

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 region is revealed in a 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 an absence of major fires in the last 150 years (Whitlock et al. 1991; Engstrom et al. 1991). In longer records spanning the last 14,000 years, periods of frequent fires are suggested by sediments containing high percentages of fire-adapted trees and high amounts of charcoal (Barnosky et al. 1987).

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 recon-

struction 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 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 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 that lie both within the 1988 burned region and at varying distances from the burn. From these sediment samples, we are relating charcoal abundance to basin size, water depth, and fire size and proximity.
2. An analysis of the last ca. 300 years from lakes

on the Central Plateau. We are examining charcoal abundance, pollen composition, and paleomagnetic characteristics at closely spaced intervals in meter-long sediment cores to determine if the stratigraphic evidence of fire correlates well with the fire chronology based on dendrological studies (Romme 1982, unpublished data).

3. 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. 300 years), we are studying a 600-year varved record from the Northern Range.
4. An analysis of long cores to determine vegetational history and fire frequency of the last 14,000 years.

◆ METHODS

Detailed methodology for this research has been described in Millsbaugh (1991) and the Final Report to the UW-NPS Research Center "Late-Quaternary vegetational and climatic history of the Yellowstone/Grand Teton region" (Whitlock 1990).

◆ RESULTS

Characterization of the 1988 fires. Charcoal particles between 125 and 250 microns are a reliable indicator of local catchment fire. Most charcoal was introduced aerielly during the fire, as evidenced by the large amounts of charcoal in lakes in burned as well as unburned catchments. Charcoal quantities in sediments in >1 m water depth increased between 1989 and 1991 in all burned lakes and in two unburned lakes. It is probable that quantities will continue to increase as more charcoal is added from slopes in burned areas and as charcoal from the shore zone is redeposited in deeper water.

The average amount of charcoal in water depths >1 m does not correlate well with the percentage of burn in a catchment. Sites that lie within 7 km of a burn on the Central Plateau have greater amounts of charcoal in their sediments than those that lie beyond 7 km of a burn. Within a 7 km radius, however, burned and unburned sites show

comparable charcoal amounts (Millsbaugh 1991). Because charcoal abundance will continue to increase in burned lakes through secondary inputs, the ability to identify a local fire from sedimentary charcoal data should improve with time.

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 lakes record major fires between ca. 1690-1750 (Fig. 1), a period that was also identified in the fire chronology developed by Romme and Despain (1989) from dendrological records. Regional fires occurred on a 40-60 year frequency from ca. 1500 to ca. 1700, but they have been relatively rare since that time.

Pollen percentages associated with historic fire events at Duck Lake show noticeable variations in the abundance of conifer pollen and total herb pollen. The increase in total herb pollen associated with fire events may reflect an increase in herb taxa that rapidly colonize a burned area. The fluctuations in conifer pollen probably reflect the burning of late-successional spruce, fir, and pine forests.

Reconstruction of the postglacial vegetational and climate history. The late-glacial pollen sequence from ca. 14,000 to 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. Between 10,000 and 9500 yr B.P. continued warming allowed lodgepole pine (*Pinus contorta*) to spread through the region, and it has been the dominant tree ever since. After 9500 yr B.P., sites in the southern and central part of the park record a different vegetational and climatic history that those in the northern range. In the southern region, Douglas-fir (*Pseudotsuga menziesii*) and (in some cases) aspen (*Populus tremuloides*) were present in the lodgepole pine forest between 9500 and 4000 yr B.P.

