Kootenay National Park of Canada

Paleoecology and Fire History

Clues from the Past, Issues from the Future Robert C. Walker and Douglas J. Hallett

Mount Shanks Fire - Kootenay National Park, August 2001

Forest management in national parks is frequently based, in whole or in part, on maintaining or restoring natural disturbance processes within an estimate of their natural range of variability. The current Kootenay National Park (KNP) Management Plan target is to maintain and/or restore 50% of the long term, average fire cycle. Typical fire reconstructions are based on dendrochronological, fire history studies that extend back approximately 500 years. Masters' (1990) KNP fire history study described changing fire frequencies over that period and indicated that the present stand-age structure and fire frequency is best explained by decade to century level climatic influences.

Forest fires, forest insects and other forest disturbance processes are directly linked to regional climate. Climatic fluctuations occur at periodicities ranging from decades to centuries and even over millennia (Hallett and Walker 2000; Hallett et al. In prep). To quantify restoration targets, managers need ecological data sets with temporal depth great enough to define long term variability. Paleological research is an important tool for determining the natural variability of ecosystems (Smol 1992) and allows analysis over millennial time scales. By defining the range of natural variability it may be possible to predict the results of climate change, both natural and human-caused, on vegetation a nd forest disturbance processes.

The goal of ongoing paleoecological research in KNP is to reconstruct vegetation, forest disturbance processes and climate with sufficient temporal depth to adequately define the range and character of natural variability. We are using high-resolution, paleoecological data to describe the effects of underlying ecological variation and its association with past and future climate change.

Methods

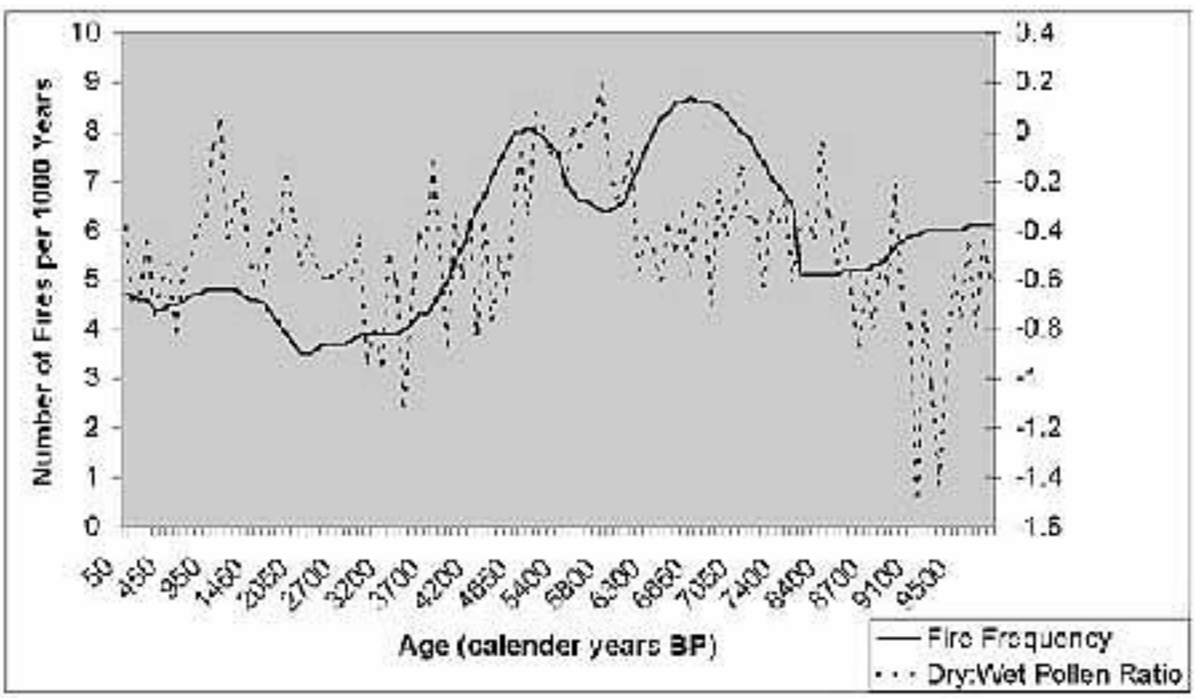
Our results are based on analysis of sediment cores taken from Dog Lake, a 15.1 ha lake in the montane valley bottom of the Kootenay Valley. Vegetation around the lake is currently in the Montane Spruce biogeoclimatic zone (Meidinger & Pojar 1991) but has changed considerably over the past 10,000 years (Hallett and Walker 2000).

Our techniques include high-resolution analyses of macroscopic charcoal, pollen and other macrofossils at two temporal scales. We extracted a 10,000-year core with a percussion corer and sampled at approximately 40-year intervals for charcoal and pollen (Hallett & Walker 2000). We also extracted a 1,000-year core with a gravity corer and sampled at 6-10 year intervals for charcoal, aquatic macrophyte fossils and arthropod macrofossils (Hallett *et al* in prep).

