Assessing Forest Age Data
In Foothills and Mountain Landscapes of Alberta

Laying the Groundwork for Natural Disturbance Research

Alberta Foothills Disturbance Ecology Research Series
Report No. 1

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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), the Alberta Department of Environmental Protection 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

Learning from “natural” patterns as a means of achieving higher levels of ecological sustainability is becoming more common in forest management. The research that forms the foundation for these activities is therefore critical to the success of this strategy. Coarse filter knowledge relies heavily on spatially complete and accurate stand age data. Poor or incomplete age data can lead to misrepresentation of age-class structure, patch size distribution, and even patch shapes. Not making the effort to test these data may inadvertently mislead management agencies willing and able to adopt more ecologically sensitive management practices based on such research findings.

Three separate sets of age data exist for the Foothills Model Forest (FMF) natural disturbance study area: the foothills east (most of which is the Weldwood of Canada FMA), Jasper National Park, and the Alberta Newsprint Company (ANC) FMA.

Weldwood is fortunate to have a time-since-fire map, developed through a specific and intensive ground sampling exercise. One would expect these age data to be of far greater quality than those derived from standard inventory aging methods. Ages from a network of over 2,000 sample plots compared favourably to the original stand ages. On average, 80% of the plot ages matched those of the original data, and 90% of the ages were within one age-class. The areas of the foothills east that did not have a time-since-fire map were mapped over the last two years. Areas aged “older than 188 years” were distributed using both sample plot age data and extensive field sampling. The age data on the foothills east may be used to study natural and cultural disturbance patterns with a high level of confidence.

Jasper National Park also has a time-since-fire map. A field sampling exercise sampled over 100 randomly located plots to test these data. Unfortunately, results showed a moderate to low level of accuracy overall. We hypothesize that much of the Park has been influenced by a combination of stand-replacing and stand-maintaining fires, as well as insect and disease outbreaks and wind throw. Time-since-fire maps have a limited capacity to describe these processes and patterns. Subsequent disturbance research in the Park will have to take this into account and design alternative research methods to develop an accurate picture of disturbance influences.

Stand ages for the Alberta Newsprint Company FMA were derived from standard inventory sampling protocols, in combination with sample plot ages. Although ages from the plot data are expected to increase the overall level of confidence in these data, there are no independent age data sets with which to test these ages. The proximity and similarity of this area to the Weldwood FMA is fortunate in that extrapolation is possible for future research.

We now have an accurate picture of the quality and quantity of age data on the FMF natural disturbance study area. This will facilitate subsequent disturbance research, as well as related ecological research on the impacts of patterns.
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 first 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.
Part 2: FOREST AGE DATA AND DISTURBANCE RESEARCH

BACKGROUND

Landscape mosaic patterns in forested areas are the combined result of geomorphic processes, stand dynamics, and disturbance (Forman and Godron 1986). While there may still be debate over the relative impact of each of these processes on forest mosaic patterns, disturbance is the process that introduces most of the variability. It could be argued that in the absence of disturbance, forest patterns would become far more predictable, driven only by stand dynamics, site, and soil, given a constant climate. Even the introduction of a regular type, extent, and level of disturbance would create more or less predictable forest patterns over large areas. Since disturbance is a stochastic process, it is largely responsible for the variation in forest patterns we observe over both time and space. A comprehensive study of the disturbance history is therefore key to understanding the “natural range of variability” in forest landscapes.

We already possess a fair amount of general-level knowledge of Alberta’s foothills and mountain landscapes. For instance, forest fires have long been recognised as the dominant process defining forest landscape mosaic patterns throughout most of North America (Suffling 1987, Noss 1994), and particularly so in the boreal forests of northern Canada. Furthermore, we have substantial evidence to suggest that the majority of these fires are stand-replacing events, killing most of the previous stand (Johnson 1992). This forms the basis of our first and most important hypothesis: Stand-replacing fire is the dominant disturbance process occurring on the Foothills Model Forest.