These taxa imply that warm arid conditions permitted Douglas-fir and aspen to extend their present-day ranges to higher elevations. After 4000 yr B.P., spruce and fir became more abundant,

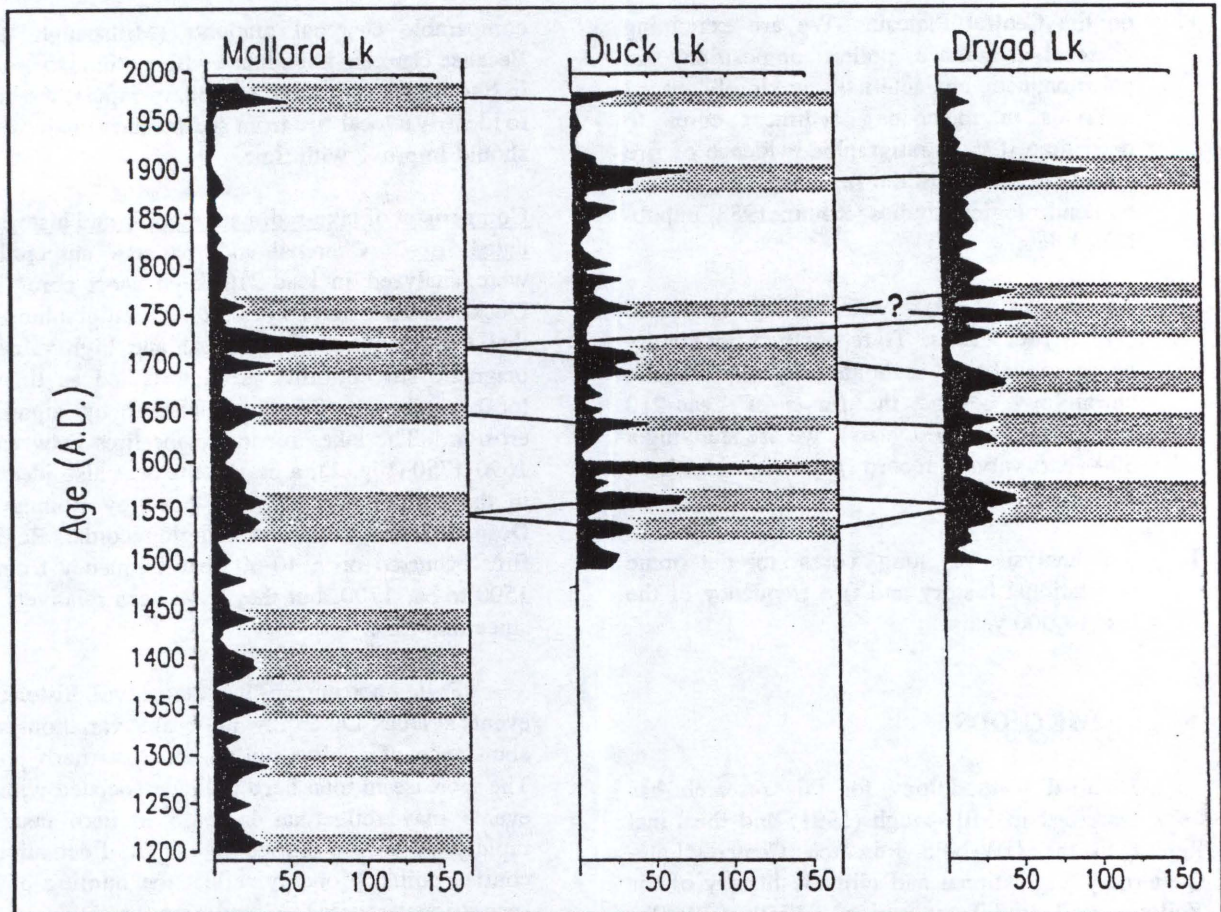


Figure 1. Comparison of the charcoal records of three lakes in the Central Plateau, showing the correlation of fire events between sites.

suggesting the onset of wetter cooler conditions in the late Holocene. In the northern range, the period from 9500 to 7000 yr B.P. is characterized by pine and juniper forest and warm, wet conditions. Douglas-fir, grass, and aspen do not appear until after 7000 yr B.P., when the climate became progressively more arid. The contrast in the vegetational sequences of the two regions suggests that northern range was under the influence of summer monsoonal precipitation in the early Holocene, while concurrently the rest of the Park experienced greater summer drought as a result of an expanded eastern Pacific subtropical high pressure system. (Fig. 2; Whitlock and Bartlein, 1991, in review).

