Landscape-Level Fire Activity on Foothills and Mountain Landscapes of Alberta

Alberta Foothills Disturbance Ecology Research Series
Report No. 2

By: D.W. Andison
Bandaloop Landscape-Ecosystem Services
Belcarra, British Columbia
July, 2000

Funding Provided by Foothills Model Forest and Weldwood of Canada Ltd.

DISCLAIMER

The views, statements and conclusions expressed and the recommendations made in this report are entirely those of the author(s) and should not be construed as statements or conclusions of, or as expressing the opinions of Weldwood of Canada Ltd., the Canadian Forest Service, the Foothills Model Forest, or the sponsors of the Foothills Model Forest.

Foothills Model Forest is one of eleven Model Forests that make up the Canadian Model Forest Network. As such, Foothills Model Forest is a non-profit organization representing a wide array of industrial, academic, government and non-government partners, and is located in Hinton, Alberta. The three principal partners representing the agencies with vested management authority for the lands that comprise the Foothills Model Forest, include Weldwood of Canada (Hinton Division), Alberta Environment and Jasper National Park. These lands encompass a combined area of more than 2.75 million hectares under active resource management.

The Canadian Forest Service of Natural Resources Canada is also a principal partner in each of the eleven Model Forest organizations and provides the primary funding and administrative support to Canada's Model Forest Program.

The Foothills Model Forest mission: We are a unique community of partners dedicated to providing practical solutions for stewardship and sustainability of our forest lands.

EXECUTIVE SUMMARY

This second report in the FMF Natural Disturbance Program research series looks at fire activity patterns over very coarse scales. Using three different age datasets from Weldwood of Canada, Jasper National Park, and Alberta Newsprint Company, pre-industrial age-class distributions, old forest areas, and historical burn rates were compared and contrasted across eight major ecological zones covering over 2.5 million hectares. The results showed that:

1) Variability at even very coarse scales is a natural phenomenon.
2) Fire control has been the most influential cultural process at landscape and regional scales.
3) Major ecological zones differentiate overall fire activity well.
4) Within major ecological zones, variable probabilities of burning are evident, and relate to different vegetation-types.

Through a Weldwood-sponsored extension to this research, it was also possible to take the analysis a step further and model the natural range of variability of different seral-stages and cover-types. The results of this simulation exercise not only confirmed that variability is a natural phenomenon, but also demonstrated that in most cases the variability was strata-specific, and thus predictable. For instance, it clearly showed that fire control efforts in the Lower Foothills (in particular) are pushing the amount of old hardwood and old spruce forests beyond that which likely occurred naturally.

The analysis also generated some questions that future research will aim to address. First and foremost, although a part of the Foothills Model Forest, the Willmore Wilderness Area did not have sufficient age data to allow coarse-scale pattern analysis. Second, the ANC FMA had age data of unknown quality, which casts some doubt upon the suggestion that fire activity in this area is higher than anywhere else on the Model Forest proper. Lastly, although so far we have good evidence suggesting that the ecological zones are meaningful in terms of differentiating fire activity, it remains to be seen how far this model can be taken. In other words, do the zones also apply to attributes like fire sizes, shapes, fire types and intensity? Would it apply at even finer scales to attributes like island remnants and coarse woody debris? For that matter, we found some preliminary evidence indicating that *within*-zone variability of fire activity exists. Does this mean that the ecological zones can be subdivided into substrata for the purposes of better understanding and quantifying fire activity?

These, and many other questions will fall out of the research and reports to follow. This is a strong beginning to understanding disturbance patterns and processes on Alberta's foothill and mountain landscapes, but it is just the foundation.

INTRODUCTION AND REPORT OVERVIEW

This report is divided into several related parts.

Part 1 is a general overview of the FMF Natural Disturbance Program, and is common to all reports in this series.

Part 2 includes the introduction, analysis, and discussion of fire activity on the study area at landscape scales and above. It is the largest, most substantial section, and includes descriptions of the data, analyses and results from each of the three main administrative areas of the study area. Several different analytical techniques are used including comparing static age-class distributions, reconstructing and comparing historical rates of burning, and landscape simulation modelling. The breadth of the analysis was such that this section includes its' own discussion and summary of the various fire regimes suggested.

Part 3 shifts to examining how fire activity might vary within a fire regime. This analysis is preliminary, and the discussion short and to some degree inconclusive. However, it was meant mainly to serve as a bridge from landscape-level findings to those at finer scales (in future reports).

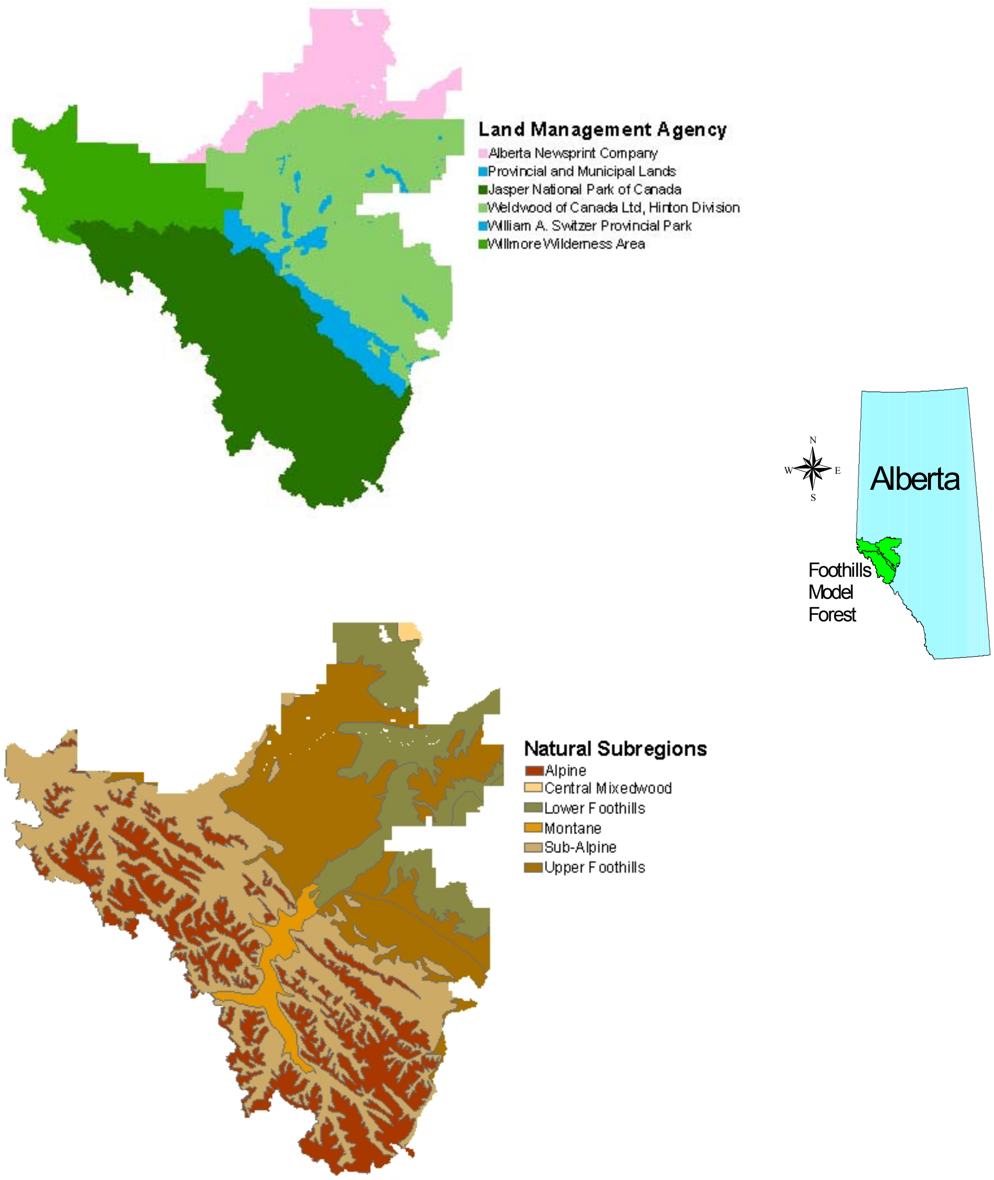
Part 4 draws some conclusions and implications based on the previous two sections.

In the last section (Part 5), a brief glimpse of where the research might go from here is provided.

Also note that there is a glossary at the end, which defines all of the technical terms used in this report.

Part 1: THE FMF NATURAL DISTURBANCE PROGRAM

In 1995, the Foothills Model Forest (FMF) in Hinton, Alberta initiated a research program to describe natural and cultural disturbance patterns across over 2.75 million hectares of foothills and mountain landscapes (Figures 1 and 2). The main purpose of the research is to provide FMF partners and co-operators with a complete picture of how natural and cultural disturbances have historically shaped these landscapes. Ultimately, each partner intends to use this information to help guide policy and management towards developing more ecologically sustainable land management practices.



Figures 1 and 2. Foothills Model Forest administrative areas and ecological zones.

The Foothills Model Forest natural disturbance program is a co-operative venture, led by a team of representatives from the Foothills Model Forest, Weldwood of Canada, Alberta Environmental Protection Land and Forest Service (LFS), Jasper National Park (JNP), and Alberta Newsprint Company (ANC). The comprehensive research program is partitioned into over 20 inter-related projects, each of which address a single disturbance question at a single scale. All projects are linked through a long-term research plan which includes details of the purpose and methods for each project and how they fit together to form a complete picture of natural disturbance patterns. It also defines ground-rules for conducting the research to maintain focus, assess progress, respond to new information, and effect the timely completion of the work. These self-imposed ground-rules are as follows:

1) The main assumption driving this research program is: ***In the absence of information on alternatives, using natural disturbance patterns to guide management is one of the best possible means of achieving ecological sustainability.*** Therefore, the main research focus is on patterns, and the disturbance processes responsible for those patterns. This is not to say that the ecological responses to those patterns are not important, but they are secondary issues/questions for which more basic knowledge and extensive research is required.

2) Since both natural and cultural disturbances affect pattern, the program implicitly considers all types of disturbances. The danger of the deliberate isolation and study of specific disturbance agents is the assumption of pre-conceived, and possibly incorrect, relationships between pattern and process.

3) The research is driven by operational needs and the results are designed to be readily interpreted. This means that the research must consider translations of results to management practices. This is being accomplished in two ways. First, direct linkages have been sought to monitoring programs through the description of pattern(s). Although the output of this research is non-species specific, it is highly quantitative, and it is possible in many cases to define “natural baselines”, making it well suited to monitoring. The second means of developing operational translations is through experimentation and demonstration. This allows for the evaluation of operational changes in terms of a) the success of creating the desired pattern(s), b) the biological responses of species and processes not part of the original research, c) practicality, and d) socio-economic impacts.

4) Finally, internalizing the research is to be avoided. High-quality research is conducted by professionals, openly peer-reviewed, presented at public meetings, conferences and tours, and published in FMF NDP Quicknotes, internal reports, news updates, posters, and refereed journals. A communications plan has been developed for the FMF Natural Disturbance Program to guide the dissemination and integration of the research.

SOME DEFINITIONS

The term "landscape" has many meanings at many different scales. As a research document, a "landscape" in this report refers to ***an ecosystem large enough to allow observation and understanding of the interaction of disturbance, geomorphology, and topography with the biota***. In other words, a large collection of forest stands, whose common link is their dynamic relationship to both disturbance and land features. In the foothills of Alberta, a landscape may be anywhere from 100,000 to 1,000,000 hectares. Like any ecological definition, this one is arguable, but it allows some convenient scale distinctions to be made:

1) **Regional**

Several landscapes spatially related and commonly influenced by regional climatic patterns. The FMF study area is a region, in which several large landscapes have been identified with unique topographic, biotic, and pattern (disturbance) features. Beyond a region is a biome.

2) **Landscape**

Ecosystems that share common disturbance and land associations, as well as the resulting arboreal (tree) relationships with disturbance and land features. The ecologically based natural subregions have proven useful in defining landscapes (which include the Lower Foothills, Upper Foothills, Subalpine East, Subalpine JNP, and the Montane – see Figure 2).

3) **Sub-landscape**

Sections of one or more landscapes that exhibit a combination of ecological, social, and economic characteristics. Sub-landscapes can be defined in different ways depending upon management needs. For example, in our research, sub-landscapes are arbitrarily chosen blocks within landscapes in which more detailed analysis will be completed at higher levels of resolution.

4) **Event / Meso**

Areas within or between landscapes that at some point in time are commonly affected by a single disturbance such as a forest fire. Events include one or more disturbance patches, and may cross landscape boundaries. They may also include both forested and non-forested patches.