Having a hypothesis is valuable because it directs data collection. If stand-replacing fire is the dominant disturbance on the FMF, then we should be using stand age data as the basis for coarse-scale analysis. Typically, such analysis involves describing historical types, sizes, shapes, and burning rates of wildfires, as well as other burning tendencies (Yarie 1981, Eberhart and Woodard 1987, Lorimer et al. 1994, Taylor et al. 1994, Andison 1996). The FMF natural disturbance research extends beyond describing fire frequencies, sizes, shapes, and types, but this is an appropriate starting point for our analysis and reporting.

The most critical data required for these types of analyses are stand ages. Without accurate and unbiased stand ages, everything from fire cycle to patch size estimates are questionable. Ideally, a “time-since-fire” (or stand origin) map would be created for the area of interest. This entails an interpretive mapping exercise using aerial photos followed by field sampling of every age polygon. Tree wedges or cross-sections (“cookies”) are taken from each sample tree at its base and counted under a microscope to determine the total age of the trees and the stand. The final ages are then used to re-define same-aged polygon boundaries where necessary, and assign the number of years since the last stand-replacing fire event (Rogeau 1996, 1997).
Time-since-fire maps are rare for large areas. The procedures are both expensive and time-consuming. In most cases, the only available stand age data are from forest inventories. Unfortunately, age data from forest inventories are not collected for fire history purposes and differ in several important ways from time-since-fire map ages:

1) Only 1-2% of all inventory polygons are field sampled, versus 100% for time-since-fire maps, and many polygons are sampled more than once.
2) Tree core samples for inventories are counted in the field, allowing room for counting errors, versus lab counts under a microscope from tree wedges or cookies for time-since-fire maps.
3) Two or three dominant or co-dominant trees are sampled in the middle of a stand for inventory ages, compared to at least five trees at the stand boundary for time-since-fire maps. Fire scars on trees at the edge of stands can be precisely cross-dated to the age of trees originating from disturbance events.
4) Trees have core samples taken at 1.3m above the ground for inventories, versus ground or stump level sampling for time-since-fire maps. Correction factors are applied by species and site in both cases, but age samples taken closer to the point of tree origin allow for less potential age correction error, and thus more accurate total ages.
5) Often an “older than” age-class is created in a forest inventory, which includes all stands older than some maximum age. The exact age of stands lumped into the “older than” age class is not known and this information is critical to accurately describing disturbance characteristics.

Any one of these points is cause for concern when using inventory ages to do fire history analysis. Together, they make calculations of fire regime metrics such as sizes, shapes, and even frequencies rough estimates at best. Because there is so much room for error and bias in estimates of these parameters, and because these metrics form the foundation for subsequent FMF research projects, this report focuses on assessing the quality and quantity of age data available from the FMF landscapes. This report also serves as a stand-alone reference to others. An accurate description of the fire history of the FMF is an excellent source of information for those who chose to do ecological research on the FMF.

Since there are two distinctive jurisdictional areas on the FMF, assessment of the stand age data will be done in two parts; the first on the foothills east, and then on Jasper National Park. A brief description and assessment of the age data available from ANC will follow.

**AGE DATA FROM THE FOOTHILLS EAST**

The Hinton Division of Weldwood of Canada Ltd. is probably the only FMA in Alberta to have a complete time-since-fire stand origin map. In 1960, Mr. Jack Wright initiated an intensive field age sampling program to supplement forest inventory data. Aerial photos from 1955 at a scale of 1:31,000 were used to delineate polygons based on age. Field crews then located the polygon boundaries from the photos and maps for site visits for tree age sampling. Priority was given to trees that were scarred by the most recent fire event but originated from the fire that preceded it. Each sample tree was either cut down or notched such that field ring counts could be made and recorded on site. The age of the stands on either side of the located boundary was estimated. Several trees per sample site, and often several sample sites per stand were taken. The ages were recorded directly on the aerial photos, and any polygon boundary corrections were noted. The information was then transferred to coloured paper maps (Jack Wright, pers. comm.). Several years ago these paper maps were digitised as a layer in ARC/INFO, and these ages are now part of the most recent Alberta Vegetation Inventory (AVI) database. (Note that this means that the Weldwood FMA does not match the rest of Alberta in terms of AVI stand age definition.) This was an undertaking far ahead of its time, but it lacked some of the procedural rigour that a similar project today would include. For instance, although destructive sampling was often used on trees at stump
height or lower, tree-rings were counted in the field, allowing room for error. Similarly, sometimes only two
or three trees per plot were counted because of the large amount of work involved (Jack Wright, pers.
comm.). Also, despite exact field counts being taken, an “older than” age-class was created for stands
originating earlier than 1808. The exact nature of the older-than tail of the age-class distribution provides
valuable fire history information (Finney 1995). The final problem with the original Weldwood fire map is that
areas outside the FMA in the foothills were not mapped. The three largest such areas were the Hinton town
site, Switzer Provincial Park, and the corridor of provincially controlled subalpine land between the FMA and
JNP. Even though these areas were not managed as part of the FMA, their absence creates holes in the
dataset, which are problematic for spatial pattern analysis. Without them, spatial descriptions such as patch
sizes and shapes are meaningless.

