

**FIRE REGIME IN DRY-BELT FORESTS OF BRITISH COLUMBIA:
PERSPECTIVES ON HISTORIC DISTURBANCES
AND IMPLICATIONS FOR MANAGEMENT.**

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ABSTRACT

We critically examine the hypothesis that dry-belt forests in BC were historically in a low-severity fire-maintained disturbance regime, and discuss some of the implications of our results to the management of these forests. We examined three sources of information that we believe lend some insight into past disturbance regimes and the stand structure conditions that likely prevailed: (1) systematic surveys prior to extensive management, (2) a fire scar analysis case study at Opax Mountain, (3) fire records.

Our analyses consistently indicate that natural disturbances were likely complex and non-equilibrium, creating changing patterns in both stand structure and landscape condition spatially and temporally. Several interacting factors including climate, forest harvesting, livestock grazing, fire suppression and changing geographic patterns of insect pest attack are key drivers in creating and maintaining the conditions observed today.

The wide range of conditions that have occurred in the last 10,000 years, and the uncertainty associated with predicting future conditions limits the utility of the concept of natural or historic variability. No one point in time should be chosen as the "ecologically correct" reference period, and past non-equilibrium disturbances illustrate conditions that are not compatible with current social expectations. Future landscape planning and stand management should avoid the use of idyllic and misleading terms like "ecosystem restoration" and focus on clearly defining desired stand conditions, the commodity objectives that will be met with these conditions, and the most effective (economical, social and ecological) tools for achieving the objective.

INTRODUCTION

The “dry-belt” grasslands and forest ecosystems of B.C. consist of the Bunchgrass zone, Ponderosa pine zone, and the Interior Douglas-fir zone that generally occur at low elevations (under 1200 m) of the interior of British Columbia (Lloyd et al. 1990). These ecosystems, also called “Natural Disturbance Type 4” subsequently referred to as NDT4 (Fig.1), are often referred to as “fire-maintained” ecosystems (BC Ministry of Forests and BC Environment. 1995) and are the focus of current debate on appropriate forest and fire management practices and restoration activities.

Depicting these ecosystems as “fire maintained” implies that these grassland and dry-forest ecosystems were historically in a state of dynamic equilibrium, being maintained in an open condition by frequent, extensive, low severity fires. The “dry forest maintained by fire” paradigm leads to the view that historically, old-growth forests were characterized by extensive areas with low crown closure, widely spaced large trees, lush grass understory, and few tree seedlings or woody shrubs. Most fire history studies from the western United States support that view particularly for Ponderosa pine forests of the Pacific Southwest (Leopold 1924, Swetnam and Baisan 1996, and many others). These studies propose that fire suppression has changed forest structure (e.g., greatly increased density of small stems) (Covington and Moore 1994, Moore et al 1999), caused species shifts (Stephenson 1999), shifted grassland-forest ecotones (Strang and Parminter 1980, Arno and Gruell 1983), and increased fuels leading to an increased risk of stand-replacing wildfire (Wagle and Eakle 1979, Keane et al. 1990). Although there is little published information on fire history in Interior Douglas-fir forests of southern British Columbia, there is a growing concern that fire exclusion is profoundly altering forest structure here as well, leading to similar changes. The concern over this perceived “unnatural change” has been growing over the last decade primarily because of large fire events and pest outbreaks in the western United States, and more recently because of numerous large wildfires in British Columbia in 2003 (Filmon 2003).

We contrast two different perspectives on the historical fire regime in dry-belt forest ecosystems of southern British Columbia. One hypothesis is that dry forests were historically kept in a state of equilibrium through frequent, low severity fires. An alternative hypothesis is that dry forests historically experienced a mixed severity, non-equilibrium disturbance regime. Both hypotheses allow predictions about fire regime and forest structure which are summarized in Table 1. The main objective of this paper is to examine which predictions are plausible using existing historical evidence from tree rings, fire scars, climate, regional fire history and fire weather data, and early forest surveys.