The geographical terminology used in this document is as follows. The FMF consists of two major land areas divided by the foothills of the Rocky Mountains (see Figure 1). To the west of the foothills lies approximately 1.1 million hectares of Jasper National Park. To the east of the mountains is an area of approximately the same size, which covers the Weldwood Forest Management Agreement Area (FMA) but also includes William A. Switzer Provincial Park, the town site of Hinton, a large coal mine, and a strip of land under the management of Alberta Land and Forest Service. Outside the boundary of the FMF, but still in our study area is approximately 370,000 hectares representing the ANC FMA (Figure 1). The area to the west of the foothills is all JNP, and will be referred to as such. Since the area to the east of the mountains is a mixture of tenure, it will simply be referred to as the "Foothills East".

Although the Willmore Wilderness Area is a part of the Foothills Model Forest, it will not be discussed in this report as little data exists for this area.

Within Jasper National Park, three natural subregions exist: the Montane, Subalpine, and the Alpine. In the Foothills East there are also three main natural subregions: Lower Foothills, Upper Foothills, and Subalpine (Figure 2). To avoid confusing the two subalpine areas, they will be referred to as the "Subalpine JNP" and "Subalpine East".

THE DISTURBANCE RESEARCH REPORT SERIES

This research report is the second in a series that will be published by the Foothills Model Forest on natural disturbance dynamics on foothills and mountain landscapes in Alberta.

For more information on the FMF Natural Disturbance Program, or the Foothills Model Forest, please contact the Foothills Model Forest in Hinton, Alberta at (780) 865-8330, or visit our website at: http://www.fmf.ab.ca. Copies of reports and Quicknotes are available on the website in Adobe Reader® format.

Reports available in the research series:

Andison, D.W. 1999. Assessing forest age data in foothills and mountain landscapes in Alberta. Alberta Foothills Disturbance Ecology Research Series, Report No. 1, December, 1999. Foothills Model Forest, Hinton, Alberta.

Part 2: FIRE ACTIVITY BETWEEN LANDCAPES
BACKGROUND

The study of disturbance patterns logically begins at a general level and very coarse scales to allow understanding of the "big picture", and is a fundamental component of the process of maintaining biodiversity (Noss 1994). Disturbance regimes describe the types, extent, severity, cycle, and predictability of disturbances over hundreds of thousands, or even millions of hectares, and hundreds of years. Other reports in this series will discuss extent, types and severity of disturbances. This report will concentrate on timing and predictability of forest fires on the Foothills Model Forest at the landscape scale and higher over the past several hundred years. Longer time frames could be studied using paleoecological methods, but the patterns over the more recent past (where other data such as climate are available) were considered a more practical benchmark for our purposes.

There are many advantages to possessing knowledge of "natural" levels or ranges of fire activity over large areas. From a practical point of view, this information gives one an idea of relative levels of fire hazard across landscapes. It also suggests what the "ecological rotation" (see Glossary) of different forest-types might be, which can be used to stratify the landscape, and then define and defend management targets for ecosystem management purposes. Similarly, historical, natural levels of seral-stages can be identified and used as management targets for long-term planning, which will ultimately allow for the maintenance of historical, and therefore sustainable, amounts of key forest-types such as old-growth. In protected areas such as parks, it can also help to define long-term targets for prescribed burning programs that will allow disturbance levels to remain (or move back) within the natural range of variability.

Despite the great value of having reliable estimates of the cycles of forest fires, they are rare for two reasons. First, the age data with which the estimates are made are often of questionable, or at least unknown quality. Second, the variable nature of fire cycles over time makes fixed estimates of limited value. It therefore becomes very important to consider both the quality of the source data, and the methods used in any analysis. Towards the first point, in the first report in this series, the age data available for the study area were carefully scrutinized and the following conclusions were drawn:

1) Stand-replacing fires dominate the study area, but not absolutely. The Montane and some parts of the Upper and Lower Foothills Natural Subregions may have been subject to a combination of stand-replacing and stand-maintaining fires (all three areas have been, or will be the object of further study).

2) The Weldwood FMA has age data of exceptional quality.

3) The Alberta Newsprint Company FMA has age data of unknown quality. Since ANC is immediately adjacent to Weldwood, there is a possibility of extrapolating research findings from one area to the other.

4) Jasper National Park has age data of only moderate quality. This is likely due to a combination of factors including the presence of multi-aged stands (suggesting historical surface-fire activity) and inadequate aging methods in older stands.

Using this knowledge, this report will summarize the age data in various ways from each of the three administrative areas in the study area (which also represent three distinct levels of data quality). For the most part, the analysis will concentrate on describing the historical, natural fire activity. In general, fire activity in the last 50-70 years was "unnatural" in that fire control activities have been particularly effective on all parts of the study area. Fire control has been by far the greatest management intervention on the FMF study area, arguably more influential than any harvesting activities. Consider, for instance, that harvesting activities on the Weldwood FMA have been ongoing since 1950, and account for close to 140,000 hectares or about 14% of the landscape. If fire control were not implemented over the last 50 years, chances are that fires would have impacted at least that much of the landscape, and likely much more. Therefore, every effort will be made to account for this cultural intervention.

The following sections are broken down by administrative area, but also take advantage of the various ecological zones as strata for reporting. No statistical tests have been done to determine the relevance of these strata. However, the Alberta Natural Subregions represent pre-determined, and otherwise practical spatial strata, which have already been proven to be ecologically distinct.

Jasper National Park

As described in the first report of this series, the weakest age data from the study area exists in Jasper National Park. Only 19% of test plot ages fell within the same 20-year age-class as the JNP fire history map indicates, and 49% of plots fell within +/- one 20-year age-class (Andison 1999b). However, no evidence of bias was found in the ages, meaning that overall, from a non-spatial point of view, the totals add up. Therefore, despite the poor showing of the stand age data, age-class distributions created from the dataset probably accurately reflect overall age patterns in the Park. However, levels of detail greater than 20-year age-classes are not justified. It should be noted that a portion of the forest ages in Montane zone was mapped in great detail by Tande (1979), but this area is the exception.

Another point to keep in mind when considering the age data from JNP is that stand-replacing fires are not the only disturbance agent active in the Park. There is evidence of surface fires, insect and disease outbreaks, and even floods. These disturbance agents all tend to create multi-aged, or possibly all-aged forests. This phenomenon was clearly demonstrated in the age validation exercise, and discussed in the first report (Andison 1999b) and other documents (Andison, draft). The date of the last stand-replacing event is still possible to determine in such forests, but the relevance of this information is less critical than in forests dominated by stand-replacing forest fires. The results in this report should therefore be considered in conjunction with research results from more detailed disturbance history studies. This research is currently underway.

The existing age data from JNP's fire history study is summarized in 20-year age-classes for each Natural Subregion. Fire control activities have been aggressive in the Park for almost 40 years, and active on some level for over 60 years (A. Westhaver[1], pers. comm.). Any age-class distribution estimate made in the Park from the last 60 years will therefore be artificially, and unnaturally biased towards older forest. Re-creating an age-class distribution from 1930 is not difficult since the amount of forested area younger than 70 years of age is only 2.6% of the Park. Distributing this 2.6% proportionately to the remaining age-classes (which is a conservative, although imperfect assumption) an age-class distribution from 1930 can be estimated. According to the provincial ecological classification system, the Park includes land area from four Natural Subregions; Montane, Subalpine, Alpine, and Upper Foothills (Beckingham *et al*. 1996). However, a second ecological classification from Jasper divides the Park into five ecological zones; Montane, Lower Subalpine, Upper Subalpine, Alpine, and Upper Foothills (Holland *et al.* 1982). Table 1 presents an overview of how both systems stratify the Park. For the purposes of the age-class analysis, both systems will be discussed, although the Jasper system is the one summarized in detail, with the following two exceptions. First, although JNP has approximately 5,400 ha of Upper Foothills, it is not large enough to be meaningful on its own. This area will be added to the Upper Foothills totals of the Weldwood land summary in the next

[1] Park Warden, Jasper National Park

section. The second exception is the addition of the 9,000 hectares of Weldwood portion of the Montane area, to the Montane area of the Park.

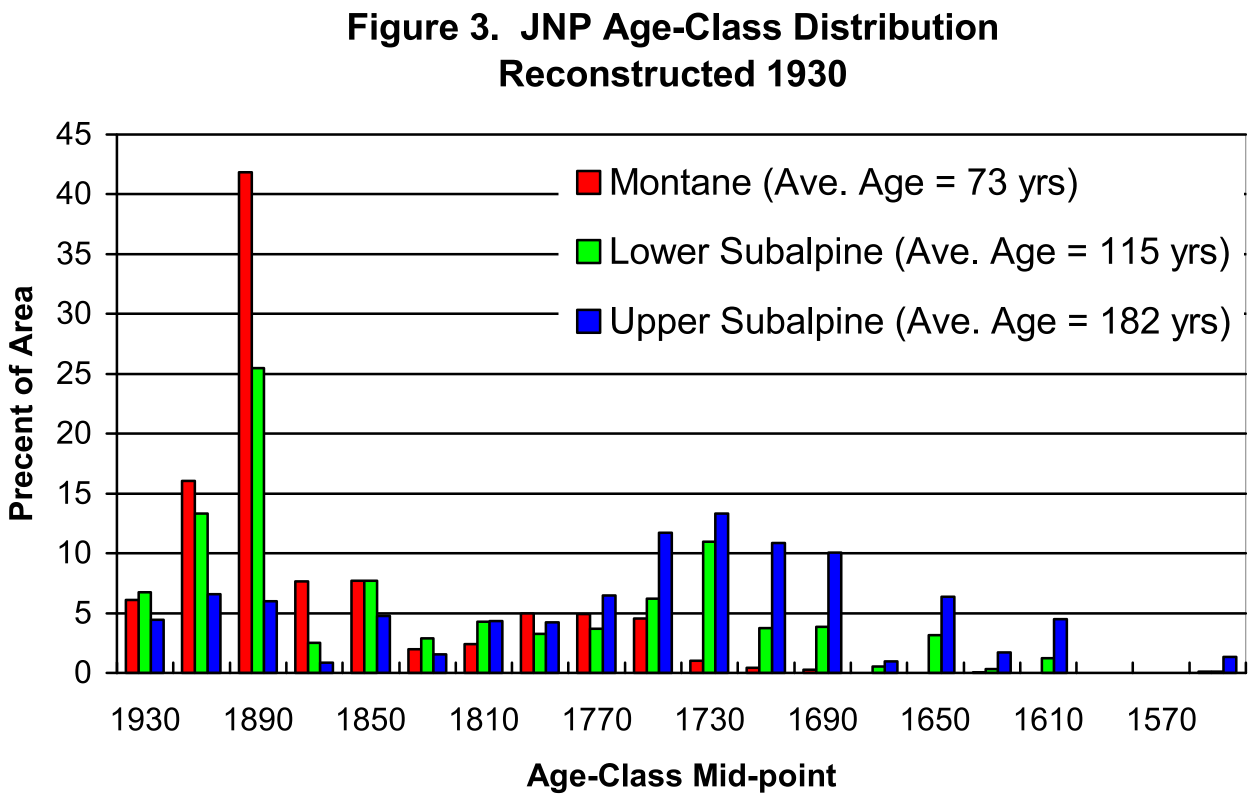
Table 1. Ecological Land Classification Overview of Jasper National Park.

Ecological Zone	Forested Hectares	Non-Forested Hectares	Total Hectares
From Weldwood Data			
Montane Natural Subregion	8,800	200 (2%)	9,000
Alberta's Natural Subregions			
Upper Foothills	5,300	100 (2%)	5,400
Montane	72,800	7,600 (10%)	80,400
Subalpine	362,000	171,700 (32%)	533,700
Alpine	39,000	461,300 (92%)	500,300
Subregions From JNP Classification			
Upper Foothills	5,200	200 (4%)	5,400
Montane	77,800	2,800 (4%)	80,600
Lower Subalpine	299,400	33,000 (10%)	332,400
Upper Subalpine	99,200	117,700 (54%)	216,900

The three Park-defined ecological zones differentiate well in terms of overall fire activity. The Montane zone averages 73 years of age, the Lower Subalpine 115 years, and the Upper Subalpine 182 years (Figure 3). Although not shown, the average age of the (Alberta) Subalpine Natural Subregion is 127 years. It is also notable that the 9,000 hectares of Montane from the Weldwood FMA is substantially older than the rest of the Montane. The average age of the Jasper portion of the Montane is only 64 years, compared to 73 years when the small Weldwood Montane area is included.