So while it is thought that the Weldwood age data is of higher than average quality, there are still questions
concerning its’ accuracy. In short, we needed to know the amount of error associated with the age data
before proceeding with pattern analysis or constructing age-class distributions. Although some pattern
metrics are simple to derive, one cannot put much stock in the analysis if the raw data are questionable.

How Good Is Weldwood’s Stand Origin Map?

Methods
The best way to validate a stand origin map is to have an adequate supply of independent age samples.
While this type of comparison cannot provide evidence that either the stand origin map or the independent
age data is correct, it can increase our confidence level in both if the ages are in agreement.

The Weldwood FMA has been under intensive management for many years, and an abundance of field
trials and projects have been completed. Included on that list is a set of 2,016 permanent growth sample
plots (PSP) covering the entire FMA. This plot network has (breast height corrected) age data and plot
locations as part of the available spatial data. These data presented an ideal opportunity for age validation.

To use the PSP data, the Universal Transverse Mercator (UTM) coordinates of each plot were cross-
referenced to the corresponding stand origin polygon. Their respective ages were entered in a database
using the ARC/INFO Geographic Information System (GIS). To allow for any error in the location of either
the plot or the polygon boundary, the age of the next-nearest forest polygon was also noted if the PSP
location landed within 100m or 200m of a polygon boundary.

Twenty-year age-classes were used for the test. If both the PSP age and the stand origin map age landed
within the same 20-year age-class, no difference in age was noted at that location. Stands with an origin
date of 1808 were excluded from the analysis, since we already know that these ages are in error (since
they are in the “older than” age-class). Ages of these older stands will be estimated in the section that
follows.
Results
The results were very encouraging. Overall, the ages of the PSPs fell within the same 20-year age-class as those of the stand origin map 77-82% of the time (Figure 3). Furthermore, 88-92% of all plots fell within one 20-year age-class, and 92-94% were within two 20-year age-classes. Although not shown, when ten-year age-classes were used, about 70% of the plot ages fell into the same age-class as the stand origin map. It is also favourable that just as many plot ages were older than the stand origin map as were younger. In other words, there was no “bias” in the age data. Note that in Figure 3, everything to the right of zero (x axis) denotes PSP age samples that were younger than those from the stand origin map, and everything to the left of zero were plot ages older than those of the stand-origin map.

Figure 3. Age Comparison on the Weldwood FMA

When 100m and 200m margins of error were allowed on the location of the plots and polygon boundaries, only marginal improvements in the results were noted. Precision of age estimates only increased by five percent when a 200m error in plot and/or polygon location was allowed (Figure 3). This consistency suggests that both the sample plots and stand origin polygon boundaries were located and digitised accurately.

When the validation exercise was repeated by natural subregion, some differences were noted (Figure 4). The Subalpine natural subregion ages were the most accurate, with 96% of all plots within one 20-year age-class of the stand origin map. The Upper Foothills natural subregion had 93% of all plot ages within one age-class, and the Lower Foothills comparison found 86% of all plot ages within one age-class of the stand origin ages. Also, the PSP ages tended to be greater than the fire origin map ages (or “negatively biased”) in the Lower Foothills and Upper Foothills natural subregions (Figure 4), suggesting that either the stand origin map underestimate actual ages, or the PSP’s overestimated the actual ages.
Overall, the comparison of the fire map ages with the PSP ages indicated a very high level of accuracy. The negative bias of the ages of the Lower Foothills, and to a lesser degree the Upper Foothills stands on the stand origin map, is not significant enough to pursue further. Considering the large sample size, and the complete, unbiased coverage of the plots across the FMA, there is more than enough evidence to suggest that the existing information from the original fire map can be used with confidence for stands that originated after 1808 (i.e., stands that were at least 188 years of age in 1996).
How Old are “Older Than” Areas on the FMA?