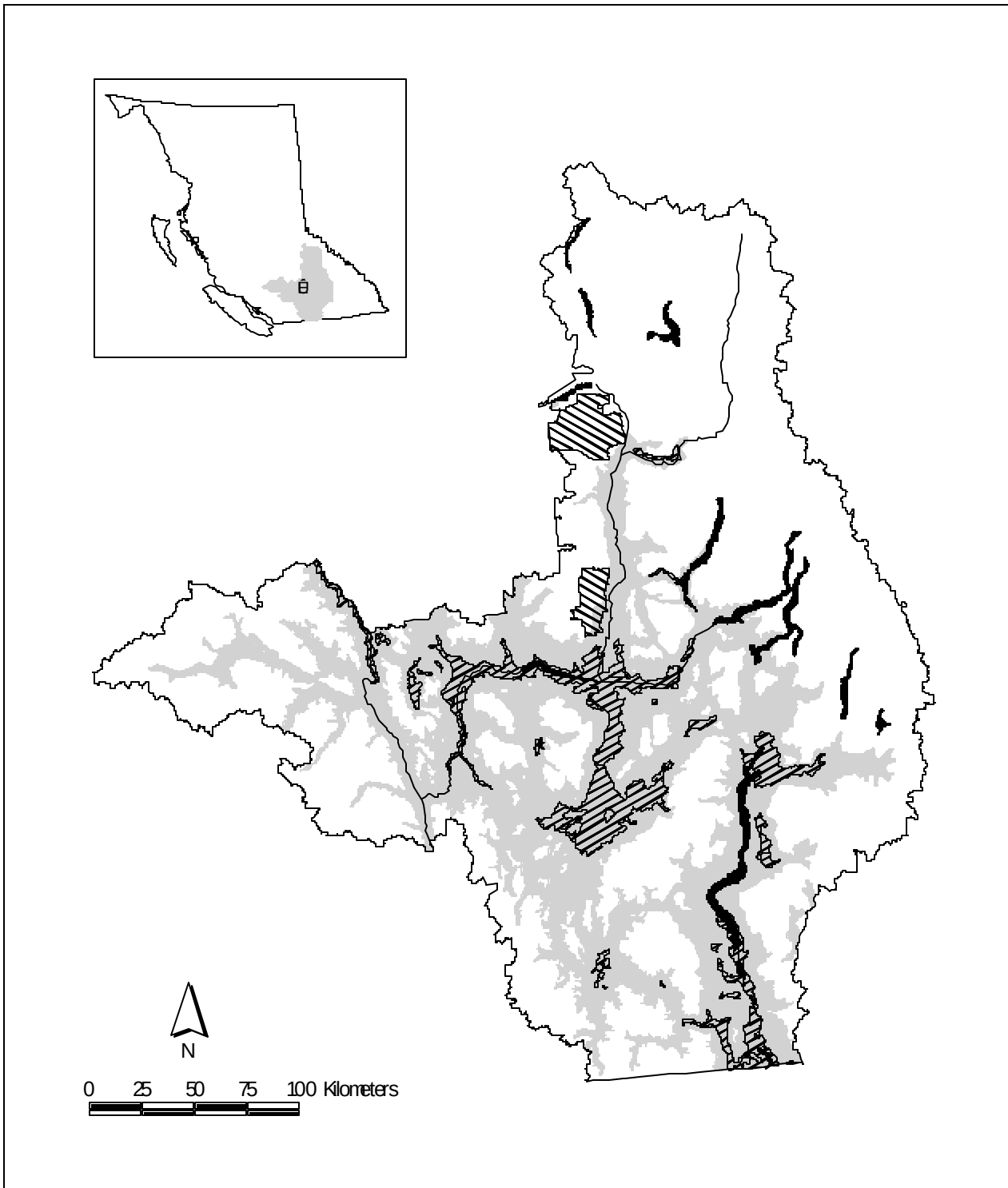


Figure 1. Overview map of the former Kamloops Forest Region. Star on the insert diagram indicates the location of the city of Kamloops ($51^{\circ} 45' N$; $120^{\circ} 20' W$). Grey areas delineate the extent of NDT4b(very dry) and 4c (dry) forest types. "Right" cross-hatched areas represent the extent of NDT4a (grasslands), "left" cross-hatching represents Tree Farm Licenses (T.F.L.'s). Large lakes indicated in black a reference locations.

Table 1. Predictions of effects of 2 alternative fire regime on dry forest landscapes.

Predictions related to the fire maintained hypothesis

- Little evidence of even-aged stands following fire.
- Large proportion of dry forest landscapes were in a very open canopy condition, with widely scattered large trees with occasional patches of regeneration that escaped fires.
- Fire intervals were short and showed little influence from climate.
- High and moderate severity fires were rare.

Predictions related to the mixed severity fire hypothesis

- Even-aged stands following fire are common.
- Large proportion of dry forest landscapes were made up of a changing spatial and temporal mosaic of stand ages and densities, some resulting from frequent, low severity fires or insect attack, others resulting from moderate and high severity fires, and others that escaped fires for extended periods.
- Fire intervals were historically quite variable and showed distinct relationship to climate. High and moderate severity fires were common.

METHODS

Surveys of historic forest conditions in NDT4 forest types

Historic documents published between 1914 and 1935 and which described conditions in dry forests in the southern interior of British Columbia were reviewed to assess the condition of NDT4 habitats at that time (Klenner, Kremsater and Arsenault 2001). We examined these reports since they were based on systematic surveys, and hence should represent a more accurate depiction of historic conditions than anecdotal accounts which seldom give insight into the frequency or extent of a particular forest or grassland condition. Surveys from an earlier period would have been helpful, but we could not locate any that provided systematically collected data from an extensive area. For this paper photographs will be used to test the prediction that “large proportion of dry forest landscapes were in a very open canopy condition, with widely scattered large trees with occasional patches of regeneration that escaped fires.”