Despite the high degree of spatial adjacency between the Lower and Upper Subalpine zones, the distinction between them in terms of fire activity is surprising. There is a 67-year difference in average age between these two areas, suggesting significantly less fire activity at higher elevations. In addition, the very high level of fire activity between 1871 and 1890 (corresponding to the 31-50 year age-class in Figure 3) is evident in both the Montane and Lower Subalpine zones, but not in the Upper Subalpine.

There are also dramatic differences in the amount of older forest between the three zones. The Montane zone only has two percent of its' forests older than 200 years of age, while the Lower Subalpine has 24%, and the Upper Subalpine 49% (Figure 3).



The tremendous impact of fire control in the Park is evident when the relative amounts of older forest in the Park from 1930 are compared to that of today. In the Montane, over the past 65 years, the amount of forest older than 100 years has increased from 21% to 78% - almost quadruple (Table 2). For the same period, the amount of forest older than 100 years in the Lower Subalpine has almost doubled from 44% to 79%. The amount of forest older than 100 years in the Upper Subalpine has probably always been high, and thus only mildly increased over the last 70 years. However, the area of the oldest forests (>300 years) has been increasing, and now accounts for ¼ of the entire zone (Table 2).

Table 2. Estimated Amount of Older Forest in JNP

Natural Subregion	Percent Older Forest in 1995/1930		
	>100 yrs	>200 yrs	>300 yrs
Montane	78 / 21	16 / 2	0 / 0
Lower Subalpine	79 / 44	37 / 24	9 / 2
Upper Subalpine	88 / 77	71 / 49	25 / 8

Another, more informative way of considering the frequency of fire over large areas is by making estimates of historical disturbance rates by "rolling back" age-class distributions. The logic of rolling back age-classes is as follows. The youngest 20-year age-class is the only one that represents the actual amount of disturbance in a 20-year period. Each successively older age-class increasingly underestimates the amount of disturbance in a 20-year period, because more recent disturbances have overlain some portion of the area previously disturbed. So although the oldest age-class may represent only 5% of the landscape now, we know that the original area burnt during that particular 20-year period was much higher.

Rolling back works by peeling off the area of the youngest age-class, and assuming that underneath are areas from all other (older) age-classes. The proportion of the area underneath in each of the other age-classes is identical to the proportion of the area of those age-classes existing on the landscape today. The assumption of proportionality is not perfect, but at least affords a simple means of making some rough estimates of historical disturbance rates. The method becomes increasingly risky as more layers are peeled off, so the more recent disturbance frequencies are more believable than later ones.

Despite the risks inherent in the rollback assumption, the exercise reveals several important patterns. First, in support of earlier arguments, the low disturbance frequencies over the three most recent 20-year periods are unprecedented, and far below the average historical levels in all areas of the Park (Table 3). Over the past 60 years, the percent area burnt in any of the three zones never exceeded 1%. The rollback estimates of fire activity for the previous 140 years suggest that natural burn rates this low are historically unprecedented (Table 3).

The second valuable piece of information gained from the rollback exercise is the concept of variability. Excluding the first three 20-year periods (those not in bold in Table 3), over the past 140 years, disturbances may have consumed anywhere from six to 54 percent of the Montane forests in a single 20-year period, and between five and 32 percent of the Lower Subalpine forests. This information is valuable ecologically since it helps to define the "natural range of variability" (NRV) of fire activity at very coarse scales. In other words, fire was highly stochastic over decades (temporally) and tens and even hundreds of thousands of hectares (spatially). The danger of using only single-number fire cycles to represent historical landscape fire behaviour is obvious.

Table 3. Estimates of 20-Year Burning Levels by Jasper Subregion in JNP

20-Year Period	Percent of Forest Burnt in each 20-Year Period		
	Jasper Ecological Zone		
	Montane	Lower Subalpine	Upper Subalpine
1971-1990	0	0.2	0.2
1951-1970	0	0.7	0.2
1931-1950	0.3	0.5	0.2
1911-1930	6	7	4
1891-1910	17	14	7
1871-1890	54	32	7
1851-1870	21	5	1
1831-1850	27	15	6
1811-1830	9	6	2
1791-1810	13	10	6
Average 1810-1911	21.0	12.7	4.6

The analysis is also valuable from a practical point of view, since it indicates how active and potentially volatile forest fire activity has been. In other words, the Park is susceptible to very high levels of forest fire activity, particularly in those areas where most people spend their time. Combine this with 60 years of fire control resulting in a dramatic increase in older, potentially more flammable forest, and the risk of conflagration is very real.

The final point to keep in mind specific to JNP is that stand-replacing fire events are only one of several disturbance agents active on the landscape. Particularly in the Montane zone, stand-maintaining disturbances such as surface fires and insect outbreaks are likely. This means that the natural frequency of disturbance is much higher than even the historical fire cycle suggested here indicates. Yet again, this has ecological and practical implications. Future reports will deal specifically with the more complex disturbance history of the Montane, and put the findings from this report into context.

Foothills East

The fire history of the east side of the study area includes the Weldwood FMA, Alberta Newsprint Company's FMA, and various bits of land under Provincial jurisdiction (see Figure 1). From report No. 1 in this series (Andison 1999b), we know that most of eastern slopes have excellent forest age data in the form of Weldwood's fire history map and additional stand-age mapping that we completed on all of the Provincial lands in 1996 and 1997 (Rogeau 1996 and 1997). The final fire history map covers over 1.1 million hectares. On the rest of the foothills east (*e.g.* the ANC FMA) age data exists, but was sampled and mapped to Alberta Vegetation Inventory (AVI) standards (Nesby 1997). As outlined in Andison (1999b), the differences in data collection methods between the ANC area and the rest of the eastern slopes are significant. Furthermore, an as yet unpublished manuscript by Andison (in draft) suggests that AVI-type ages in both Alberta and Saskatchewan are both inaccurate and imprecise relative to stand-origin ages. The age-class distributions of these two datasets will therefore be presented separately for this analysis, and the differences and similarities discussed.

Weldwood of Canada Ltd.

Methods

Since the age data from the greater Weldwood FMA (which includes Provincial and Municipal land in and surrounding the actual FMA) is of such high quality these data are worthy of more rigorous analysis.

Since the point of this report is to reconstruct as closely as possible the "natural" age-class scenario(s), the stand origin-data discussed in Report #1 was used, with some small adjustments to account for disturbance activity during 1950 to 1990. Even though harvesting activity is not included in this dataset, openings created by more recent fires, or clearing for mine sites or other cultural activity was recorded. In the Lower Foothills, these other disturbances account for 19,012 ha (7.3%) in that period, for the Upper Foothills, 27,118 ha (5.4%), and for the Subalpine 3,056 ha (1.3%). Almost all of this area is accounted for by nine large openings, most of which are fires or mines.

Regardless of the cause, these disturbances are "unnatural" from an historical perspective, and therefore must be removed from the dataset. The simplest way of doing so is to eliminate these areas before making estimates of percent area in each age-class. This supposes that the non-harvested area disturbed between 1950 and 1990 is evenly distributed between all remaining age-classes, which is a conservative assumption (and the same one made for the Jasper data).

The area for which the following summaries are made is the contiguous piece of land in the foothills east referred to as the greater Weldwood FMA. It includes data for all of the non-FMA land such as Switzer Park and the Hinton townsite, as well as the small patch of Upper Foothills forest that is within JNP (since this is too small an area to consider for stand-alone analysis). Similarly, the small piece of Montane forest in the FMA was combined and summarized with the Montane forest of JNP (see Table 1). Finally, although by definition "forest" does not exist in the Alpine zone, over 12,000 ha of Alpine forest was reported in the summaries (Table 4). These were assumed to be Subalpine forest, and merged with these data for analysis (Table 4). These differences are important to detail since the age-class distributions developed in this report for the greater Weldwood FMA will differ somewhat from those created from the raw age data from the Weldwood inventory alone.

Table 4. Area Summary for the Greater Weldwood FMA

	U. Foothills From JNP	U. Foothills from Weldwood	**Total Upper Foothills**	Reported Alpine	Reported Subalpine	**Subalpine +Alpine**	**Lower Foothills**
Forested	5,274	515,078	**520,352**	12,175	230,453	**242,628**	**260,499**
Non-Forested	117 (2%)	66,878 (11%)	**66,995 (11%)**	(n/a)	14,472 (6%)	**(6%)**	**35,154 (12%)**
Total	5,391	581,956	**587,347**	41,096	244,925	**286,021**	**295,653**

As discussed in the first report in this series (Andison 1999b), the original stand-origin map of the FMA used an “older than” age-class. The results of our stand-origin mapping from 1997 and 1998, plus the original 2,000 PSP plots ages, were used to make non-spatial estimates of the actual distribution of the older-than age-class for each natural subregion on the FMA. See Andison (1996) for detailed methods and results.

Results

The final age-class distribution for the greater Weldwood FMA clearly distinguishes the Subalpine from both of the other two natural subregions (Figure 4). Average age of the 1950 Subalpine forest snapshot is 29 to 35 years older than the Lower Foothills and Upper Foothills areas respectively, suggesting a longer fire cycle in that area.

The average ages of the Lower and Upper Foothills (from 1950) are within six years of each other indicating that fire activity in these areas is similar. However, if we roll back the age-classes similar to that done for JNP, differences between the two areas are more evident. As expected, 20-year fire activity estimates in the Subalpine area are far less than in the other parts of the FMA (Table 5). However, the roll-back also suggests that the Lower Foothills had more extreme fire behaviour than did the Upper Foothills area. On average, over the last 140 years, over 29% of the Lower Foothills forest burnt in any single 20-year period, compared to just under 24% for the Upper Foothills (Table 5). These roughly translate to 69 and 84-year fire cycles for the Lower Foothills and Upper Foothills areas respectively over the last 140 years.

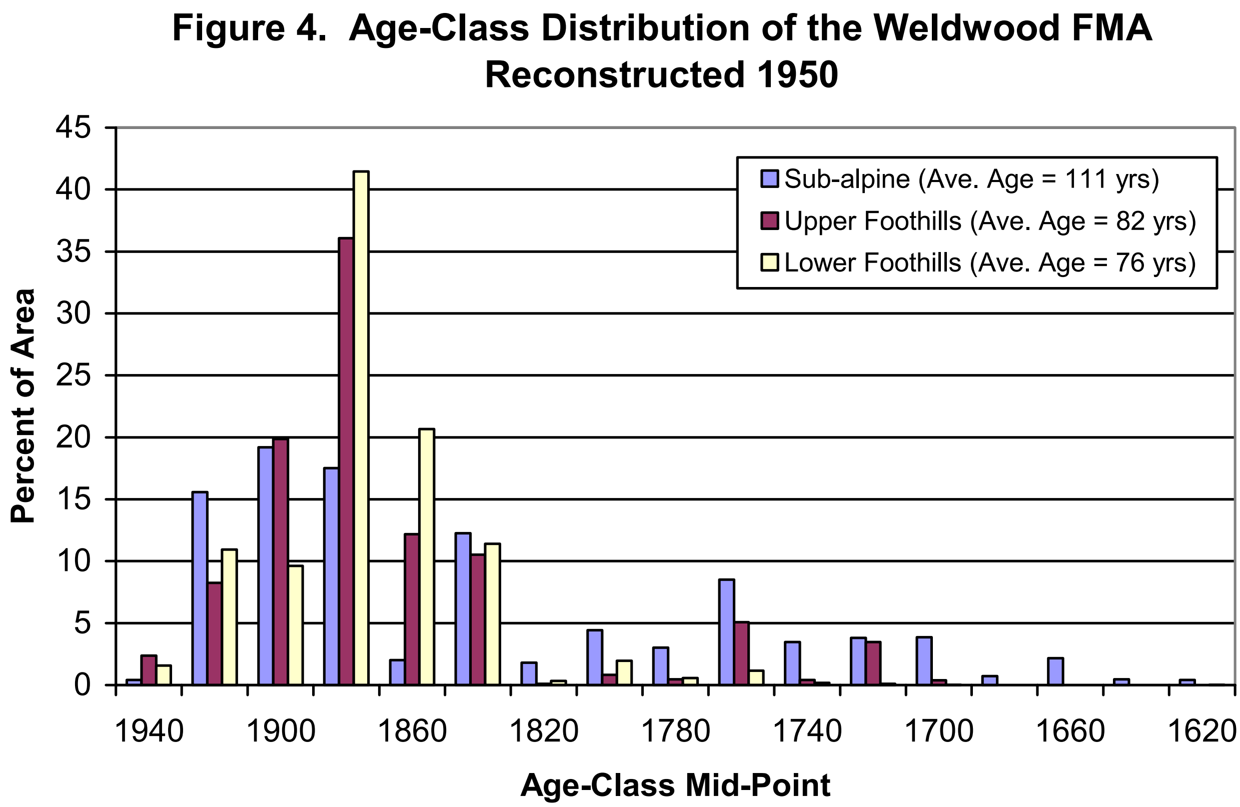


Table 5. Estimates of 20-Year Burning Levels by Subregion on the Greater Weldwood FMA

	Percent of Forest Burnt in each 20-year Period by Subregion		
20-Year Period	Subalpine	Lower Foothills	Upper Foothills
1931-1950	<1	2	2
1911-1930	15	11	8
1891-1910	23	11	22
1871-1890	27	52	51
1851-1870	4	55	36
1831-1850	28	67	47
1811-1830	4	6	1
Average 1810-1950	14.6	29.1	23.9

Seral-stage Natural Range of Variability

Additional analysis was completed with the Weldwood FMA data at the request of Weldwood. Estimations of burning rates by natural subregion are a useful indicator of the average and range of fire activity on the FMA over the last century or more. However, it does not fully resolve the question of what the natural ranges of different age-classes might be. Despite the superior quality of the Weldwood age data, it still only represents a single snapshot in time of what a "natural" forest might look like. The evidence from Table 5 suggests that there is significant variability over time in the amount of forest in each age-class. To quantify this variability, one must either have historical records of age-class distributions through time, or be able to estimate such distributions through modelling. As part of their management planning exercise, Weldwood of

Canada chose to sponsor a modelling exercise to complement the FMF research, as a means of developing natural ranges of age-class variability.