Methods
Two independent sources of data were used to determine the age of stands in the older-than age-class of the foothills east. First, the PSP information was summarised and analysed similar to the method used for the age validation exercise above. Re-mapping selected areas of older forest in the foothills east supplemented this. To avoid bias, sampling for older sites should have been randomly distributed. However, this was impractical due to cost and access. Instead, several accessible areas of older forest were sampled, including the largest contiguous piece of old forest (about 40,000 hectares). The details of the sampling are given in Rogeau (1996) and Rogeau (1997) and will not be repeated here. Essentially, this exercise resulted in a second stand origin map of these areas of the foothills east with ages for areas previously designed as “older than”.

Results
The age-class distributions of 1) the PSP ages and 2) the 1996/97 sampling were compared in 20-year age-classes for the “older than” areas. The age-class that the 1808 year of origin falls into (1800-1820) was used as the zero point for the x-axis in the following figures. Thus, if this were truly an older-than age category, all data would fall either into, or to the left of the 1810 age-class.

The results were variable, and subregion specific.

Lower Foothills
The Lower Foothills was the only area in which there was no negative age bias (Figure 5). In fact, the PSP ages suggest that most of the actual stand ages from the “older than” age-class are younger than 188 years (i.e., a positive bias). In other words, most of the stand ages from the oldest stands in the Lower Foothills are in error. It is also the only natural subregion in which the data from the PSPs and the re-mapped data disagree. While the 1996/97 stand origin mapping indicates that the actual ages of old areas are very close to the 188 year limit, the PSP data that suggests that the majority of area is actually younger than 188 years. In this case, the PSP data probably best represents the actual distribution of “older than” forest since the area sampled during the re-mapping exercise was quite small (1,770 hectares) and spatially clustered.

Upper Foothills
Predictably, most of the 1808 area in the Upper Foothills area was much older than 188 years. In fact, 59-63% of the 1808 area was more than one age-class older than 188 years (Figure 6). In contrast, only 15-19% of the area was more than one age-class younger than 188 years.

For the Upper Foothills area, the new stand origin map data and the PSP data distribute stands in the “older-than” area similarly, which lends credibility to both datasets. The main difference between the two distributions in Figure 6 is the large portion of samples that the PSP distribution allocated in the 1730 age-class. Inspection of the raw PSP data revealed that all of these plots had a recorded stand age of 255 years. The fact that the age of 255 occurred so often, yet none greater, suggests that PSP aging may also have created an "older than" age category, although no written record of this was found. An identical pattern was noted for PSP ages in the other two subregions (although it was not a limiting factor in the Lower Foothills area). Accordingly, the re-mapped stand origin data would better represent the true “older than” age-class distribution for the Upper Foothills.
Subalpine

The distribution of the “older-than” Subalpine forest was highly negatively biased (older) according to both the PSP ages and the re-mapping exercise (Figure 7). Between 50-79% of the ages were more than one age-class older than 188 years, depending on the data source, and only 0-11% were more than one age-class younger (Figure 7).

Once again, the presence of the 255 year age limit for the PSP data was noted as a potential problem, since the 1996/97 sampling found many areas much older than 255 years. The age data from the 1996/97 sampling is therefore a better choice to represent the distribution of the “older than” age category in the Subalpine area. In addition to the same arguments used for choosing this dataset for the Upper Foothills, the sample size for the PSP data in the Subalpine area was small (n=28 plots).
SAMPLING FOR DATA GAPS ON THE FOOTHILLS EAST
The large gaps in the foothills east age dataset necessitated a field sampling program. Given the relatively high degree of confidence in the accuracy of time-since-fire estimates for the rest of the area, we felt justified in supplementing these data with proper time-since-fire maps to complete the mosaic. Over the course of the field seasons of 1996 and 1997, the three major non-FMA gaps noted earlier were targeted using standard fire history sampling techniques similar to those mentioned above (Rogeau 1996, 1997). The final maps were digitised and merged with existing digital age data.