Recent regional fire history of dry forests in the southern Interior

Historic fire patterns were assessed using the Historical Fire records maintained by the Protection Branch of the BC Ministry of Forests, and the BC Forest Service Provincial Annual Reports. Historical Fire records were available for the 1950 to 1996 period, and the summary Annual Reports for the 1915 to 1998 period (supplemented by unpublished fire records for 1999-2004). Kamloops Forest Region annual reports for the 1938 to 1980 period were used to verify information in the Provincial Annual Reports. It is acknowledged that these databases may be flawed by errors or omissions, but they represent the only systematic information available that documented the time, location and size of fires.

Multicentury fire history deduced from tree-rings

The interpretation of a historical fire regime when deduced from tree rings is strongly influenced by sampling and analytical methods. Preliminary results from the Opax Mt. fire history study near Kamloops are presented as a case study to illustrate a situation where using traditional fire scar sampling and analysis (Dieterich 1980) may not be appropriate.

The Opax Mt. study used standard methods based on dendrochronological analysis of fire scars and tree age. The project includes 2 study areas of approximately 200 ha each, one in the lower elevation Interior Douglas-fir dry warm subzone and one in the higher elevation Interior Douglas-fir dry cool subzone. Fire scar and tree core samples were collected across the site using already established wildlife monitoring transects. Initially fire scars were obtained by searching along forty belt transects situated at 125 metre intervals and measuring approximately 50 metres in width and 1000 metres in length. We complemented this approach by adding a number of 25 meter radius plots. Fire scar locations were recorded and the height and position of the scar on the tree were noted. A chainsaw was used to remove wedges from live fire scarred trees as well as cross-sections from recently cut stumps (trees cut in 1994), logs, and snags which had apparent fire scars. The larger samples were sectioned with a band saw and sanded with a belt sander using a series of progressively finer sanding papers. Three hundred trees were cored throughout the area using the same 25 metre radius plot to identify post-wildfire cohorts and obtain information on tree growth. More detailed stand age structure was also obtained by coring all trees over 5cm dbh in 4 plots of different sizes. Tree cores were carefully mounted on grooved wooden platforms and later sanded similar to the cross-sections. All tree cores and cross-sections were aged and visually cross-dated using marker rings (Yamaguchi 1991) and a 1673-2000 masterchronology. Fire return intervals were calculated at multiple spatial scales, (single tree~0.0001ha-transect~5ha-study area ~200 ha using the initial fire scar collection for discussion. Analysis of the complete data set will be completed shortly and submitted to a peer-reviewed journal in the spring of 2005.

RESULTS AND DISCUSSION

Historical conditions of Ponderosa pine and Douglas-fir forests

Photographs from the early twentieth century of some Ponderosa pine stands provide evidence that widely spaced trees with an open understory dominated by grass occurred on some sites (Fig. 2). These conditions support prediction of the frequent, low severity fire hypothesis. However, also evident in many of these photographs are dense thickets in the background (Fig. 2 b), a paucity of grass and forbs in the understory (Fig. 3 a,b), and sites with a high density of stems (Fig. 3). This suggests that other types of disturbances also played a role in shaping forest stand conditions.

On Douglas-fir dominated sites, the “open, park-like” stand description also appears to be a relative term used to describe a wide range of stand conditions. Most of the survey reports that encompassed areas of

dry-belt Douglas-fir described these stands as “open” or “open, park-like”. Again these terms appear to have been relative and were used to describe a variety of stand structure conditions as illustrated in the sample of photographs presented in Figs. 4,5,6.

The range of stand conditions illustrated in the historic photographs presented in the Provincial Forest survey reports supports the predictions of both the frequent, low severity and infrequent, stand replacing disturbance hypotheses. The diverse overstory and understory conditions suggest that a mixed severity fire (a mosaic of low, moderate and high severity fires) was most likely. Low severity fires may be the result of frequent ignitions that periodically remove accumulated fuels (Keane et al. 1990, Agee 1993), or simply be the consequence of low fuel accumulations stemming from the low productivity on xeric sites. On sites with low or very low productivity, fuel accumulations may either be insufficient, or too patchy to produce high severity crown fires regardless of the frequency of ignition.



Figure 2. Examples of historic conditions in yellow pine forests. (a) Western yellow pine, Nicola Valley from Whitford and Craig (1918), (b) Western yellow pine, *P. ponderosa* from Mulholland (1937).