Computer simulation allows one to see the impacts of allowing the range of 20-year burning rates play out over space and time. If the probabilities of both the frequencies and sizes of fires are accurately estimated, a computer model can "burn" fires across landscapes indefinitely, literally creating an infinite number of landscape pattern possibilities. In other words, the right computer model can create many different, equally possible, landscape snapshots, and thus many different, equally possible, age-class distributions. The LANDMINE computer model is designed to do exactly this.

The details of how LANDMINE works can be found in Andison (1996), and the specifics of how it was used on the Weldwood FMA have already been published in Andison (1998). Briefly, LANDMINE uses a dispersal algorithm to spread fires from one pixel to another in such a way that fire movement responds probabilistically to fuel-type and topography. These movements can be calibrated to create different fire shapes and unburnt island remnants details that match empirical data. Fire size is controlled by an equation that represents the actual fire size distribution for each landscape. Ignition location probabilities also require calibration, but are loosely based on historical lightning probabilities. Finally, the total amount of forest burnt in any single time step (20 years in this case) is established through another equation describing the historical areas burnt from Table 5. Each of these steps is stochastic, meaning that LANDMINE never burns the same way twice. However, over the long term it is consistent with internally defined probabilities. It is thus a powerful landscape disturbance model (*i.e.*, it is good for exploring long-term burning trends over space and time), but a poor fire behaviour model (*i.e.*, it is not very good at predicting individual fire events).

To simplify the output, age-classes were grouped into four seral-stages: Young, Pole, Mature, and Old. Since these stages are achieved at different ages for different forest-types, the age breaks vary. For all pine and spruce-dominated stands, "Young" forest is 0-20 years, "Pole" 21-100 years, "Mature" 101-180 years, and "Old" is anything over 180 years. For all mixedwood and hardwood-dominated stands, "Young" forest is again 0-20 years, but "Pole" is 21-80, "Mature" 81-120, and "Old" is anything older than 120 years. The simulations thus tracked the percent area for (4 x 4 =) 16 strata. The results were also summarized for different-sized areas beginning at 30,000, then 60,000, 120,000, 240,000, and for the Upper Foothills, 480,000 hectares.

Figures 5-9 depict the frequency with which the simulation model generated different percentages of each of the four seral-stages, for each of the four leading cover-types, by Natural Subregion. The percentage of each seral-stage is based on the proportion of age-class relative to the total area in those strata. So for example, in Figure 5, 18% of the time, the runs generated 0-2% of Young Pine area in the 30,000 ha landscapes of the Lower Foothills, but only 9% of the time for the 240,000 ha landscape. In addition, the percent of each particular seral/species strata from both 1950 and 1998 are included as reference points in the Figures.

Note that this analysis was completed for, and supported by Weldwood of Canada Ltd., and the results included in their most recent Forest Management Plan (FMP). Any differences noted between the numbers presented here and those in the plan are due to differences between the FMA area proper, and the greater FMA area used for this report.

Overall, the most dominant feature of the historical frequencies of the different seral-stages is the wide range of variation. In other words, fire activity was such that highly variable levels of different seral-stages could and did occur over the last 2-300 years. The 1950 and 1998 landscape "snapshots" for the most part are well within these ranges, suggesting that at the broadest scale, the 1998 landscape is *almost* as "natural" as any that occurred over the last few centuries, including 1950 (Figures 5-9).

I say the broad-scale pattern is *almost* natural because there are two exceptions. First, on both the Upper Foothills and Lower Foothills landscapes, the existing (1998) amount of Old Hardwood is extremely high (Figures 6 and 9). The corresponding amount of Young Hardwood is virtually zero in both cases, which is rare according to the simulation output. One could argue that the hardwood forest-type has not been disturbed enough, and is therefore beyond the so-called “natural range of variability”, or NRV. To a degree, the same fate is awaiting the Mixedwood component of the Lower Foothills landscape.

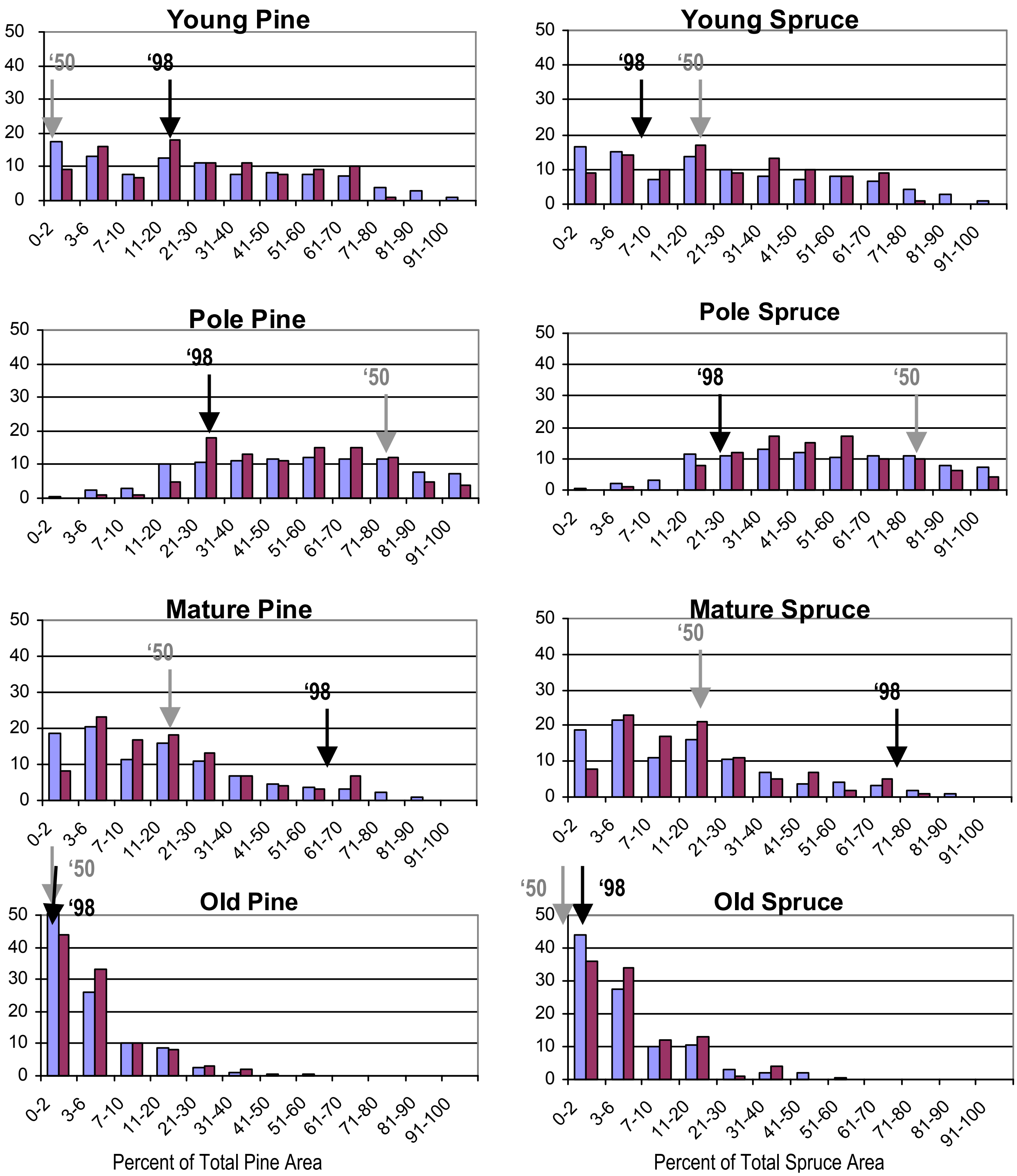


Figure 5. Historical frequency or probability of the occurrence of Young (0-20 yrs), Pole (21-100 yrs), Mature (101-180 yrs) and Old (>180 yrs) seral-stages of Pine and Spruce-dominated cover-types in the Lower Foothills Natural Subregion on the greater Weldwood FMA (from simulation). Blue bars depict the historical range for 30,000 ha areas, dark purple bars for 240,000 ha areas. The 1950 and 1998 percentages of forest in each strata for 240,000 ha are also shown.

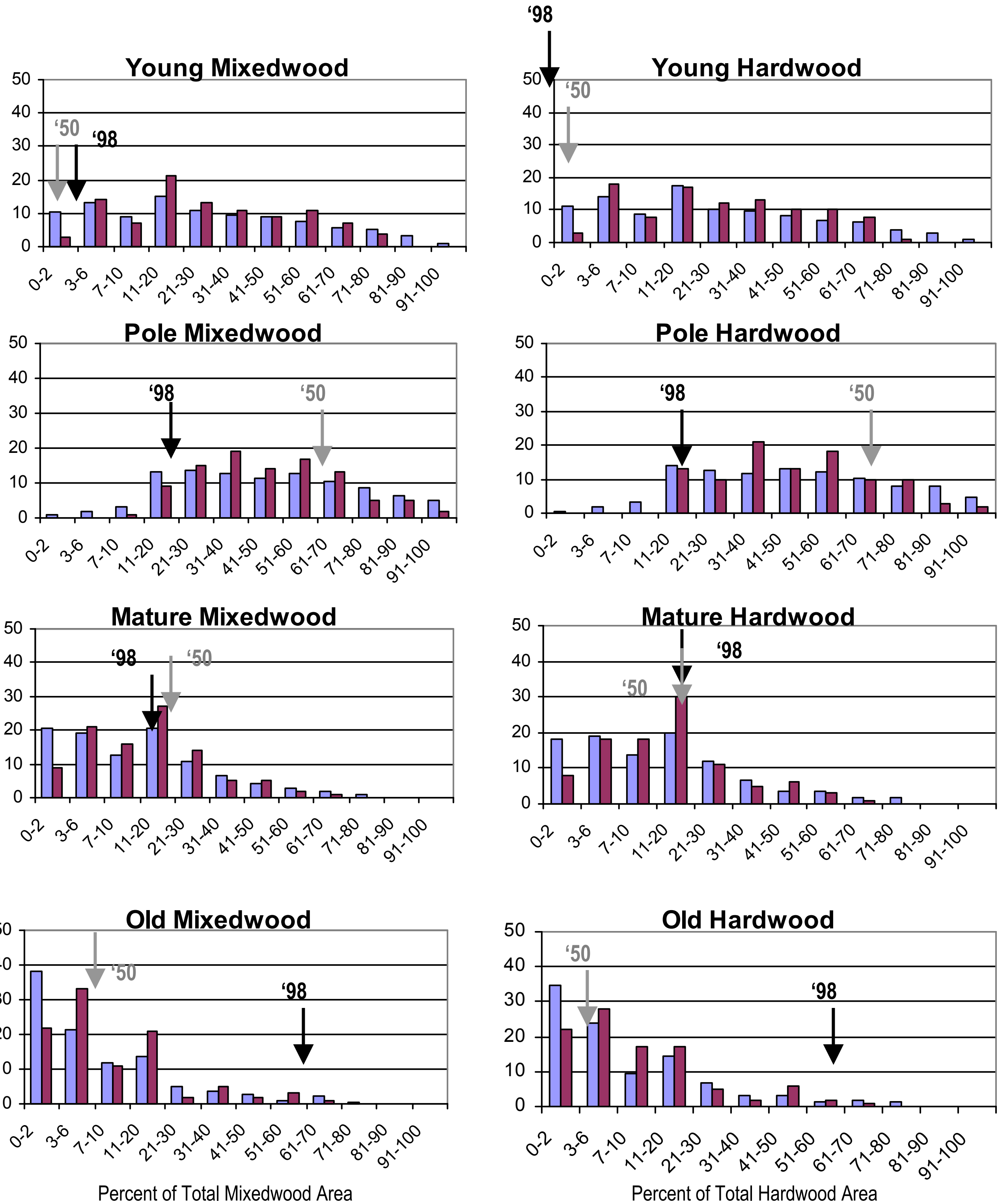


Figure 6. Historical frequency or probability of the occurrence of Young (0-20 yrs), Pole (21-80 yrs), Mature (80-120 yrs) and Old (>120 yrs) seral-stages of Mixedwood and Hardwood-dominated cover-types in the Lower Foothills Natural Subregion on the greater Weldwood FMA (from simulation). Blue bars depict the historical range for 30,000 ha areas, dark purple for 240,000 ha areas. The 1950 and 1998 percentages of forest in each strata for 240,000 ha are also shown.

