POSTGLACIAL FIRE FREQUENCY AND ITS RELATION TO LONG-TERM VEGETATIONAL AND CLIMATIC CHANGES IN YELLOWSTONE PARK

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The paleoecologic record provides unique insights into the response of communities to environmental perturbations of different duration and intensity. Climate is a primary agent of environmental change and its long-term effect on the vegetation of the Yellowstone/Grand Teton region is revealed in a regional network of pollen records. Fire frequency is controlled by climate, and as climate changes, so too does the importance of fire in shaping and maintaining spatial patterns of vegetation. The prehistoric record of Yellowstone's Northern Range, for example, shows the response of vegetation to the absence of major fires in the last 150 years (Whitlock et. al. 1991; Engstrom et. al. in press). In longer records spanning the last 13,000 years, periods of frequent fires are suggested by sediments containing high percentages of lodgepole pine (Pinus contorta) and Douglas-fir (Pseudotsuga menziesii) and high amounts of charcoal (Barnosky et. al. 1987; Whitlock in prep.).

In Yellowstone National Park, determination of the prehistoric fire frequency over long time ranges has taken two approaches. The first involves the study of fire-scarred tree rings on surviving trees, along with an analysis of stand ages for trees that depend on fire for regeneration (Romme 1982; Romme and Despain 1989; Houston 1973). The second approach and the focus of this project is to analyze the frequency of charcoal particles and other fire indicators in dated lake-sediment cores. Intervals with abundant charcoal and other indicators are interpreted as times of past fires. The fire reconstruction is improved at sites where annually laminated (varved) sediments offer a high-resolution time scale.

The significance of charcoal size or abundance in lake-sediment records has been poorly understood in the absence of case studies on modern charcoal deposition. The 1988 fires in Yellowstone Park offer an opportunity to obtain this information and to study the processes by which charcoal, pollen, and magnetic minerals accumulate in lakes during and after a major fire. The calibration of these data with size and type of burn allows us to reconstruct more precisely past fire events from lake-stratigraphic data.

♦ OBJECTIVES

The primary research objective has been to study the vegetational history of Yellowstone and its sensitivity to changes in climate and fire frequency. To establish the sequence of vegetational changes, a network of pollen records, spanning the last 13,000 years has been studied from different types of vegetation within the Park. The fossil pollen record 188

has been interpreted in terms of past vegetation based on the relationship between modern pollen rain and modern vegetation.

The fire research has been divided into three parts:

- 1. A study of the depositional processes that incorporate charcoal into lake sediments. At regular time intervals, we are collecting surface sediments from different water depths in lakes in the 1988 burned region and lakes at varying distances from the burn (Figure 1). From these sediment samples, we are relating charcoal abundance to basin size, water depth, and fire size and proximity.
- An analysis of the last 200 years of sediments from lakes on the Central Plateau. To determine if the stratigraphic evidence of fire correlates well with the fire chronology based on dendrological studies (Romme 1982, unpublished data), we are examining charcoal abundance, pollen composition, and palaeomagnetic characteristics at closely spaced intervals in meter-long sediment cores.
- An analysis of a lake with annually laminated (varved) sediments. To reconstruct fire history on an annual time scale and to extend the fire chronology beyond the limits of Lead-210 dating (i.e., ca. 200 years), we are studying a varved record from the Northern Range.





METHODS

Detailed methodology for this research has been described in the Final Report to the UW-NPS Research Center "Late-Quaternary vegetational and climatic history of the Yellowstone/Grand Teton region" (Whitlock 1990) and will not be repeated here.

RESULTS

Characterization of the 1988 fires. Charcoal particles between 125 and 250 microns have been found to be a reliable indicator of local catchment fire (Millspaugh and Whitlock Barnosky 1990). Lakes with steep catchments in most cases show steady increases in charcoal concentration since 1988, suggesting significant inwashing of material from the slopes. The charcoal concentration in lakes with lowgradient catchments has not changed significantly, apparently because most charcoal was introduced as airborne fall-out during the fire. Charcoal abundance declines significantly in lakes that lie more than 5 km from the burned area (Figure 2). These observations will continue to be tested with additional charcoal sampling.