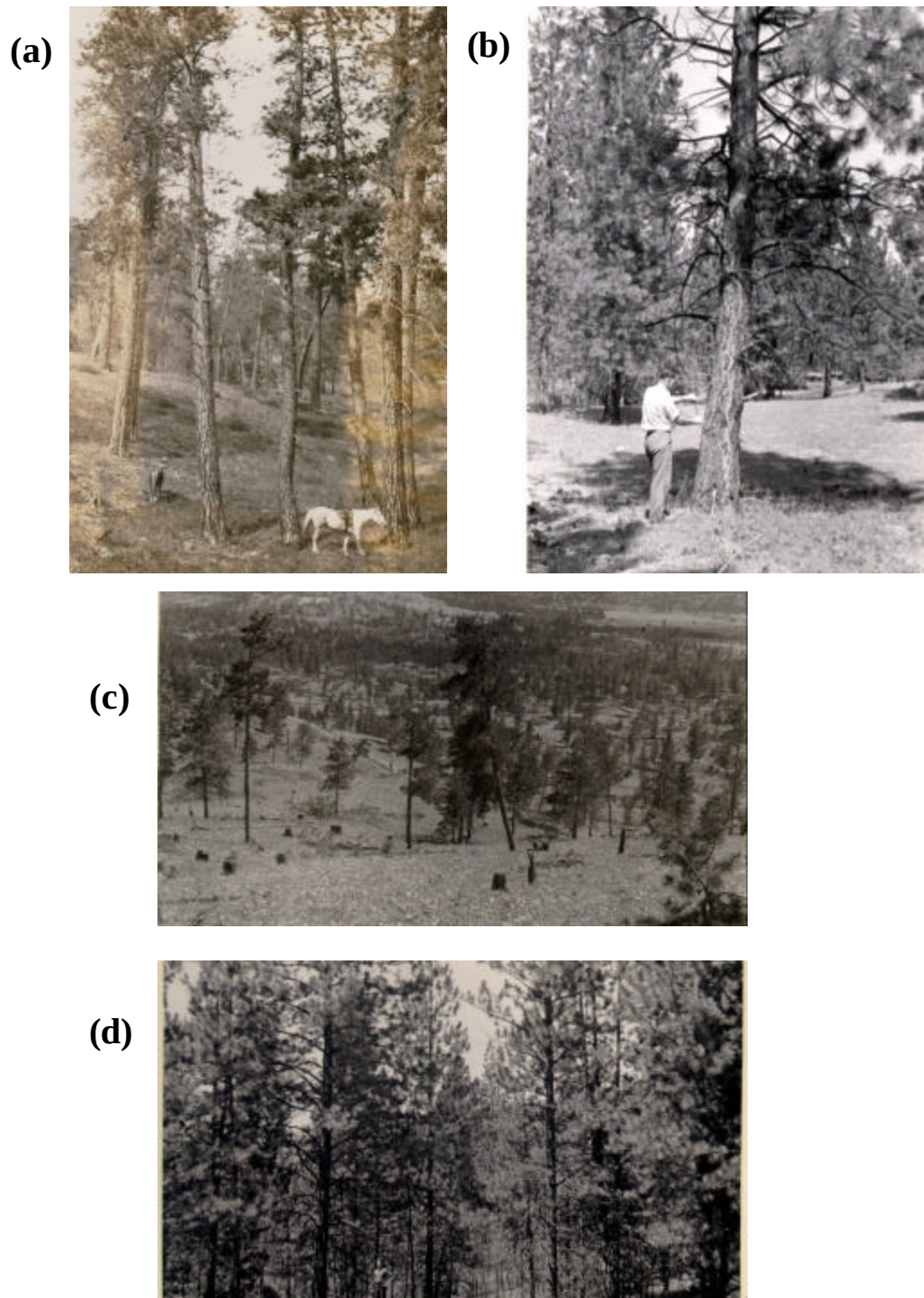


Figure 3. Examples of yellow pine forests in the Little White (a), (Stevens et al. 1925) and Okanagan (b,c,d) Forests (McBride and Nixon 1939). Original figure captions “(a) Yellow Pine stand on the boundary of the Forest on Penticton Ck. (S.L.24). (b) Yellow pine 14” 53 years old. Garnet Lake. (c) Yellow pine selectively logged. Compartment 23A. West of Summerland. (d) Even-aged stand of yellow pine 50 years old. Garnet Lake.”

(a)



(b)



(c)



Figure 4. Examples of forest conditions in the Arrowstone Forest (Hodgins, 1932a). Original figure captions “(a) Illustrative of the pure fir types. Portion of compartment 2 averaging 5 cords and 550 f.b.m. per acre. Note the open grazing. (b) A portion of compartment 4. Fir – yellow pine type of poor quality averaging 600 f.b.m. and 4 cords per acre. Note the over grazed condition of the forest floor. (c) Illustrative of fir – yellow pine type. Portion of Compartment 4 averaging 2,500 f.b.m. per acre (80% yellow pine) and 2 cords per acre (75% fir). Note the open grazing.”

