly dated the forest only 24% of the time. Note that half of the sites belonged to age-class 9, which is an extremely broad class (>250 years) and should be fairly difficult to mis-interpret. Overall, 40% of the time the MoF age-class map was off by more than 40 years in its age assignment. Data also show that there is about a 50/50 chance that the MoF age map over-estimates or under-estimates stand ages. However, when the data is re-assessed by using dates from the nearby age-classes, the age-classification does improve. It is unknown if this is a simple luck factor. In this case, 47% of the time the MoF age-class map classified the forest age properly. Over a third of these plots belonged in age-class 9. And only 18% of the plots were off by more than 40 years.

Although the validation process for the "nearby classes" provided a better correlation between the two aging methods, there are still many concerns about the ability of the age-class map to date forest fires and thus, date the age of the forest in a reliable manner. Added concerns should also come from the fact that the validation area is located along main transportation corridors, which would have made it easy to position check plots as part of the forest inventory mapping. It would be reasonable to expect a drop in stand dating accuracy in remote areas of limited access where no check plots exist, where the age-class designation simply resides in the skills of the air photo-interpreter and, where relationships of height to age ratio are applied in order to assign a stand date. It is well known that in mountain areas that forests' growth rate depends on aspect, elevation, slope steepness and fire severity. Using height as a surrogate for age is simply not acceptable.

Table 4 Age validation between fire origin dates and MoF stand dates.

Plot Id	Plot #	Fire Origin	Other fires	MoF age-class	MoF mean age	nearby classes	Age difference	Age difference (nearby classes)
67	98-57	1934	1894	8	1803	45	-131	-5
32	98-27/2*	1800	1880	8	1803	5	3	3
31	98-27/1	1880	1750	8	1803	8	-77	-77
76	99-28/3	1894		1 (8 or 9)	1803	478	-91	-25
74	99-28/1*	1625	1775	1 (8 or 9)	1699	8	[redacted]	[redacted]
34	99-28/2	1894	1885	8	1803	16	-91	-5
33	98-28/1*	1791	1625	4	1929	86	138	12
36	99-31/1	1896		5	1909	15	13	13
37	99-31/2	1855		n/a	n/a	5	n/a	54
38	99-32	1896	185017501675	n/a	n/a	6	n/a	-7
39	99-33/1	1896	1.882185e+15	n/a	n/a	8	n/a	-93
40	99-33/2	1960		8	1803	8	-157	-157
45	99-37/2	1896	188217701620	5	1909	4	13	13
44	99-37/1	1896		5	1909	37	13	13
71	99-60	1760		9	1699	5	[redacted]	[redacted]
88	99-63/2*	1685	1855	9	1699	8	14	14
89	99-63/3	1920	1855	9	1699	34	-221	9
87	99-63/1	1920		3	1949	94	29	9
79	99-71	1905	1673	5	1909	98	4	4
80	99-72	1720	1905,1880	9	1699	9	-21	-21
86	99-4/2	1905	195018861775	8	1803	6	-102	-16
85	99-4/3*	1670	1800	8	1803	6	133	133
72	99-4/1	1905	1850	8	1803	6	-102	-16
4	98-02	1935		3	1949	8	14	14
3	98-01	1775	1850,1685	8	1803	3	28	28
9	99-12*	1730		9	1699	83	-31	-31
16	98-17/1	1914	1894	5	1909	4	-5	-5
17	98-17/2	1894		5	1909	4	15	15

*: multi-aged

Exact plot site (total of 25 plots)

perfect classification	12%	MoF over-estimated ages	52%
off by one class (20 years)	20%	MoF under-estimated ages	48%
off by two classes (40 yrs)	16%		
off by more than 40 years	40%		
class 9, well classified	12%		

Classification based on nearby classes (28 plots)

perfect classification	29%
off by one class (20 years)	28%
off by two classes (40 yrs)	7%
off by more than 40 years	18%
class 9, well classified	18%

From my experience in Alberta, BC and Saskatchewan, it has always been difficult to extract good and reliable fire information from the forest inventory age data. Not to say that the inventory data is “bad” in itself but the goals, and thus the sampling and interpreting methods for stand aging, are very different between assessing and aging timber for economical value versus aging it to learn about the fire regime. I have worked on stand dating validation projects in the Mackenzie TSA of BC, in the Foothills of Alberta and north of Meadow Lake Provincial Park, SK. In all cases the inventory data, due to its broad age lumping process, use of increment borer cores at DBH, use of recent photos instead of 1950 air photos and, choice and number of sampled trees, have failed to identify the majority of the fires and their sizes.

As part of a Pilot Study Report for Mistik Management, Sk, which compared stand origin ages with forest inventory ages in a boreal mixedwood landscape, (Andison et. al 2002) (Murray I sent you this report), it was found that there are a number of possible error sources that may cause the forest inventory approach for dating fires to be very inaccurate. These include:
1) errors caused by insufficient ground-truthing of the inventory age estimates (i.e., sampling error);
2) systematic errors from counting increment cores in the field (i.e., measurement error);
3) the process used for selecting sample trees for acquiring precise tree age data (i.e., sampling protocol);
4) correcting breast height ages to provide estimates of total age (i.e., equation error);
5) lack of precise ages in an inventory (i.e., broad classes and using an “older than” age class); and
6) direct inferences made between estimated tree height from air photos and tree ages.

In closing, at this time I believe that the MoF age-class data lacks the credibility to imply that much larger areas of old growth forests exist in the region. I also believe that a great number of inaccuracies exist with the ages from the inventory data. Therefore, great caution should be exercised when MRNP and GNP are being asked, by the Ministry of Sustainable Resource Management and the forest industry alike, to act as old growth forests and biodiversity pools. My recommendation is that a better understanding of the amount and distribution of old growth forests in a “fire context” is needed and that, for a much larger landscape than the one used for the fire regime analysis of the Greater MRNP, which was about 1,000 km^2 (without MRNP). The approach to be used to address this knowledge gap will be incorporated in your request for an old growth/fire research proposal.

I hope that this "short letter" has shed some light about the issues raised at the workshop and that this will give you some leverage in terms of your negotiations with the MSRM and the forest industry.

Best Regards,

M-P. Rogeau

CC: Bob Brade, MSRM
CC: Mark Heathcott, Parks Canada Regional Fire Center