Charcoal analyses are based on macroscopic charcoal particle accumulation rates or CHAR, which allow us to reconstruct local fire frequency around a lake site. The KNP fire history study (Masters 1990) was used to calibrate the most recent CHAR data. Pollen ratio analyses are based on a dry:wet pollen ratio using local indicator pollen types from Hallett (1996). Dry-forest indicator pollen represents dry-open forests (*Pseudotsuga* and *Larix*, and *Poaceae*). Wet-forest indicator pollen represents wetter, closed forests (*Picea* and *Abies*). *Chara* oospore macrofossil analyses are based on the algal macrophytes' requirement of a minimum water level to colonize shallower areas of the flat lake basin. The core was extracted from an area just outside the current Chara zone, which is currently restricted to the areas deeper than 3.5 m in the basin. During high water levels Chara expands in the broad basin and conversely, it contracts to the deeper holes during low water levels.

Macroscopic Charcoal Analysis

The inferred fire frequency, based on the charcoal record, is plotted together with the dry:wet pollen ratio data (Figure 1). The 10,000 year CHAR record divides visually into three periods: Period 3 (ca. 10,000-8200 calendar years BP) of intermediate charcoal peak frequency; Period 2 (ca. 8200-4000 years BP) of high charcoal peak frequency, and; Period 1 (ca. 4,000 to present).



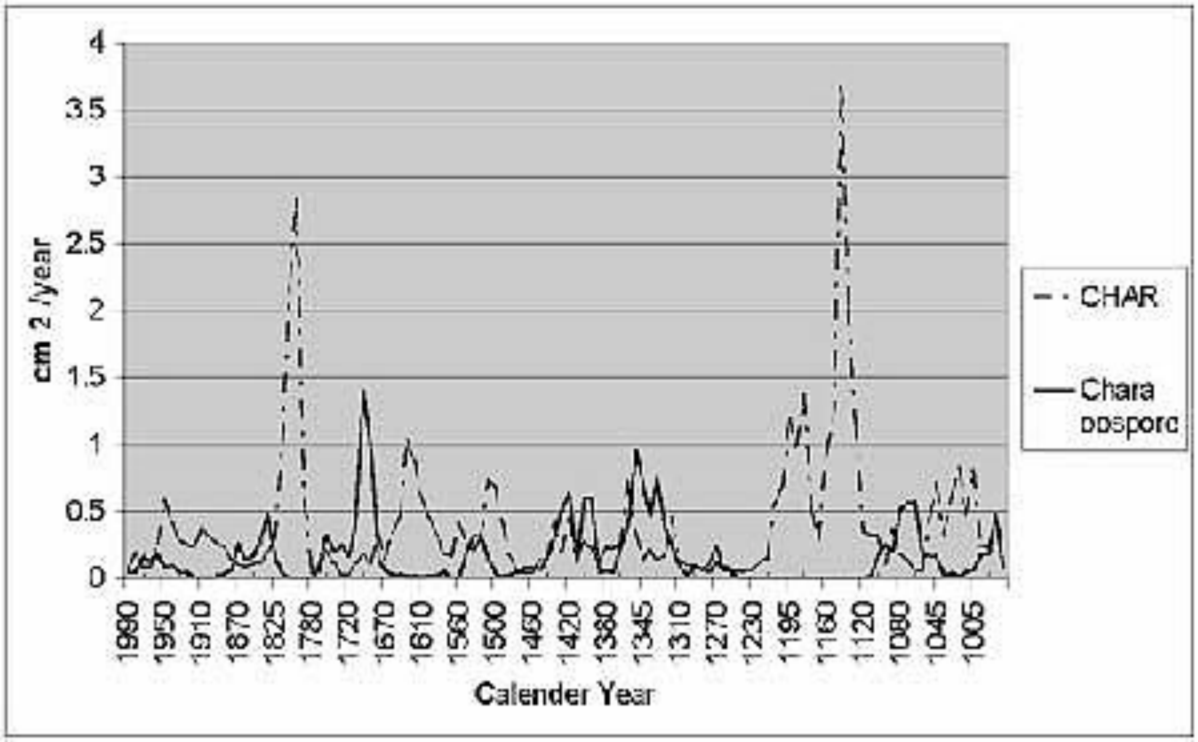
Charcoal levels and fire frequency for last 10,000 years in Dog Lake sediment cores, Kootenay National Park

Figure 1. The inferred fire frequency, based on the charcoal record, and dry:wet pollen ratios are shown for the 10,000 year Dog Lake sediment core. Log (base 10) pollen ratios of Pseudotsuga-Larix + Poaceae divided by Picea + Abies are used to infer periods of dry-open

and wet-closed forests. Increasing pollen ratio numbers indicate drier, more open forest conditions. The dry:wet ratio is only meaningful after the first arrival of Pseudotsuga-Larix pollen in the core at approximately 9000 years BP. Dashed horizontal line represents current forest conditions indicated by pollen ratios. For a more detailed presentation of these results, see Hallett and Walker 2000.