Figure 2

Comparison of lake-sediment records and historically dated fires. Charcoal and magnetic susceptibility were analyzed in lead-210-dated short cores from Duck, Mallard, and Dryad lakes. Stratigraphic levels that feature abundant charcoal and high values of magnetic susceptibility are interpreted as times of local catchment fire accompanied by significant erosion. The study lakes all record a major fire ca. 1690, which corresponds with the large Yellowstone fire reported by Romme and Despain (1989). Lesser peaks in charcoal and magnetic susceptibility, representing smaller scale fires, are noted at Duck Lake at 1630 and 1890, in Mallard Lake at 1906, and in Dryad Lake at 1680 and 1750. Pollen analysis is underway to determine whether changes in pollen rain occurred as part of the short-term fire cycle.

The varved sediments of Crevice Lake are under study to reconstruct the fire and vegetation history with greater precision than is possible in nonlaminated sediments. A frozen core obtained last summer preserves the last ca. 300 years of annual laminations. This core is being counted and subsampled for charcoal, pollen, geochemical analyses, and diatoms, in a collaborative study with the U.S. Geological Survey.

Reconstruction of the postglacial fire history for different parts of the Park. A transect of pollen records are available in the region from Jackson Lake northward to the Pinyon Peak Highlands. The lateglacial pollen sequence (ca. 13,000-10,000 yr B.P.) suggests a progression from tundra vegetation with birch and juniper to spruce parkland to spruce, fir, whitebark pine (Pinus albicaulis) forest. Sites above 6800 m record the development of a lodgepole pine forest in early Holocene time (10,000-7000 yr B.P.), and a replacement by lodgepole pine and Douglas-fir forest in the middle Holocene (7000-4000 yr B.P.). Spruce and fir are more important in the forest in the late Holocene (4000 yr B.P. - present). At low elevations, the record is somewhat different. A mixed forest of lodgepole and limber pine (Pinus flexilis was present between 10,000 and 7000 yr B.P., followed by an open parkland of Douglas fir parkland. The contrast in the vegetational sequence suggests that regional climatic changes affected high and low elevations differently.

PROBLEMS ENCOUNTERED DURING PROJECT

We did not anticipate the time or cost involved in collecting, sampling, and analyzing the varve record from Crevice Lake. The varved cores must be planed, photographed, and sampled in a freezer room. Subsamples for pollen, geochemistry, and diatoms must be carefully documented in terms of their varve year and varve thickness. Charcoal analysis involves sectioning the core, impregnating the samples with epoxy, making thin-sections of the core, and counting charcoal under a stereoscope. While these tasks are underway, the research is proceeding more slowly than anticipated.

FUTURE WORK IN THE CONTRACT YEAR

Charcoal samples collected between 1988 and 1990 will be analyzed from all the study sites. Additional samples will be collected in March 1991 from Duck, Goose, Cascade, and Grizzly lakes. Confidence intervals will be calculated for the Duck Lake transect from replicate samples. Short cores will be obtained for charcoal and paleomagnetic analyses from Grizzly and Goose lakes. The varve record from Crevice Lake will be counted, photographed and subsampled for pollen, charcoal, geochemistry, and diatoms.

SUMMARY

In an ongoing study of the fire history in Yellowstone Park, some preliminary conclusions can be drawn:

- Sedimentary charcoal in closed basin lakes can be used effectively to distinguish between local catchment fires and extralocal fires. The amount of charcoal in lake surface sediments is a function of the burn area, type of vegetation burned, and the gradient of the catchment.
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- 2. The 1690 Yellowstone fire is recorded by charcoal and magnetic susceptibility in all the study lakes examined thus far. These data are consistent with evidence from the dendrological record that this was a fire at least as large as that of 1988. Smaller scale fires are also documented in the charcoal record.
- 3. The pollen record shows that the postglacial vegetational history is significantly different at high and low elevations. The reconstructions suggest that fire history at middle elevations should have been greatest between 10,000 and 6000 years ago, when lodgepole pine and Douglas-fir were widespread. At low elevations fire

frequency may have been highest in the last 7000 years when Douglas-fir parkland developed.

 Crevice Lake is the only varve-sediment lake reported from the Rocky Mountain region. Analysis of a frozen core from the site will provide a high resolution of climatic, vegetational, and limnological changes not possible from nonvarved lakesediment records.

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4