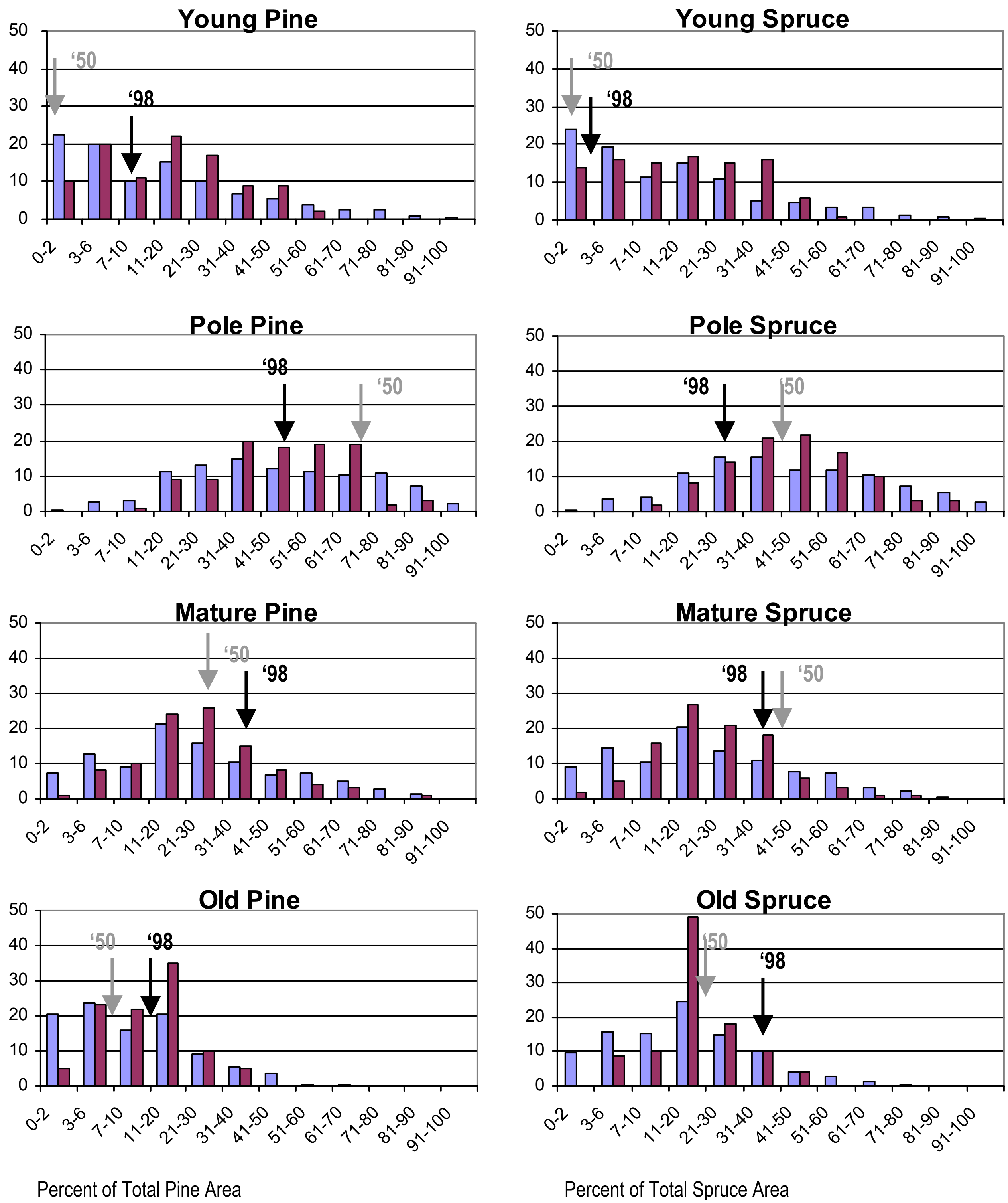


Figure 7 Historical frequency or probability of the occurrence of Young (0-20 yrs), Pole (21-100 yrs), Mature (100-180 yrs) and Old (>180 yrs) seral-stages of Pine and Spruce-dominated cover-types in the Subalpine Natural Subregion on the greater Weldwood FMA (from simulation). Blue bars depict the historical range for 30,000 ha areas, dark purple bars for 240,000 ha areas. The 1950 and 1998 percentages of forest in each strata for 240,000 ha are also shown.

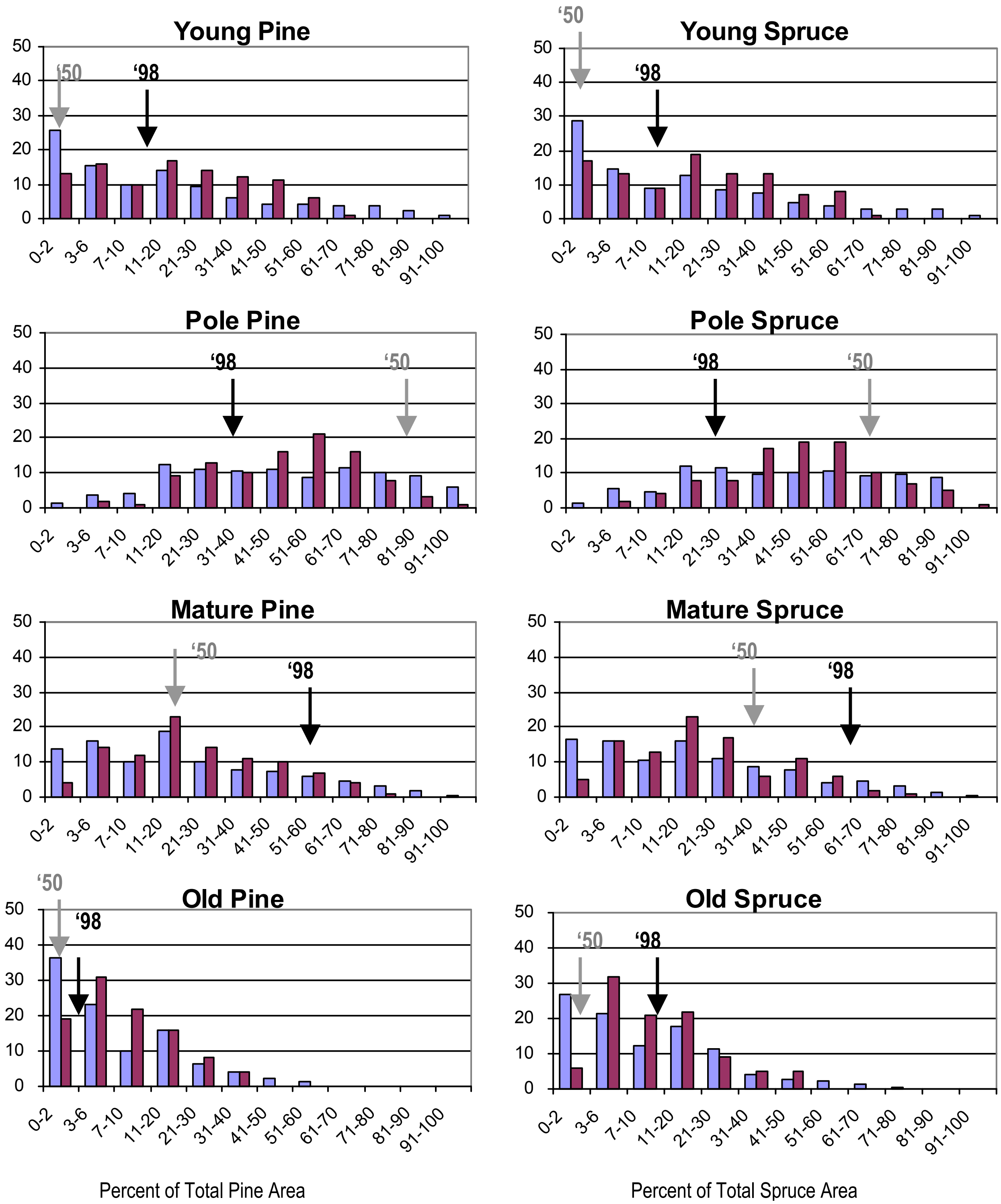


Figure 8. Historical frequency or probability of the occurrence of Young (0-20 yrs), Pole (21-100 yrs), Mature (100-180 yrs) and Old (>180 yrs) seral-stages of Pine and Spruce-dominated cover-types in the Upper Foothills Natural Subregion on the greater Weldwood FMA (from simulation). Blue bars depict the historical range for 30,000 ha areas, dark purple bars for 480,000 ha areas. The 1950 and 1998 percentages of forest in each strata for 480,000 ha are also shown.

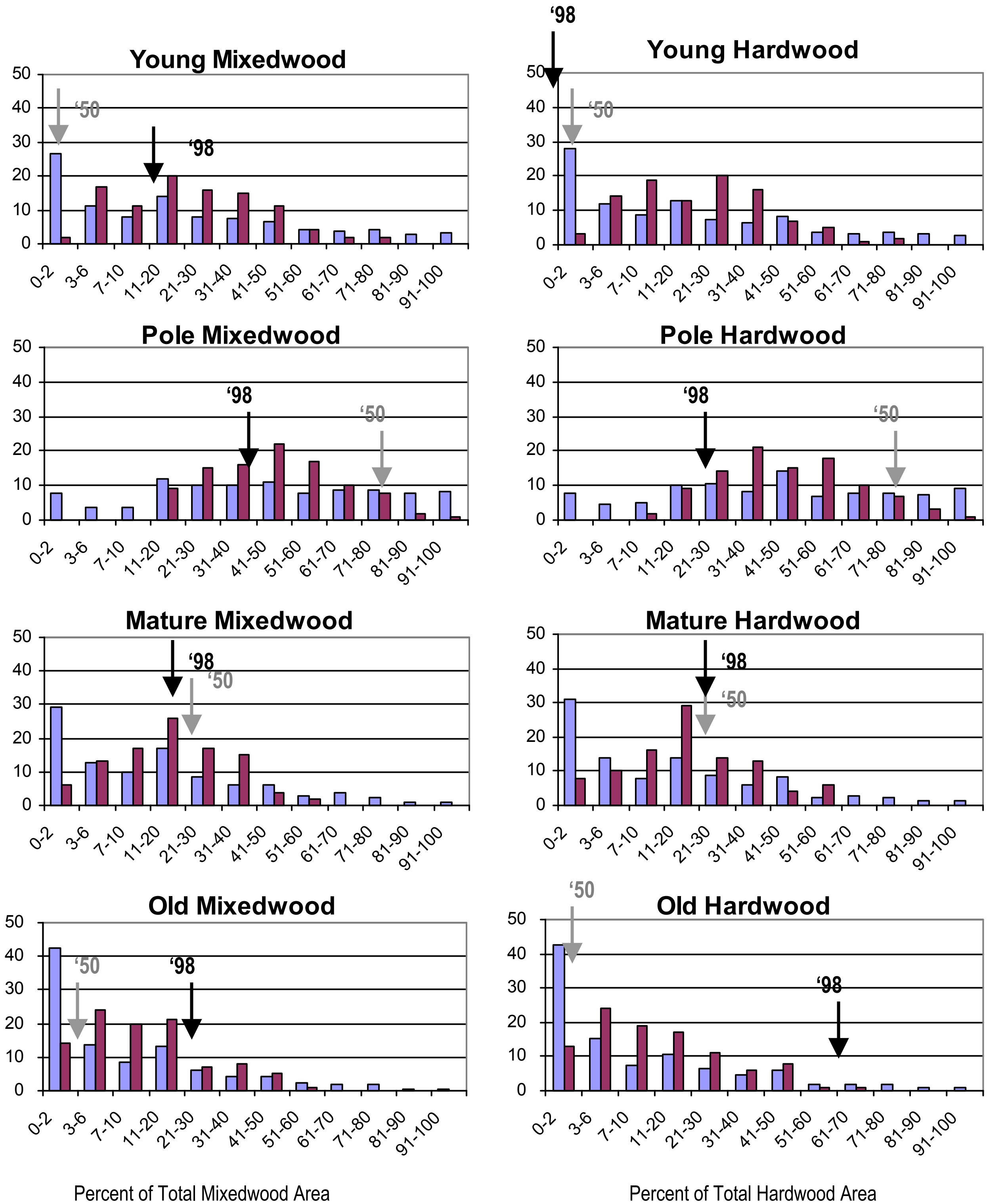


Figure 9. Historical frequency or probability of the occurrence of Young (0-20 yrs), Pole (21-80 yrs), Mature (80-120 yrs) and Old (>120 yrs) seral-stages of Mixedwood and Hardwood-dominated cover-types in the Upper Foothills Natural Subregion on the greater Weldwood FMA (from simulation). Blue bars depict the historical range for 30,000 ha areas, dark purple for 480,000 ha areas. The 1950 and 1998 percentages of forest in each strata for 480,000 ha are also shown.