AGE DATA FROM JASPER NATIONAL PARK
Jasper National Park also has a complete time-since-fire map. Intensive field age data were collected from stumps at stand boundaries. Fortunately, no “older than” age-class was defined, which simplifies the validation exercise. The quality of JNP’s time-since-fire-map also benefited from detailed aging and map work done by Tande (1979) in the Montane natural subregion. However, like the foothills east, there were questions of procedural rigour, which could not be answered with available data and information. This warranted an age validation exercise.
How Good Are Jasper’s Age Data?

Methods
No existing independent age data were available to assess the JNP time-since-fire map for accuracy and bias. Instead, a two-stage sampling design was used to test polygon ages. Six townships were randomly chosen in both the Montane and Subalpine natural subregions of the Park. Within each township, 20 plots were randomly located for ground sampling. Each plot was located in the field, and the closest mature tree used as the plot centre. The point-quarter method was used to select four additional mature trees within 10m of the plot centre. Cross-sectional cookies were cut from these five trees and prepared and counted for total age in the office. The ages were recorded on a spreadsheet and compared to the recorded stand age from the time-since-fire map. Plots with less than three aged trees were eliminated, leaving a sample size of 107 plots.

Results
The accuracy of the Park stand ages using 20-year age-classes is poor. Only 19% of the plot ages fell within the same 20-year age-class as the JNP fire history map indicates (Figure 8). Forty nine percent of plots fell within one 20-year age-class, and 73% fell within two 20-year classes. On a positive note, no bias was evident; 40% of the plots were younger than the stand map, and 41% were older (Figure 8).

Figure 8. Jasper National Park Stand Age Accuracy
At first glance these results are disappointing, especially considering the effort that went into collecting stand ages in the Park. However, there may be mitigating circumstances that caused these discrepancies. In many plots, tree ages ranged widely. On average, the number of years between the youngest and oldest sample tree in each plot was 47 years. This not only makes it difficult to obtain an accurate date since the last stand-replacing event, but may also suggest other disturbance processes are influencing stand dynamics. The possibilities are worth discussing further, as they bear on how JNP data are analysed and/or how far analysis of the Park data may proceed with confidence at this scale.

When determining the age of each polygon for stand-origin purposes, the usual procedure is to use the age of the oldest stems that have not obviously survived a fire. This assumes that the oldest stems originated from the last fire that occurred in that area. There are at least three ways in which this procedure can be complicated. First, the process of stand establishment may take place over several years or decades. This is thought to be the case with some white spruce regeneration (Lieffers et al. 1996). Since the probability of spruce surviving even a moderate fire in anything but an isolated island is low, this phenomenon can still be accounted for by aging the oldest stems of spruce found, if and when a spruce stand is sampled.

In JNP, the spruce plots did in fact have a wider age range than other plots. The 37 plots that were white spruce-dominated had an average age range of 67 years, compared to 32 years for the 70 pine-dominated plots. However, the age accuracy of pine-dominated stands is no better than that of spruce-dominated stands. Therefore, unless pine regeneration also takes place over many years (which is not likely) there is little evidence to suggest that a lengthy regeneration period is a significant factor in determining the age of JNP stands.

The second potential complication to stand origin dating is with stands that may be so old that individual stems begin dying and/or falling down, creating “gaps” and allowing regeneration to invade. This theory is simple enough to test by separating young from old stands in the sample. Using 300 years as the break point, we found that older stands were less accurately aged than younger ones (Figure 9). Thirty six percent of the sample plots fall within the same age-class as the JNP stand origin map for stands less than 300 years of age, compared to only 5% for stands greater than 300 years (Figure 9). Similarly, 86% of the plots were within two 20-year age-classes for younger stands, compared to only 55% for older stands (Figure 9).
Despite the difficulty of aging very old stands and the possibility of extended periods of regeneration for spruce stands, the accuracy of the JNP stand ages is still far less than one would expect of a time-since-fire map. The third and final complication to stand origin mapping is the occurrence of disturbances that create patchy or partial mortality. This is the more substantial theory in that it suggests that the Park may have a mixture of crown and surface fires, along with insect and disease outbreaks, floods, and browse episodes. In other words, the hypothesis that most stands in the FMF are of stand-replacement origin may be in question in the Park. This hypothesis requires more directed data collection, and cannot be determined using these data. However, about 25% of the sample plots did have fire scars on at least one of the sample trees, suggesting a high degree of survival from fire.