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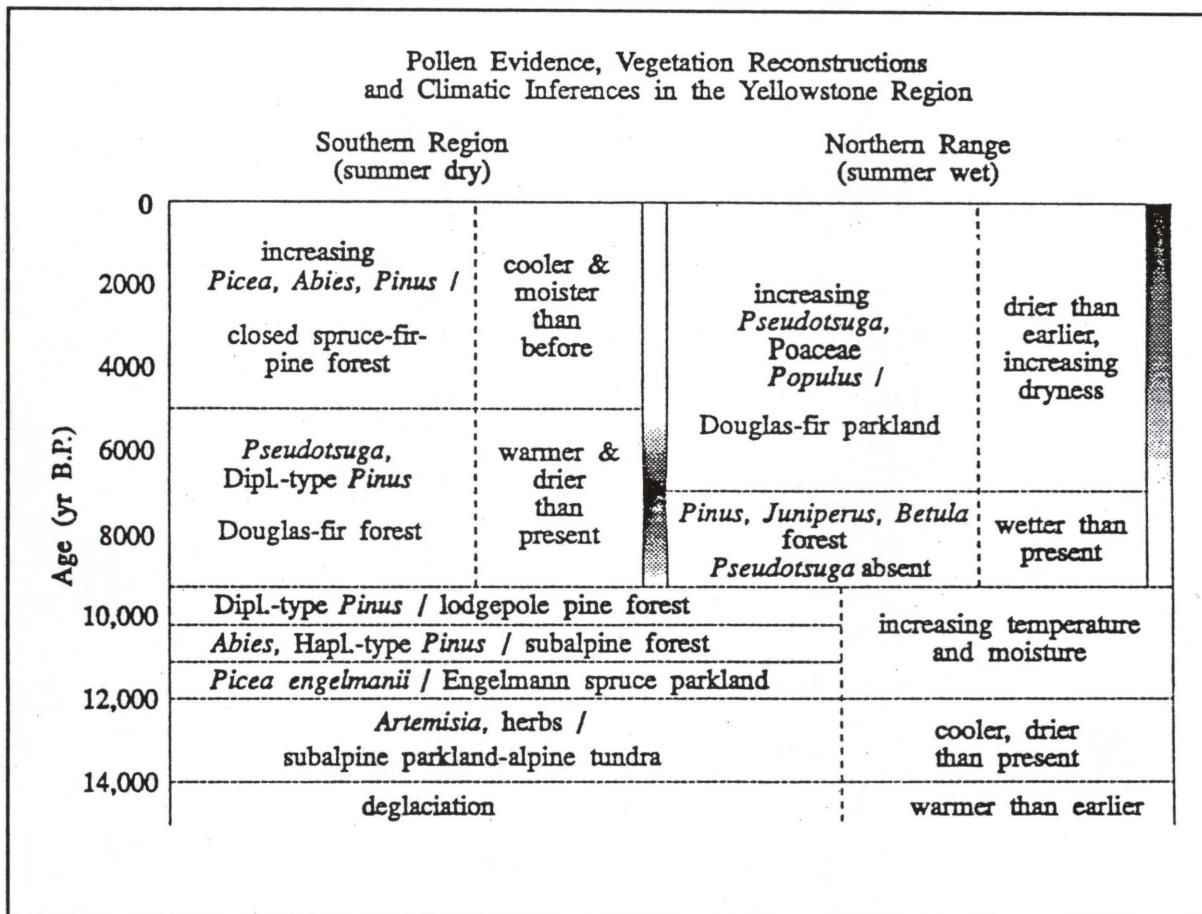


Figure 2. Summary of pollen, vegetational and climatic changes in Yellowstone National Park.

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