Paleoecology and Fire History of Kootenay National Park: Clues from the Past, Issues for the Future

Robert C. Walker and Douglas J. Hallett

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 and 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 biogeoeclimatic 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 Picea). 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 - continued on page 6 -
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).

Pollen Ratio Analysis
The 10,000 year pollen ratio data corre-
sponds 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 con-
tinues 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 rep-
resent the last periods of dry open forests similar
to those of Period 2. The ratio decreases rap-
idly after 700 years BP and indicates a return
to wet-closed forests.

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 presen-
tence 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 com-
pletely 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 cli-
matic 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 high-
est 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 fre-
quencies 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 cor-
responds 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
- continued on page 7 -

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
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 & Pajor 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.

Robert C. Walker is a Fire & Vegetation Specialist, Lake Louise, Yoho & Kootenay National Parks, Box 220, Radium Hot Springs, BC V0A 1M0 Tel: (250) 347-6155, fax:(250) 347-6150, rob_walker@pch.gc.ca

Douglas J. Hallett is with the Department of Biological Sciences and the Institute for Quaternary Research, Simon Fraser University, Burnaby, BC V5A 1S6; Tel: (604) 291-4458, fax: (604) 291-3496; dhallett@sfu.ca

REFERENCES CITED


---

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.