If stand-maintaining disturbances do play a significant role in JNP, then one would expect stand aging methods as described here to be inaccurate since they assume homogeneity of ages within a polygon. The ages of the oldest stems are therefore meaningless since they could have survived many fires since germination. If stand-maintaining disturbances (or other periodic disturbance processes) are active in areas of the Park, then multiple age cohorts should be evident. One way of testing this theory is to repeat the age comparison using the age of the tree from the sample plots closest to that of the stand age from the stand origin map (as opposed to the oldest).

If this strategy is applied to the 107 JNP sample plots, the level of agreement between plot and stand ages increases from 19 to 45%. This would seem to support the theory of non-lethal disturbance events such as surface fires. However, the exact significance of this result is difficult to interpret because, regardless of the
disturbance regime, one would expect the level of age agreement to increase with this test. At this point, further discussion of what might be taking place in the Park is conjecture. The projects to follow will shed more light on these questions. Suffice to say that we have enough evidence to suspect that a mixed disturbance regime is active in the Park.

Lastly, we must also be open to the possibility that JNP stand ages were simply inaccurately calculated. We know that selected areas of the Park were heavily sampled for age, but more remote areas were far less intensively sampled. The only way to test this is to repeat the stand-origin mapping exercise for a sample of both accessible and non-accessible areas.

ANC AGE DATA ASSESSMENT

The age data for the Alberta Newsprint Company FMA is derived from a combination of AVI photo interpretation, and sample tree ages from approximately 3,650 temporary sample plots (TSPs). Although the stand ages here are probably of higher than average accuracy, the resulting age map does not qualify as a time-since-fire map. The greatest concern is that only one tree age was taken at breast height for each TSP (G. Branton, pers. comm.). Furthermore, the plots were randomly located, and therefore more likely to land in the middle of polygons, where the chances of selected trees that survived the last fire event are greater (which can be misleading). Finally, even if the TSP age sample size were greater, these data could not be used as an independent sample for a test of accuracy, since photo interpreters used these ages to assist in inventory stand aging.

The ANC age data are therefore of unknown quality. Given the use of TSP ages, it is probable that the stand ages are of at least fair quality. However, it would be unwise to combine the Weldwood and ANC age data together for analysis since this would add an unknown element into an otherwise excellent dataset.

DISCUSSION

The two fire history maps of the Foothills Model Forest form an interesting contrast. On the east side of the mountains, the stand age data from the Weldwood FMA is of exceptional quality. Up to 96% of stand ages matched independent stand age data within one age-class. This high level of accuracy warranted the considerable effort expended to “fill in” the non-FMA lands of the eastern portion of the Foothills Model Forest using fire origin stand-dating methods. These findings also indirectly confirm our original hypothesis that stand-replacing fires dominate the foothills east forest.

The principal weakness of the original foothills east stand-origin map was the presence of an “older than” age-class. This was partially addressed by the additional fire origin mapping and sampling carried out during the 1996 and 1997 field seasons. For other areas, we were fortunate enough to have two excellent independent age samples with which to define distributions for these older forests. Most, but not all, of the actual ages for the older-than forests were assigned spatially. Some isolated pockets of forest in the foothills east still bear the “older than” designation on the fire history map.
The FMF and Weldwood now have a completed, validated contiguous stand origin map for about 1.1 million hectares of foothills forest. This is a formidable (and rare) advantage for landscape and pattern analyses. The credibility of any future analyses based on these data will be greatly enhanced. This means that we may continue with confidence to analyse the foothills east landscapes on a coarse level using traditional methods (in subsequent FMF natural disturbance reports).