The second notable exception to the current age-classes being within NRV is the high level of Mature Spruce in the Lower Foothills zone (Figure 8). Although 70% Mature Spruce is not unprecedented, it is clearly a rare occurrence relative to the simulation probabilities. Furthermore, if the situation is not soon mitigated, the Mature Spruce will soon become Old Spruce, creating the same situation found in the Old Hardwood strata.

In both situations where seral-stage NRV has been exceeded, the most likely cause is again fire control activities, combined with a lack of other disturbances. The Lower Foothills area in particular has not been actively managed for several decades, yet fire control efforts have been quite effective. The forest is simply getting too old.

A closer look at the simulation output reveals some interesting insights. For instance, as landscape size increases, the output range (or variation) decreases. In some cases, the probability distribution is even becoming “normal”. An excellent example of this phenomenon is the Old Spruce strata for the Subalpine zone (Figure 7). At 30,000 hectares the percentage of Old Spruce ranges from zero to over 70%, with only a vague central tendency. At 240,000 hectares, the range of Old Spruce is limited to 8-50%, with a clear central tendency around 15% (Figure 7).

One may hypothesize from this pattern that very large landscapes then actually support stable or relatively constant levels of different seral-stages. Although not shown in this report, the output from these simulations was in fact used to extrapolate variation in seral-stages to predict what the theoretical landscape sizes might be. The results suggested that “stable” age-class distributions would not be *theoretically* possible for natural subregion areas less than 5-10 million hectares. Practically speaking, “stable” age-class distributions do not exist in this part of Alberta.

Another relevant feature of the simulation output data is the frequency with which landscapes 30,000 hectares in size show little or no “Old” forest. For instance, over 1/3 of the time, 30,000 ha areas of Pine-dominated landscapes had less than 2% Old forest on the Upper Foothills (Figure 5). In the Lower Foothills, no more than 2% of the Pine-dominated stands were “Old” over ½ the time in 30,000 ha areas (Figure 8). Chances were pretty good that at any one point in time over the last few hundred years, fire activity was such that little or no Old Pine existed at this scale.

b) Alberta Newsprint Company

Methods

The age data from the Alberta Newsprint Company could not be validated using independent data. However, we know that age data for this FMA was collected and summarised using standard AVI methods, which are fundamentally different than those used to create stand-origin maps (Johnson 1992). In the next report in this series, this issue will be explored in greater detail. For now, we have no concrete evidence to suggest whether or not ANC’s age data are reliable. Accordingly, we will compile and discuss the existing age data for ANC conservatively.

There is another reason to be conservative with ANC age-class summaries – landscape size. The ANC FMA includes parts of four natural subregions: the Subalpine, Lower Foothills, Upper Foothills, and Central Mixedwood (Beckingham *et al.* 1996). The Subalpine and Central Mixedwood zones are unquestionably far too small to be meaningful in terms of estimating age-class distributions (Table 6). With less than 200,000 hectares each, even the areas in the Lower and Upper Foothills are marginal to be making such estimates. However, at the very least it will provide a useful comparison against the Weldwood age data.

Table 6. Area Summary for the Alberta Newsprint Company FMA

Land-type	Subalpine	Lower Foothills	Upper Foothills	Central Mixedwood
Forested	13,905	165,633	174,688	8,224
Non-Forested	489 (3%)	11,170 (6%)	6,292 (3%)	684 (7%)
Total	14,395	176,685	180,982	8,908

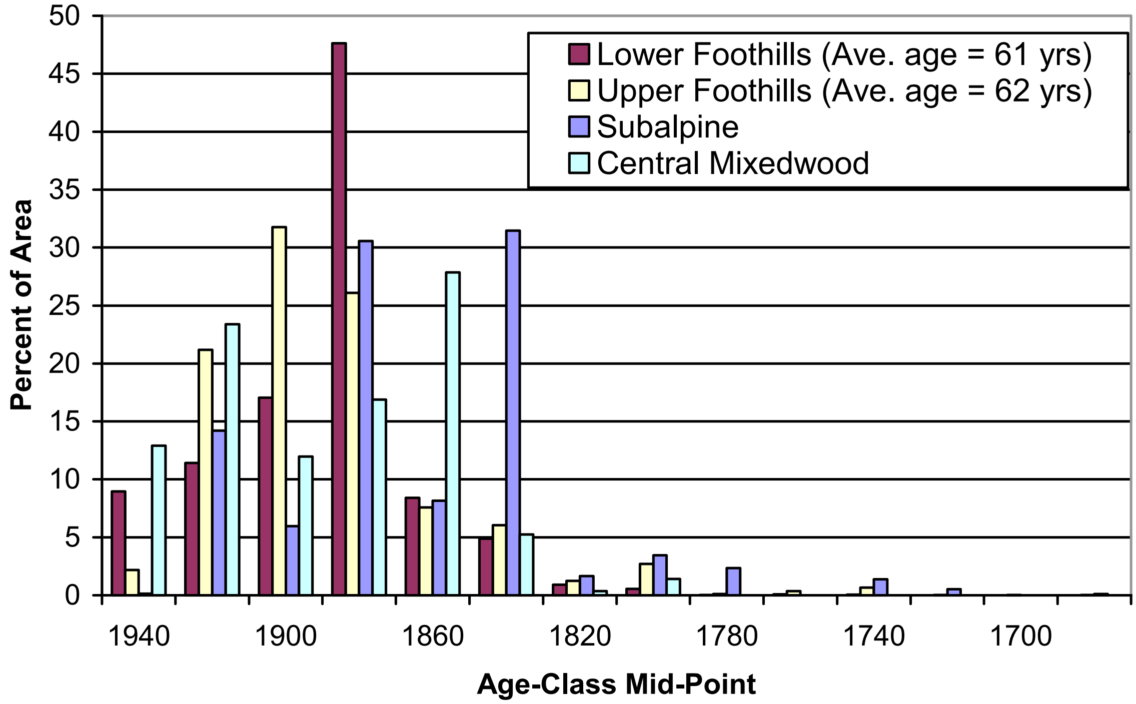
One of the advantages of the AVI data available for the ANC FMA is that it records the original stand data of most stands within each polygon record. So although harvesting activity has been ongoing for many years in the area, most of the original stand origin dates have been retained in the records. Thus the task of reconstructing a pre-cultural landscape is simplified.

Using the same logic as with Weldwood, the approximate date at which cultural activities such as fire control and harvesting became a significant influence on the eastern landscapes of the FMF is 1950 – at least 20 years later than in the Park (J. Wright, pers. comm.). By using the historical year of origin in the AVI database, the age-class distribution for the ANC landbase for 1950 was reconstructed (Figure 10). As with the Weldwood data, there were small amounts of unidentified forest with origin dates between 1950 and 1999. These areas were proportionally re-distributed in the remaining age-classes.

Results

The average ages of the Lower Foothills (61 years) and Upper Foothills (62 years) areas are lower than those from the Weldwood FMA (76 and 82 years respectively for the Lower and Upper Foothills) (Figure 10). There is no way of knowing if these differences are significant. All we can say for sure is that given the areas and raw data involved, we have much more confidence in the Weldwood data.

Figure 10. Estimated 1950 Age-Class Distribution for ANC



Similar to the Weldwood FMA, when 20-year disturbance rates are reconstructed, the differences between the Lower and Upper Foothills are more significant. The average area burnt in a 20-year period for the Lower Foothills was almost 39%, compared to only 33% for the Upper Foothills (Table 7). This translates to an average fire cycle of 52 and 61 years respectively for these two areas, which is still quite a bit lower than the fire cycles estimated for the same Natural Subregions on the Weldwood FMA in the same way (Table 6). On the other hand, similar patterns of fire activity are noted between the ANC and Weldwood areas (Tables 6 and 7). For instance, very high levels of fire activity are noted in both areas between 1871-1890.

Table 7. Estimates of 20-Year Burning Levels by Subregion on the Greater Weldwood FMA

20-Year Period	% of Forest Burnt in each 20-year Period by Subregion	
	Lower Foothills	Upper Foothills
1931-1950	9	2
1911-1930	12	22
1891-1910	21	41
1871-1890	75	57
1851-1870	53	38
1831-1850	66	50
1811-1830	36	20
Average 1810-1911	38.8	32.8

DISCUSSION: Is There Method in the Landscape Madness?

Fire activity is clearly highly variable over a period of decades to centuries, and millions of hectares. Even at the scale of the entire study area (2.5 million hectares), the age-class distribution is far from "stable". However, it is important to distinguish different types of variability. For instance, at the coarsest scale, periods of high and low fire activity in Alberta are frequent and pervasive. Others have attributed these large-scale fluctuations to continental climatic factors (Johnson and Wowchuk 1993), which is consistent with the parallels of fire activity pattern we see across the study area, between landscapes.

This study identified another type of age-class variation that exists at slightly finer scales due to differential fire activity by ecological zone. At this scale, several factors may contribute to the observed differences including climate, fuel-type and pattern, topographic complexity, and historical ignition sources. Here we will describe each of these attributes for each landscape in the study area, in an attempt to understand long-term fire behaviour tendencies. However, first we must reduce the raw climate data (Environment Canada 1994) to something concise.

Summaries of climate data for selected stations in the FMF area are presented in Table 8. Stations with suitable records could not be found for all parts of the study area, and the record periods are not consistent. However, what we have is informative on a general level. Climate variables were chosen that are most strongly related to burning conditions. Summer (rain) and to a lesser degree winter (snow) precipitation both indicate relative levels of flammability. Growing-degree-days provide a relative measure of the length of both the growing and fire season. The average numbers of days above 10 and 20 degrees C suggest critical burning conditions.

Table 8. Climate Summary for the Foothills Model Forest (Source: Environment Canada)

Location	Natural Subregion	Climate Station Life	Growing Degree Days	mm Rain	cm Snow	No. Days >10oC	No. Days >20oC
Columbia Icefields	Alpine	1961-93	430	252	711	113	9
Jasper W. Gate	Montane/Subalpi ne	1974-93	903	328	162	170	62
Jasper	Montane	1914-93	1185	244	124	177	74
Hinton	Lower Foothills	1956-80	1120	345	125	182	71
Edson	Lower Foothills	1914-60	1134	402	164	184	75
Robb	Upper Foothills	1965-93	1062	452	197	183	65
Coal Spur	Upper Foothills/ Sub	1913-38	698	354	269	168	57

The tremendous influence of elevation on potential burning conditions is evident in a comparison of the three mountain stations. Within the Park, the Montane zone has perhaps the most severe fire season. Summer precipitation is low (244mm), and the number of growing-degree-days is high (1185), as is the number of "hot" days (74 days over 20^{o}C on average) (Table 8). Across the transition to the Subalpine (Jasper West Gate station), we see a substantially shorter fire season, higher precipitation, and cooler burning conditions. Up even further near the Alpine / Subalpine transition, the fire season is very short, cool, and the snow depth substantial enough to keep fuel wet for most of the spring (Table 8). These dramatic differences in burning conditions over relatively short distances are consistent with the large differences in fire activity between the different ecological zones of the Park. In relative terms then, the

Montane has very good burning conditions, the Lower Subalpine poor burning conditions, and the Upper Subalpine very poor burning conditions.