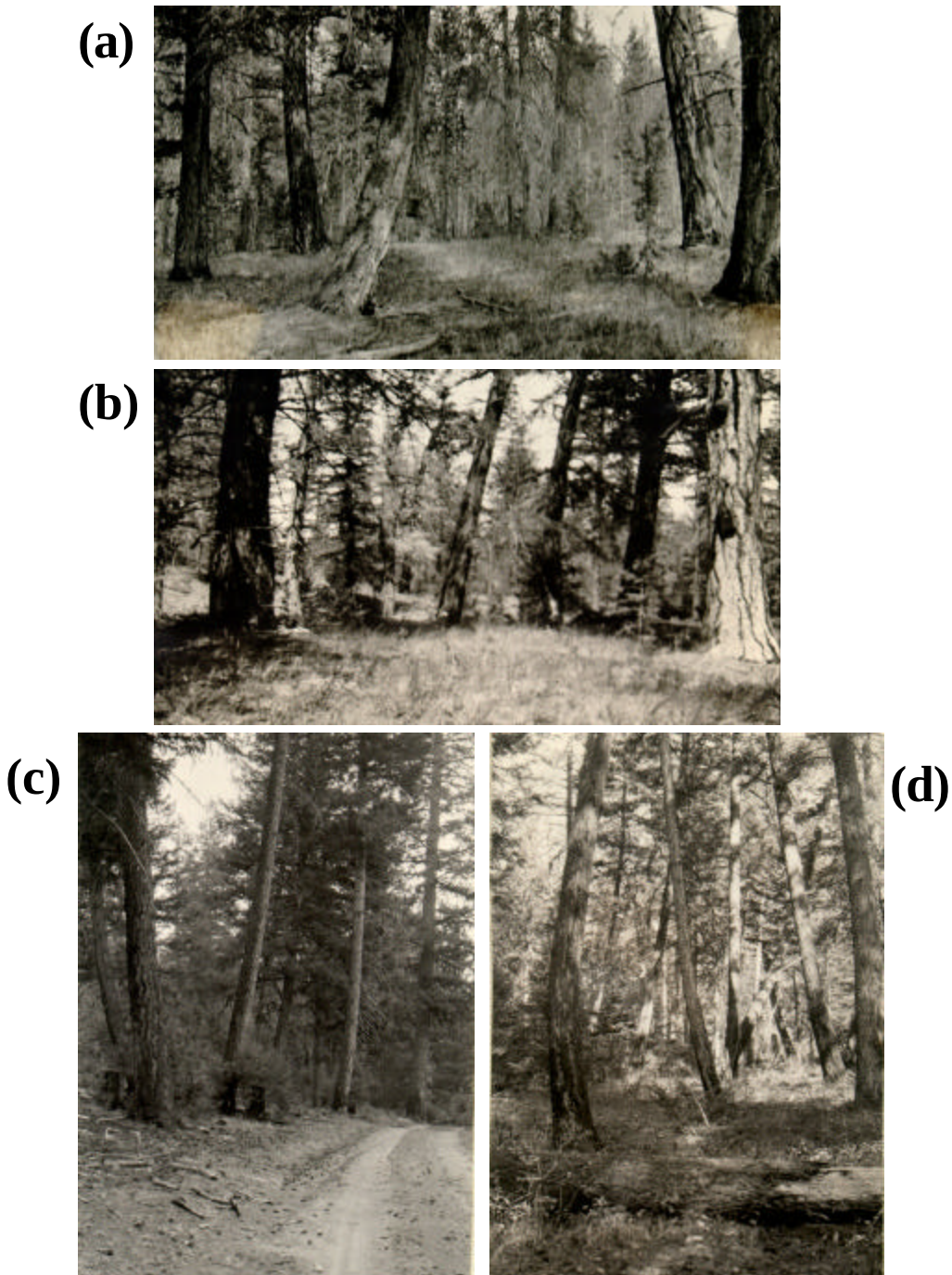


Figure 5. Examples of forest conditions in the Long Lake (Hodgins 1931), Nicola (Hodgins 1932b), Martin Mt. (Hodgins 1932c) and Monte Hills Forests (Hodgins 1932d). Original figure captions “(a) Uneven-aged fir forest. Portion of compartment 28 averaging 14 cords of fuel wood and 700 f.b.m. saw-timber per acre (Long Lake Forest). (b) Uneven-aged fir – yellow pine type. Portion of Compartment 5, averaging 1000 f.b.m. and 4 cords per acre. Note the open grazing (Nicola Forest). (c) Fir selection forest. Portion of Compartment 18 averaging 6,000 f.b.m. per acre (Martin Mt. Forest). (d) Typical stand of mature Douglas-fir in the Monte Hills Forest. Note the open grazing possibilities.”



Figure 6. Historical photograph from 1930's showing dense stands in the dry-belt following a catastrophic natural disturbance, western bark beetle outbreak, *Dendroctonus brevicomis* Le Conte). (Mulholland 1937)

Regional pattern of fires

The seasonal pattern in the number of fires of human vs. lightning origin in the former Kamloops Forest Region (Fig. 1) illustrates that while most lightning origin fires occur in July and August, human-caused fires tend to be more widely spread out between April and September (Fig. 7a,b). Although there are consistent differences in the seasonal pattern of the number of human and lightning-caused fires, both the number of fires and area burned are greatest in July and August. We also found this pattern to be consistent across each decade from 1950 to 1990. Although there is some variability in the number of ignitions, the pattern of a greater number of fires and area burned in July and August is consistent.

The density of lightning strikes and the fire weather index (a composite index that includes daily noon measures of temperature, relative humidity, windspeed and previous 24 hr. precipitation; see Van Wagner 1987) also peak in July and August, but there is high annual variability in this pattern (Fig. 7c, d). For example, in July, the lightning strike density can range from as low as 100 strikes per 100 km², to as high as 2600 strikes per 100 km². We believe that this variability in lightning strike density and the fire weather index (an index of droughtiness and likely fire behaviour), combined with a complex, incised topography is unlikely to consistently generate extensive, low severity fires. Complex interactions between lightning patterns and weather conditions generate considerable variability in not only the area affected by fire (Fig. 8), but also the severity of the fire. The extensive fires that burned in the southern interior of BC in 2003 occurred under extreme fire weather index conditions ranging between 30 – 60, and often resulted in high severity, stand replacing fires regardless of stand structure conditions.