The ANC age data are probably of at least moderate to good quality. However, time and resources do not permit us to test this theory. The geographic proximity and ecological / climatological similarity to the Weldwood FMA suggests that research findings from the Weldwood FMA may be extrapolated to the ANC FMA. However, every effort should be made to confirm the validity of this assumption (of similarity) before extrapolation can be justified.

On the west side of the mountains, Jasper National Park’s stand origin map did not fare nearly as well in a test of accuracy. A combination of factors likely played a role in this result, including the difficulty of accurately aging very old stands, spruce regeneration timing, and possible problems with the original field methods or sample size used to date JNP’s forests. However, the evidence also suggests that stand-origin mapping may not always be appropriate for the forests types in the Park. Circumstantial evidence indicates that stand-replacing fire events may not always be the main agent of disturbance here. Extensive tree scarring and the presence of a high proportion of multi-aged stands suggest that stand-maintaining disturbance events such as surface fires, flooding, insect and disease outbreak, or even browsing may be active in the Park as well.

At this coarse level of resolution, no more can be said of the disturbance dynamics in Jasper National Park. However, we have generated a new (and not unlikely) hypothesis about disturbance in JNP. There is little doubt from other evidence that stand-replacing fires have played a significant role in JNP (probably more so in Douglas Fir areas for instance), but we cannot assume this is the case everywhere in the Park. Therefore, the application of coarse-scale pattern metrics should be done only as a first-cut guide to disturbance patterns in JNP. Other, more detailed studies will be required to determine the exact nature of the relationship of the other disturbance processes with stand-replacing fire events.

**CONCLUSIONS**

The Foothills Model Forest Natural Disturbance Program studies patterns that result from disturbance processes at all time and space scales. Generally, the research proceeds from coarse to fine-scale questions. Coarse-scale findings form the foundation for research at progressively finer scales. The success of the program as a whole therefore depends on the credibility of coarse-scale analysis. Like all science, the credibility of the analysis in turn relies heavily on the data quality. In this case, it is vital that stand age data are accurate and unbiased. Poor age data can render age-class distributions, patch size and shape distributions, and other spatially relevant measures inaccurate or misleading.

The best age data come from field methods directed at determining the year in which the last stand-replacing disturbance event (i.e., fire) occurred. These are called “time-since-fire” maps. Age data from other sources such as forest inventories are collected in such a way that introduces unknown levels of bias and inaccuracy. This is understandable given that their main purpose was not to date every polygon to the year of origin.

Thanks to the foresight of several individuals, the Foothills Model Forest is fortunate to have two time-since-fire maps. However, in each case there were questions of reliability and coverage that had to be addressed. The Weldwood stand-origin map was validated against ages obtained from over 2,000 PSPs, the “older
than age-class distributed using two independent age datasets, and a stand-origin map completed for all of the non-FMA forested areas. There now exists a complete and accurate time-since-fire map of the foothills east that likely has no equal in Canada.

In Jasper National Park, a field-sampling program was used to gather independent age data for validation. The results of this comparison suggest that either the original stand aging was of poor quality, or other circumstances are complicating the stand aging procedure. Without more information it is not possible to determine the exact nature of the problem, but one of the most likely scenarios is that smaller, less severe disturbances such as surface fires are active in some areas of the Park in combination with larger more severe crown fires.

Overall, the effort to assess age data on the Foothills Model Forest has been well worth the effort. On the foothills east, analysis of coarse-scale patterns can proceed since we have a high level of confidence that the age data are complete and accurate, and that stand-replacing fires are the dominant disturbance agent. The same cannot be said of the ANC FMA, although we suspect that age data here are of at least moderate to good quality. In Jasper National Park, a more complex history of disturbance is evident. In the Park, it is understood that coarse-scale analysis will need to be supplemented with other techniques and projects to fully understand the patterns observed in the context of disturbance processes.
LITERATURE CITED


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


GLOSSARY OF TERMS
The following is a list of terms used in this document that are either uncommonly technical, or have ambiguous definitions. As used in this document, the list is as follows:

**Age dependence** - susceptibility to fire changes (usually increases) with age.

**Age invariance** - forests of all ages are equally susceptible to fire.

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

**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.

**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.

**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.

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.

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

Time-since-fire map- map showing the year of stand origin. Also referred to as a "fire map" and “stand origin map” in this document.