Pollen Ratio Analysis

The 10,000 year pollen ratio data corresponds to the charcoal zones (Fig. 2). The Zone 3 pollen ratio does not become effective until Pseudotsuga-Larix pollen enters the core at around 9000 years BP. Near the end of Period 3 the ratio increases and indicates dry-open forests. The Period 2 ratio consistently indicates dry-open forests. The highest values (0.2) occur from ca. 6100-4500 years BP. A decrease begins by 4500 years BP, indicating wetter closed forests. The Period 1 ratio continues to decrease indicating predominately wet-closed forests. The lowest values (-1.0) occur from ca. 3500-2800 years BP. This represents a prolonged period of wet-closed forests and corresponds to glacial advances in the Rockies (Hallett and Walker, 2000). After 2800 years BP, the ratio increases with two high values centred at 1900 and 1000 years BP. These two peaks of dry-open forest represent the last periods of dry open forests similar to those of Period 2. The ratio decreases rapidly after 700 years BP and indicates a return to wet-closed forests.



Charcoal levels and Chara macrofossil levels for last 1,000 years in Dog Lake sediments, Kootenay National Park

Figure 2. Charcoal particles/cm2/year and *Chara* oogonia /cm2/year are shown for the 1,000 year Dog Lake sediment core. CHAR peaks above 0.4 represent fires close to the lake. CHAR peaks from 1.0 to 3.0 represent large, stand destroying fires in the watershed. Increasing levels of *Chara* macrofossils indicate increasingly wetter climate. Absence of Chara macrofossils indicates drought conditions. Note the periods of absent Chara macrofossils and associated CHAR peaks. For a more detailed representation of these results, see Hallett *et al* in preparation.

The 1,000 year record indicates a strong relationship between periodic drought and large fires (Figure 2). Charcoal peaks in the 1,000 year sediments correspond to nearby, upwind polygons on the time-since-fire map (Masters 1990) through the 1640s. The presence or absence of Chara indicates high or low lake levels. The lowest lake levels and largest fires occur during the Medieval Warm Period 1000-1300 and at approximately 1800 AD. These are the only times when Chara is completely absent from the record. Other periods of low lake levels and large fires are 1490-1500s, 1600-1650s, and 1890-1920s. The Little Ice Age (1300-1850) was generally a period of high lake levels and little fire activity.

Discussion

The 10,000 year Dog Lake record indicates a wide range of natural variability for climate, fire and vegetation change in the Kootenay Valley since glaciation. In general, forest cover and fire frequency around the lake has shifted with regional climate through 3 distinct climatic periods.

Period 3 (ca. 10,000-8,200 calendar years BP)
Amounts of Poaceae, Juniperus and Pinus pollen from 10,000 to 9000 years BP (Hallett, 1996) are indications of dry-open conditions. Low pollen ratios in this zone are not indicative of dry:wet vegetation cover because Pseudotsuga/Larix pollen does not enter the core until 9000 years BP. By the end of zone three, Pseudotsuga/Larix pollen begins to change the ratio to dry-open forests.

Period 2 (ca. 8,200-4,000 calendar years BP)
The time of maximum aridity in much of western North America occurred around 6000 years BP (Thompson et al., 1993). The highest fire frequencies recorded in the Dog Lake record occur in this zone when dry open forests dominated the valley.

Period 1 (ca. 4,000 calendar years BP-present)
The decline in fire frequency, indicative of wetter/cooler conditions, after 4500 calendar years BP corresponds with the first recorded Neoglacial advances in the Rockies. Fire frequencies appear to increase slightly in the last 2000 years and pollen ratios indicate a return to drier, more open forests.

The high resolution reconstructions for the last millennium at Dog Lake demonstrate the close coupling of regional climate and fire regimes. Droughts occurred periodically and were accompanied by large, stand destroying fire events. The Medieval Warm Period corresponds to low lake levels and frequent fire activity. The Little Ice Age corresponds to generally high lake levels and little fire activity.

Conclusions

Three main conclusions arise from the data discussed above. First, there is no steady state for vegetation or fire in the Kootenay Valley.

Rather, there are several possible ecosystem states corresponding to Periods 1-3 as well as periods of transition.

Second, the range of natural variability for climate and fire in the Kootenay Valley is very broad. Resulting forest conditions at Dog Lake range from dry, open, Interior Douglas Fir to closed, wet, Englemann Spruce/Subalpine Fir (Meidinger & Pojar 1991). Current conditions are intermediate to these forest types.

Third, current global climate trends and the evidence of periodic drought at Dog Lake and at other locations throughout western North America, indicate that the frequency and severity of fire events may increase in the near future (Flannigan & Van Wagner 1991, Wotton & Flannigan 1993). Based on the drought and fire frequency reconstruction for Dog Lake, the next peak drought period is forecast for 2030-2050 AD (Hallett *et al.* in prep). Drought may also cause increases in forest insects and other pathogenic organisms that may be currently climate limited (Price & Apps 1996). Interactions between climate, fire and bark beetles over the last millennium are currently under investigation in KNP following the preliminary work reported in Prenzel and Walker (1996).

Managers must look beyond traditional methods of assessing natural variability of forested ecosystems when determining management targets. Traditional, dendrochronological fire histories analyze a small portion of a continuously varying record and may provide a false sense of the range of both past conditions and possible future conditions. Short term datasheets must be considered in relation to longer term paleoecological data sets.

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