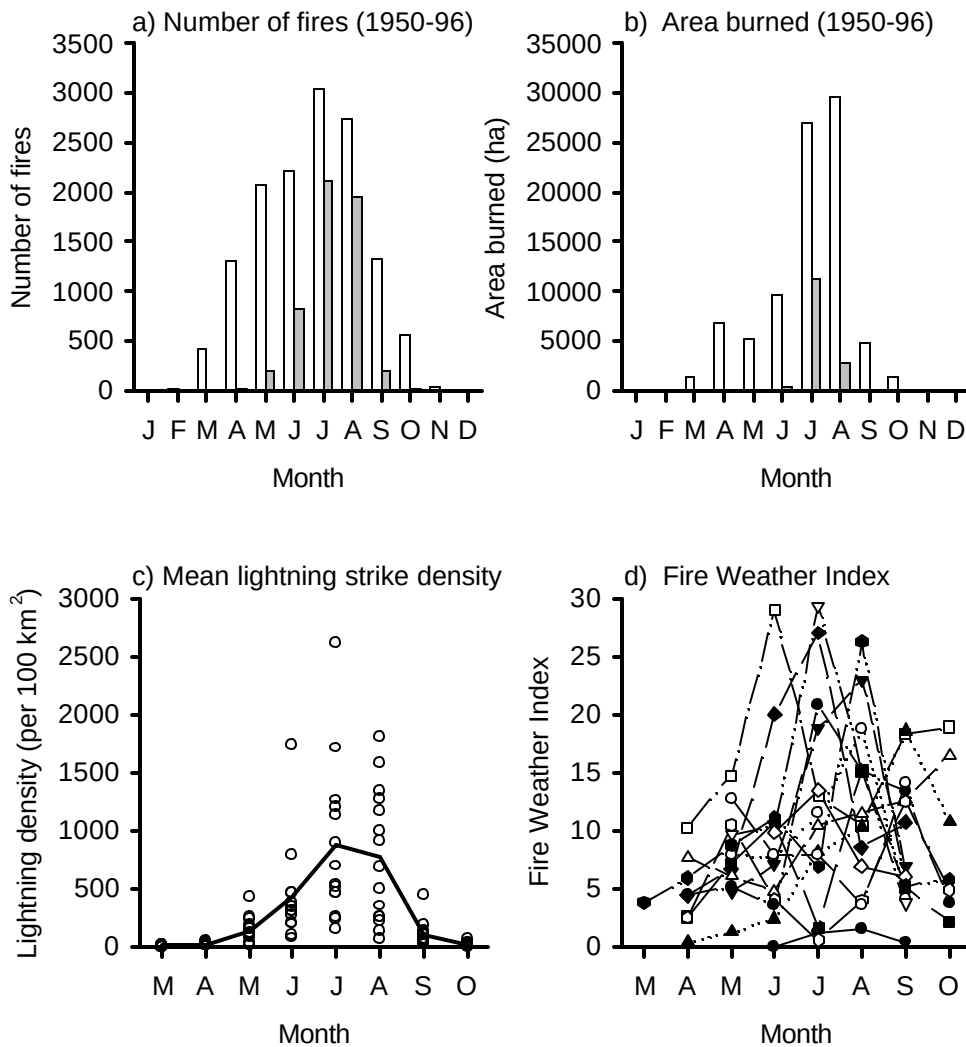


Figure 7. The average a) number of fires and b) area burned each month by human (light fill) and lightning-caused (grey fill) fires in dry forests and grasslands (NDT 4) in the former Kamloops Forest Region between 1950 and 1996. (Source: Historic fire records, Ministry of Forests Protection Branch). c) The annual variability in the monthly lightning strike density in NDT 4 habitats from March to October in the Kamloops Forest Region, 1981-95. Each circle represents the monthly density for each of the 14 years, and the average lightning strike density represented by the line. (Source: Lightning history records, Ministry of Forests Protection Branch). d) Annual variability over 13 years in the monthly average values for the Fire Weather Index (FWI) at the Leighton station (1982-95), representing conditions in the Interior Douglas-fir (IDF) Biogeoclimatic zone. Each symbol represents monthly average values for a different year. (Source: Weather Station Records, Ministry of Forests Protection Branch).