East of the Rockies, both elevation and distance to the mountains seem to be factors. Both Lower Foothills stations have fairly long growing / fire seasons, and plenty of days over 10 and 20°C, but Edson has more rain than does Hinton. Although growing / burning conditions do not substantially change from the Lower Foothills stations to the Robb station in the Upper Foothills, the Robb station gets quite a bit more precipitation. Closer to the Subalpine (Coal Spur station), overall precipitation is slightly higher, but growing/burning conditions deteriorate (Table 8). So overall, the Lower Foothills has good burning conditions, the Upper Foothills good to fair, and the Subalpine poor.

The burning condition levels (very good, good, fair, poor, or very poor) derived from the climate data above are summarized by the eight ecological zones in the study area in Table 9. Also provided in the table is a relative measure of historical lightning activity, normalized to a maximum score of 100 for the zone with the greatest level of annual lightning activity, in this case the Lower Foothills natural subregion of the ANC FMA. The lightning ranking for the remaining seven zones are relative to a score of 100. Thus the Upper Foothills of the Weldwood FMA with a score of 70 receives 70% as much lightning activity as the Lower Foothills of ANC.

Table 9. Overview of Biophysical and Climatic Characteristics of the Major Ecological Zones in the Study Area

Ecological Zone	Landscape Attribute				
	Ave. Age (base yr)	Burning Conditions	Lightning Rank	Topographic Complexity	Non-Forested Percentage
JNP					
Montane	73 ('30)	Very Good	26	Flat/rolling	10%
Lower Subalpine	115 ('30)	Poor	17	Complex	10%
Upper Subalpine	182 ('30)	Very Poor	15	V. Complex	54%
Weldwood					
Subalpine	111 ('50)	Poor	42	Complex	6%
Upper Foothills	82 ('50)	Fair	70	Rolling	11%
Lower Foothills	76 ('50)	Good	85	Rolling	12%
ANC					
Lower Foothills	61 ('50)	(Good?)	100	Rolling	6%
Upper Foothills	62 ('50)	(Fair?)	67	Rolling	3%

Also given in Table 9 is a subjective description of the topographic complexity, from almost flat in the Montane, to very complex in the Upper Subalpine areas. Finally, the non-forested percentages from the area summaries in Tables 1,4, and 6 are repeated. Although most "non-forested" areas do in fact have "fuel", they generally act as fuel-breaks of sorts.

Table 9 is not particularly scientific due to its' subjectivity. However, if anything the landscape attributes have been oversimplified as opposed to overstated. Such as it is, the summary does allow us to begin to understand how and why fire may burn differentially over large areas.

JNP Montane

Despite the fact that natural ignition sources are quite low, topography and burning conditions are both conducive to fires making runs. The Montane is also a special case in that historically, cultural sources of ignition were likely a significant factor in this area (P. Murphy, pers. comm.). Thus the low average age of the Montane (74 years overall, 64 years in the Park) is not surprising.

One would almost expect the number to be lower when compared to other zones. However, keep in mind that average age as a reflection of fire activity is only as good as the assumption that all stands are even-aged. Recall that we have strong suspicions that this is not the case in the Montane. Thus the true nature of fire activity in the Montane is probably not well captured by this coarse-scale analysis. Future reports will target this issue in the Montane.

JNP Lower Subalpine

Complex topography, low levels of ignition sources, and poor burning conditions conspire to create a landscape that burns less often than most. It is not difficult to imagine that many Lower Subalpine fires originated from the Montane zone. Were it not for the immediate adjacency to the Montane, the Lower Subalpine area of the Park would probably have far less fire activity than it does.

JNP Upper Subalpine

The Upper Subalpine burns far less often than any other landscape in the study area. Nor is this particularly surprising. Burning conditions, lightning activity, topography, and continuity of fuel all discourage fire start and spread. It is also surrounded completely by areas with either moderately low (Lower Subalpine), or non-existent (Alpine) fire activity.

Weldwood Subalpine

It is interesting that the average age of this landscape is almost identical to that for the Lower Subalpine from the Park. While it is true that burning conditions and topography are very similar, there is significantly more lightning activity in the Weldwood Subalpine. All other things being equal, one would expect higher levels of fire activity in the Weldwood Subalpine relative to the Park Lower Subalpine. The percent of non-forested area is somewhat lower than in the Park, suggesting more favourable fuel continuity on the Weldwood side of the mountains. However, it is unlikely that this alone is making much of a difference. Another possibility is that the higher levels of lightning activity on the Weldwood Subalpine slopes is being offset by lower levels of adjacent landscape fire activity compared to in the Park. Not only does the Montane burn more often than the Upper Foothills zone, but the ecotone between the Montane and the Lower Subalpine is much more substantial than that between the Upper Foothills and the Subalpine to the east. In other words, there is a greater chance of fires burning *into* the Lower Subalpine from the Montane, than into the Subalpine from the Upper Foothills.

Weldwood Upper Foothills

The largest landscape in the study area, the Upper Foothills, is intermediate in every sense. At 82 years, the average age of the forest here is almost exactly the median value for the entire study area. Burning conditions are fair, topography is rolling to gently rolling, and the percent of non-forested area is moderate at 11%. It does have fairly high levels of lightning activity, and shares an ecotone with the more fire-active Lower Foothills landscape. These last two features are probably the main reasons the average age of the Upper Foothills is not all that different than that of the Lower Foothills.

Weldwood Lower Foothills

Moving from the Upper to Lower Foothills, lightning activity increases, and burning conditions improve. One would expect the level of fire activity (suggested by the average age) between these two landscapes to be greater. However, keep in mind that average age is only a very simple indication of fire activity. Recall that the 20-year burn rate rollback estimates from Table 5 did in fact suggest that fire activity between these two areas was quite different. There is also a significant shift in cover-type that may be a factor (which will be discussed further in the future reports).

ANC Lower Foothills and Upper Foothills

These two landscapes have been combined here since a) they are quite small, b) neither had long-term local climate stations, and c) they share many characteristics. The average age data suggests that fire activity here is higher on the ANC FMA than anywhere on the Model Forest. Lightning activity is certainly very high, and the percentage of non-forested areas are low, but it is unclear whether or not this is a “real” difference in fire activity, compared to the Upper and Lower Foothills of the Weldwood FMA.

There are several possible reasons why there may be higher levels of fire activity on the ANC FMA than on the Weldwood FMA. First, we must consider that it may be an artefact of AVI age sampling methods. According to Andison (draft), inventory ages on Boreal Mixedwood landscapes of western Saskatchewan are highly inaccurate, and possibly biased. Furthermore, it suggests that inventory age data underestimate the amount of older forest on the landscape. If this is true for the ANC FMA, the average age is actually higher than the reported 61 and 62 years.

There are also cultural differences between the two FMAs. Cultural activity would arguably have been higher historically in and around Hinton, within the Weldwood FMA, perhaps leading to fire control efforts prior to those implemented further north on the ANC FMA, and/or higher aboriginal use of fire around Whitecourt.

Finally, the ANC FMA is transitional between Foothills and Boreal Mixedwood Natural Regions according to Beckingham *et al*. (1996). Boreal Mixedwood landscapes in Alberta have much shorter fire cycles than we are finding in this study, often between 40-60 years (S. Cumming, pers. comm.). The higher levels of lightning activity that are evident on the ANC FMA are probably part of the reason, but this could also be a climate-driven phenomenon. Better climate data would have addressed this issue.

As with the Weldwood FMA, one would expect the higher levels of lightning activity in the ANC Lower Foothills to result in higher levels of fire activity here relative to the ANC Upper Foothills. Although the average ages of these areas are virtually identical, the 20-year burn-rate estimates from Table 7 do suggest consistently higher historical rates of burning. Again, these landscapes are too small to know for certain at this point whether these differences are significant.

Overall, the ecological zones do a good job of differentiating fire behaviour on a coarse scale. In the Park, there is no question of this. On the foothills east, the ecological zones differentiate themselves in a consistent and logical manner, but at this point it is debatable whether the differences in fire activity between the Upper and Lower Foothills are significant.

More importantly, by comparing and contrasting key biophysical and climatic attributes of the landscapes in the study area, there emerges a logical pattern, which at least begins to explain why differential fire activity exists. In other words, so far, there is good evidence to suggest that stratifying land based on major ecological zones will capture much of the variability in disturbance regimes in this part of Alberta.

Part 3: FIRE ACTIVITY WITHIN LANDSCAPES

The previous analysis suggests that very large land areas can be stratified spatially such that disturbance history within such strata is more similar than between the strata. So we have now accomplished a first approximation at defining different fire regimes spatially on the study area. Along the way, we have also made some useful non-spatial estimates of averages and ranges of historical rates of burning, and in the case of Weldwood, projected levels of different seral-stages within each of those strata. But the Weldwood simulation touched on another type of variation at the landscape level that we can explore further here – that of different levels of burning, and thus different age-class distributions for different cover-types.

Suitable data are available for all eight ecological strata to create substrata based on dominant vegetation. In Jasper Park, the local Ecological Land Classification system divides the Park into 18 substrata, 11 of which are forest-types (Holland *et al.* 1982). Weldwood and ANC both have AVI data, which includes species data by percent. For convenience, Weldwood's 15 species "groups" were used to create vegetation strata. Using these classification systems, for each dominant-vegetation substrata, the average age was calculated for each of the eight main ecological zones in the study area.

Although dominant vegetation is spatial in nature, technically, at this stage this is a non-spatial analysis because the substrata are not perfectly discreet. In other words, the vegetation types can mix on the landscape, and medium to large-sized areas will have more than one type of dominant vegetation present. This analysis is more accurately described as estimating "burn fractions", which is akin to assigning probabilities of burning to various parts of the landscape. I used nine of the most dominant forest-types, which provided good coverage of all three administrative areas in the study area.

As with the analysis of the ecological zones, if we concentrate on the general trends rather than the specifics, the patterns that emerge are revealing yet logical. For instance, it is interesting to note that the variation of average age between the various ecological zones is almost matched by the average age variation within each zone. In other words, the range is as almost as great reading across rows, as it is reading down the columns (Table 10). On the surface, this might be interpreted as evidence that the within-zone variation in burning tendencies is so great that it weakens the argument that the ecological zones are meaningful strata. However, the fact that the patterns of age remain constant within an ecological zone suggests quite the opposite. For instance, the first three sub-strata (Douglas Fir, Pine, and Hardwood) have consistently the lowest average ages of any other vegetation-types (Table 10). These are also tree species that we would expect to be responding positively to high levels of disturbance. At the other end of the scale, the average age of white spruce, black spruce / larch, and high altitude spruce / subalpine fir stands is consistently the highest of all vegetation-types. Aside perhaps from larch, these species are all shade tolerant, and tend to succeed in areas where fires are less common. The middle three vegetation-types are all mixtures of species from the first two categories, and thus we would expect them to thrive in areas intermediate in terms of fire activity.

Table 10. Average Age by Dominant Vegetation Types for the Study Area.

Ecological Zone	Dominant Vegetation								
	D. Fir	Pine	Hdwd	Mixedwood	Pine / Sb	P/S/Fir mix	Sb / Lt	Sw	Closed S/Sa Fir
JNP (ages as of 1930)									
Montane	57	63	-	-	-	93	-	77	-
L Subalpine	-	78	-	-	-	150	-	-	160
U Subalpine	-	-	-	-	-	-	-	-	184
Weldwood (ages as of 1950)									
L Foothills	-	79	77	82	84	87	92	96	-
U Foothills	-	73	78	82	86	91	97	106	-
Subalpine	-	82	-	-	107	108	130	141	-
ANC (ages as of 1950)									
L Foothills	-	59	51	60	61	-	70	77	-
U Foothills	-	51	-	-	57	-	69	101	-

So even though the average age of stand-types is highly variable within any one ecological zone, the fact that they vary consistently between the different ecological zones not only supports the conclusion that the ecological zones are relevant, but further suggests that variable burn fractions within each ecological zone are relevant as well.

Whether or not this translates into spatial substrata for disturbance regime determination purposes cannot be said. We have to be careful here not to assume an unproven relationship of cause and effect. One could easily argue that stand or cover-type are wholly dependent on soils or micro-climate, and the differences in burn fractions noted here are just the result of fine-scale fuel-type differences. The alternative argument would be that consistent, but spatially heterogeneous fire behaviour has created the existing stand-type pattern. Reality is most likely somewhere between these two extremes, where fire and species preferences interact dynamically and stochastically over space and time. In other words, the location and extent of different stand-types across a fire-prone landscape to some extent moves through space and over time, and can therefore only be predicted using probabilities (Andison and Kimmins 1999). Relating this back to our dilemma, if the location or extent of a stand-type changes over time on a landscape, the burn fraction of that stand-type would presumably remain constant, meaning the coarse-scale fire activity for that area might change. We thus cannot conclude from these analyses that spatially-stable substrata (smaller than the ecological zone) exist on the study area. What we can say is that at any one time, the frequency and risk of burning is variable within an ecological zone, but predictably so.