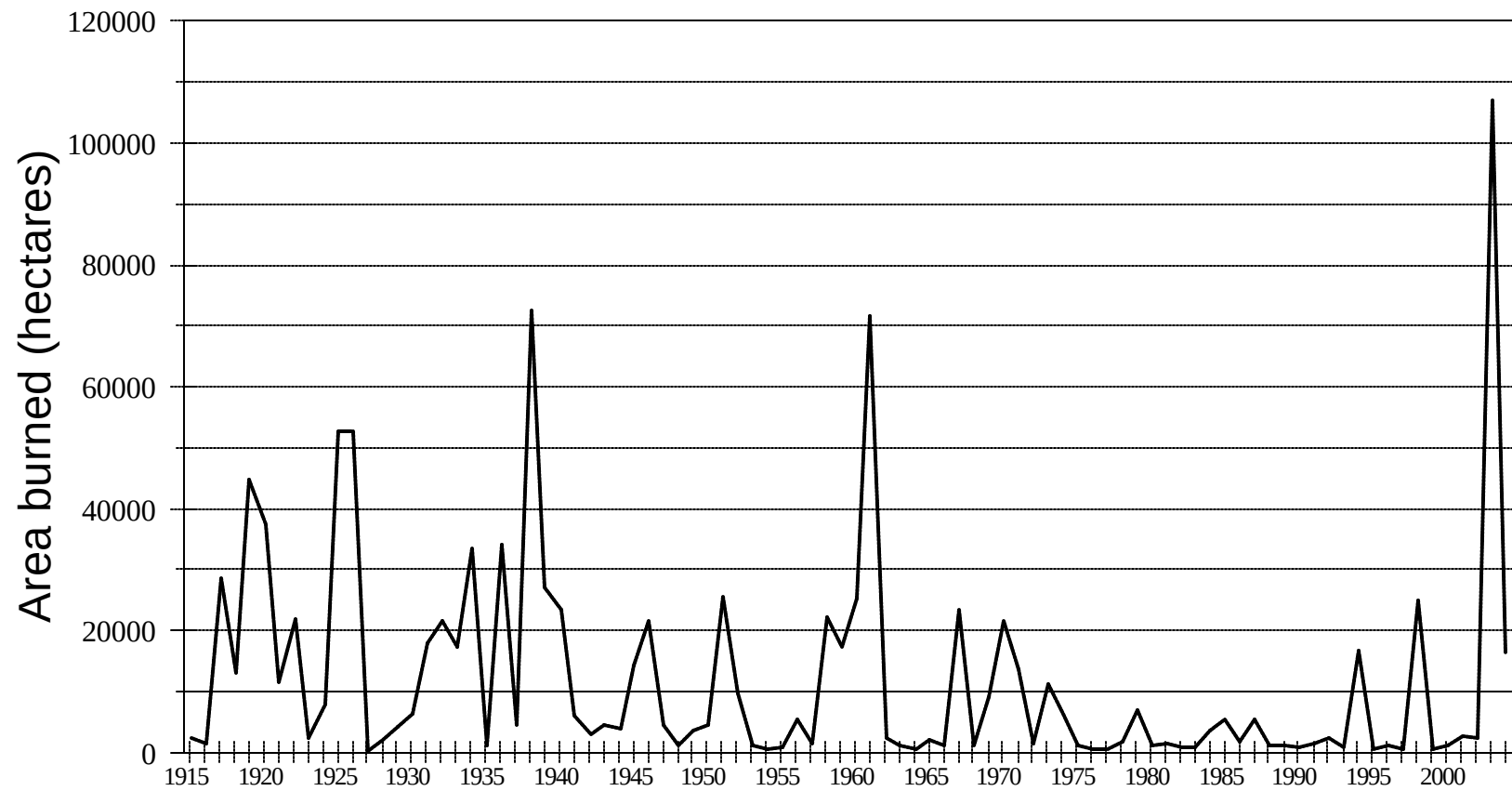


Figure 8. Total area burned in the Kamloops fire region between 1915 and 2004. Source: Ministry of Forests Protection Branch.

Multicentury fire history deduced from tree-rings

Field sampling

The traditional approach for reconstructing fire history in dry forest types generally favour sites with evidence of multiple fires and samples with multiple fire scars (Dieterich 1980). Although this may be appropriate in the American Southwest, we propose that such an approach has inherent limitations for detecting a mixed-severity fire regime. Firstly, it excludes sites that may have historically burned with moderate or high severity. Observations throughout the southern Interior of BC suggest that moderate and high severity fires in dry forests are a lot more common than previously thought. Data from the Opax Mt. project show a lot of variation in the height distribution of fire scars (Fig. 9) suggesting that fire severity was historically quite variable on the site. Areas with signs of moderate to high severity fires also often correspond with even-aged patches of forests. Shinneman and Baker (1997) have also presented evidence showing that high and mixed severity fires were very important in Ponderosa pine forests in the Black Hills of South Dakota, contrary to what had been reported through fire scar analysis studies. These observations support predictions for a mixed-severity fire regime.

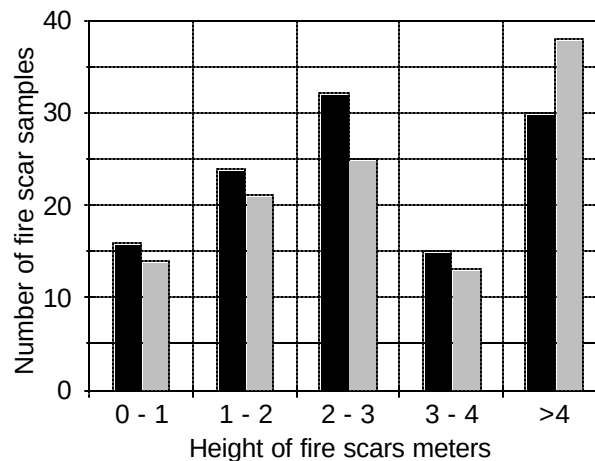


Figure 9. Height distribution of fire scars for 456 trees used as a surrogate of fire severity. Bars in black are for the lower elevation IDFxh area and bars in grey are for the higher elevation IDFdk area.

Secondly, fire return intervals deduced from fire scars are often used to characterize the fire regime of an area. One of the challenges of using this approach is determining the extent to which one wants to extrapolate a fire record. For example, a preliminary calculation of the mean fire return interval from the Opax Mt. project varies between approximately 9 years for an entire fire chronology composite of the site to around 60 years when calculated on individual trees (Fig. 10). The notion that mean fire return interval is scale dependent is well known (Agee 1993) but is often ignored in fire history studies. The traditional argument used for using composite fire chronologies is that individual trees will not capture all fires. However there is not

really a straight-forward way to extrapolate fire records in space from individual tree recorders. It is important to acknowledge that this constitutes an element of uncertainty which will be highest in mixed-severity fire regimes (Baker and Ehle 2001). Sampling that is focused on multiple-scarred trees in stands that have many fire-scarred trees will favour an interpretation towards a low severity fire regime.

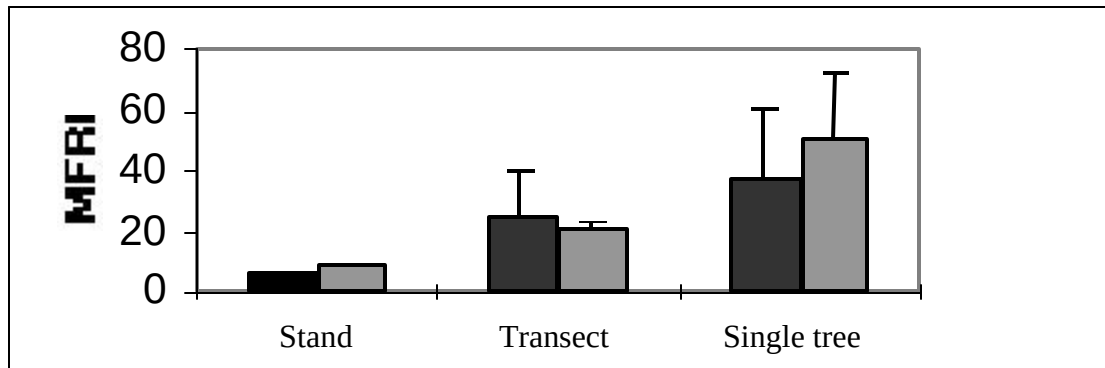


Figure 10. An example of calculating mean fire-return interval and standard deviation (years) using fire scar samples at different spatial scales. Bars in black are for the lower elevation IDFxh area and bars in grey are for the higher elevation IDFdk area. Data are preliminary and presented for discussion only.

Fire frequency

Most fire history studies have traditionally used the mean/median fire return interval in the interpretation of the fire regime instead of examining the distribution of fire intervals. The focus on the mean also biases interpretation towards more frequent fires. For example fire scars in the Dewdrop valley near Kamloops have been used to calculate mean fire return intervals as low as 18 years and it has been suggested that the fire regime had changed drastically because the last fire recorded was around fifty years ago, hence much higher than the mean (See Fig. 11 in Arsenault 2003). This supports the belief that fire suppression for the last 80 yr. had a profound effect on the fire regime. However, a closer examination of these data reveal that fire intervals of around fifty years occurred centuries before fire suppression and suggest that the current period is not outside of the natural range of variation. At Opax Mountain some trees show a reduced frequency of fire while others show no change at all. This appears to be consistent with other areas in the Southern Interior of BC and although the underlying causes for this pattern are not clear, the predictions are again consistent with that of a mixed-severity fire regime.

SUMMARY AND CONCLUSIONS

This paper has taken a comprehensive approach using different lines of evidence to test the popular idea that dry forests in the Southern Interior of British Columbia were historically maintained extensively in an open condition by frequent and extensive low severity fires. The evidence we examined does not support this idea and suggests that historically dry forests were likely affected by a mixed severity fire regime. This finding has important implications because it

means that historical conditions like today were quite variable and therefore choosing a reference condition for “ecological restoration” is virtually impossible. No one point in time should be chosen as the “ecologically correct” reference period, and past non-equilibrium disturbances illustrate conditions that are not compatible with current social expectations. Future landscape planning and stand management should avoid the use of idyllic and misleading terms like “ecosystem restoration” and focus on clearly defining desired stand conditions, the commodity objectives that will be met with these conditions, and the most effective (economical, social and ecological) tools for achieving the objective.

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