Part 4: CONCLUSIONS

Thanks to an extraordinary dataset, it is possible to draw some fairly strong conclusions from the study of disturbance activity at broad scales on the FMF and beyond. At the same time, the depth of the analysis generated several new questions.

1) Fire Control is a Landscape Process

At the risk of stating the obvious, fire control activities on the FMF and beyond have had a substantial impact on landscape pattern over the past ½ century or more. In the Park in particular, there has been little or no cultural equivalent to fire, allowing large areas of older forest to build – probably beyond the natural range of variability. Furthermore, even without raw data, we can guess that the same risks likely apply to the Willmore Wilderness area.

There are potentially serious ecological and fire hazard implications associated with this inference. Not only are the Park and the Willmore susceptible to larger, more intense fires, but the risk of conflagrations spreading into the working landbase increase.

On the two FMAs, where harvesting activities serve as coarse-scale fire substitutes, the situation is less serious. However, the "fire proxy" argument weakens at finer scales. This will be discussed in greater depth in future reports.

2) Variation is Natural

Variation is a "natural" component of the forest system at the very coarsest scales. None of the age-class distributions showed any signs of being "stable". The age-class roll-backs all suggest that historical fire activity within even 20-year spans is fairly inconsistent. Perhaps the most convincing evidence is the Weldwood computer model simulations, which suggest that historically, the relative amounts of different seral-stages range widely, on a regular basis. Furthermore, such stability likely does not exist even on the scale of millions of hectares.

The implications of this are potentially enormous. First, targeting and managing for "stable" age-class distributions may be culturally and economically prudent, but might also be ecologically hazardous. We are only beginning to grasp the connections between natural patterns and processes, but there are no documented instances where managing beyond natural thresholds have resulted in more species, more productivity, or superior function (Andison and Kimmins 1999).

Clearly, self-sustaining "landscape units" are ecologically inappropriate. British Columbia has chosen to define self-sustaining landscape units in similar landscape-types 60,000 – 120,000 hectares in size. Within these landscapes the amounts of different seral-stages are maintained as either maximums or minimums – which effectively become single numbers to maximize woodflow. Yet the Weldwood simulations demonstrated that landscapes of this size historically experience a vast range of seral-stage amounts. For instance, although the minimum allowable percent of the "Old" seral-stage is ten 10% (BC Ministry of Forests and BC Environment 1995), on comparable landscapes on the Weldwood FMA anything between zero and thirty percent is possible naturally. The BC "landscapes" are simply not large enough to justify stabilizing age-class distributions (Andison and Marshall 1999).

In fact, the results suggest that even FMAs are not large enough to stabilize age-class distributions. Clearly Weldwood's one million hectares is not suitable, and it is one of the largest administrative areas in the province. Alberta Pacific, at almost six million hectares is probably not suitable either (S. Cumming, pers. comm.). The issue is potentially biome or at least provincial in nature, and suggests that large-scale wood-supply strategies should be considered.

3) Ecological Classifications are Useful Means of Stratifying Disturbance Behaviour

The evidence to date on this has been far from conclusive, and debate still rages. However, in this case there is little doubt that the eight main ecological zones of the study area represent different fire regimes. The only question that remains is that of the differentiation between the Upper and Lower Foothills areas. Some, but not all evidence suggests they are significantly different in terms of how often fires replace forests. Upcoming reports in this series will expand the analysis to include fire sizes, types, and even burning preferences to help address this question.

The potential implications of this are good news to most. It means that the existing, well-established ecological stratification system can be used to identify and classify natural patterns of fire and other disturbances. It thus aids both research and management. Jasper Park's differentiation of the Subalpine natural subregion into the Lower Subalpine and Upper Subalpine zones is particularly well justified.

4) Fire Activity Within an Ecological Zone is Variable, but Predictable

The burn fraction analysis by no means proves that a landscape can be subdivided into meaningful zones with distinctive fire activity. In fact, since the dominant vegetation-types are spatially non-discreet, it may very well be true that the ecological zones are the smallest possible strata for determining fire regimes. However, the burn fraction analysis did establish that although fire activity within an ecological zone may be highly variable, it is not randomly so. In other words, there is probabilistic (*i.e.*, not random) internal heterogeneity within an ecological zone.

The nature of the probabilistic internal heterogeneity has yet to be fully explored, so the implications of this finding are difficult to project. If other evidence bears out the theory, it may mean stand-type specific rotations, and harvesting and silvicultural prescriptions, both of which are already common practice today.

Part 5: WHERE TO FROM HERE?

In keeping with our long-term research plan (Andison 1999a), this report described the coarse-scale patterns of fire activity on the Foothills Model Forest and ANC FMA. At least three outstanding questions at the coarse-scale were raised by this analysis:

1) Is quantifying the fire history of the Willmore Wilderness Area a priority?
2) Is fire activity on the ANC FMA significantly higher than on ecologically equivalent areas of the Weldwood FMA?
3) Are there significant differences between overall fire activity on the Lower Foothills and Upper Foothills ecological zones?

The first question can be dealt with in a variety of ways. The Willmore is part of the FMF, but we were unable to perform even rudimentary age-class analysis due to lack of data. A decision will have to be made to either a) forgo coarse-scale analysis, b) concentrate instead on other methods, scales, or issues, or c) find the resources to create the proper, necessary spatial dataset for the entire area.

The second question about fire activity on the ANC FMA is the most difficult to answer. An independent test of AVI ages on the ANC FMA would help in terms of identifying any age bias, and a more thorough search for local climate data would answer the question of climatic differences. Another solution would be to redo the analysis with a larger, northern (non-Weldwood) dataset to increase the size of the zones being tested. Right now the amount of forest in each ecological zones is marginal for age-class analysis.

The third question, while valid, is not of great concern at this point. It, and many others will be addressed as the research progresses to finer scales. We have only begun to tackle many issues here, and at the very least, summaries of fire and patch sizes and shapes will either support or challenge the preliminary conclusions reached in this report. Research at even finer scales will hopefully continue to build a more complete understanding of natural disturbance as a process, at all scales.

LITERATURE CITED

Andison, D.W. (in draft). The risks of using inventory age data for landscape analysis in the Boreal Forests of Canada. (to be submitted to Landscape Ecology).

Andison, D.W. 1999a. Foothills Model Forest Natural Disturbance Program long-term research plan. 4th edition. Foothills Model Forest, Hinton, Alberta.

Andison, D.W. 1999b. Assessing forest age data in foothills and mountain landscapes in Alberta. Alberta Foothills Disturbance Ecology Research Series, Report No. 1. December, 1999. Foothills Model Forest, Hinton, Alberta.

Andison, D.W. 1998. Patterns of temporal variability and age-class distributions on a Foothills landscape in Alberta. Ecography 21:543-550.

Andison, D.W. 1996. Managing for landscape patterns in the sub-boreal forests of British Columbia. Ph.D. thesis. Forest Management Dept., University of British Columbia, Vancouver, BC.

Andison, D.W. and J.P. Kimmins. 1999. Scaling up to understand British Columbia's boreal mixedwoods. Environmental Reviews. 7(1): 19-30.

Andison, D.W. and P.L. Marshall. 1999. Simulating the impact of landscape-level biodiversity guidelines: A case study. The Forestry Chronicle. 75(4): 655-665.

Beckingham, J.D., I.G.W. Corns, and J.H. Archibald. 1996. Field guide to ecosites of West-Central Alberta. Special Report 9, Canadian Forest Service, Northwest Region, Northern Forestry Centre, Edmonton, Alberta.

British Columbia Ministry of Forests and BC Environment. 1995. Forest practices code of British Columbia Biodiversity Guidebook. BC Ministry of Forests, Victoria, BC

Environment Canada. 1994. Canadian monthly climate data and 1961-1990 normals, 1994 Release. Cd ROM. Environment Canada, Ottawa, Ontario.

Forman, R.T.T. and M. Godron. 1986. Landscape ecology. J. Wiley and Sons. NY.

Holland, W.D., G.M. Cohen, D.T. Allan, G.L. Holroyd, and K. VanTighem. 1982. Ecological (Biophysical) land classification of Banff and Jasper National Parks. Alberta Institute of Pedology, Canadian Wildlife Service. Publication No. SS-82-44

Johnson, E.A. 1992. Fire and vegetation dynamics: Studies from the North American Boreal Forest. Cambridge U. Press, Great Britain.

Johnson, E.A. and D.R. Wowchuk. 1993. Wildfires in southern Canadian Rocky Mountains and their relationship to mid-tropospheric anomalies. Can. J. For. Res. 23: 1213-1222.

Nesby, R. 1997. Alberta Vegetation Inventory standards manual. Version 2.2. Alberta Environmental Protection, Edmonton, Alberta.

Noss, R.F. 1994. At what scale should we manage biodiversity? Oregon State University, Corvallis, Or.

Rogeau, M.P. 1996. Landscape disturbance project stand origin mapping. Prepared for the Foothills Model Forest. Banff, Alberta.

Rogeau, M.P. 1997. Landscape disturbance project stand origin mapping 1997. Prepared for the Foothills Model Forest. Banff, Alberta.

Tande, G.F. 1979. Fire history and vegetation pattern of coniferous forest in Jasper National Park. Can. J. Bot. 68: 1763-1767.

GLOSSARY OF TERMS

The following is a list of technical terms used in this document that are either uncommonly technical, or are used ambiguously.

Biodiversity - a qualitative feature of natural systems describing the numbers and types of different biological elements at different scales. Not the same thing as diversity.

Burn fraction – a relative measure of flammability, or probability of burning for different parts of a forest landscape. Normally expressed as the average percentage burnt, per type, per year.

Crown fire - fire actively or passively reaches into the crowns of trees. Crown fires are virtually always associated with surface fires, but mortality can vary widely.

Cultural disturbance – Disturbances from anthropogenic sources only. (*e.g.*, harvesting, prescribed burning, road building).

Disturbance - any abrupt event that results in the destruction or damage of any part of the biota. Disturbances can occur at any scale.

Disturbance frequency - the probability that a specific area is disturbed in a given time period. Reciprocal of return interval.

Disturbance rate - the percentage of area affected by disturbance over a given period. In this case, the period was 20 years. Sometimes the reciprocal of fire cycle when expressed on an annual basis.

Disturbance regime - types, frequencies, periodicity, severity, and sizes of disturbances.

Diversity - the number (and sometimes the relative amounts) of different types of elements. Diversity is *one* element of biodiversity.

Ecological rotation – The number of years that forest stand-types generally survive intact before being disturbed from natural sources, or otherwise change form or function.

Fire behaviour - how, how fast, where, and what an individual fire burns. Contrast with Landscape fire behaviour below.

Fire cycle - the average number of years required to burn an area equivalent in size to the study area / landscape.

Fire intensity - the actual temperature at which a fire burns **-** as opposed to fire severity

Fire refugia - a fine-scale area which has survived one or more fire events, and therefore tend to be older than surrounding areas of forest.

Fire return interval - the average return time of fire at a specific location. North-facing slopes may have longer fire return intervals than south-facing slopes.

Fire severity - the amount of damage or mortality caused by a fire. Not necessarily related to fire intensity.

Landscape - a mosaic of stands large enough to have identifiable large-scale (fire) behaviour emerge. The Natural Subregions were referred to as landscapes in this document.

Landscape fire behaviour - how, how often, where, and what fires burn – on average - over decades or centuries.

Meso-scale - the scale of an individual fire. Between stand and landscape scales.

Natural disturbance – Disturbances that originate from natural, non-anthropogenic sources. In this report, “natural” is usually used together with “historical” to describe disturbance processes, this allows for the inclusion of unknown levels of historical aboriginal activity.

Natural range of variability / variation – (NRV) Structural, compositional, and functional variation of an ecological system, at any spatial or temporal scale, predominantly (but not wholly) caused by natural disturbance regimes.

Non-forested - anything other than merchantable forest, including water, meadow, brush, rock outcrop, swamp, and under-stocked forest.

Patch - a contiguous area of the same type (defined by age, composition, structure, or other feature). Patches are not necessarily fires, since fires skip and overlap each other.

Pattern - any behaviour (spatial or temporal) that is not random.

Seral-stage – Stand development categories that relate to structure and composition, but often simply associated with broad age-classes. In this report we use four seral-stages; Young, Pole, Mature, and Old.

Surface fire - fires that burn along the ground, only occasionally "torching" individual trees. Tree crowns are usually unaffected.

Stand-origin map – map showing the year of the origin of the stand, or the date of the last stand-replacing disturbance event. Also often referred to as a time-since-fire map.