FOREST FIRE HISTORY IN RELATION TO LANDSCAPE DIVERSITY ON THE LITTLE FIREHOLE RIVER WATERSHED, YELLOWSTONE NATIONAL PARK

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Objectives

Fire is now recognized as a major ecosystem process and Yellowstone National Park has recently implemented a fire management plan that permits lightning fires to burn without interference under certain conditions. To predict the kinds of wildfires we can now expect in the Park, and to evaluate the effectiveness of this plan in restoring fire to the Yellowstone ecosystem, it is important to know the natural frequency and size of wildfires under pristine conditions. This study, which began in 1977 and was completed in August 1979, had the following objectives: (1) to determine the incidence and size of major fires during the last 300-400 years on the 73-km^2 Little Firehole River watershed, an area dominated by extensive lodgepole pine and some spruce-fir forests; (2) to determine average fire frequency, i.e., the time interval between successive major fires on any particular sites; (3) to determine the relationships between stand age or successional stage and fuel accumulation or the probability of fire; and (4) to examine the effect of fire on patterns of landscape diversity. Three components of landscape diversity were recognized--richness, evenness, and patchiness. Richness is simply the number of different community types represented, while evenness is an expression of the proportion of the landscape covered by each community type (maximum evenness occurring when every type occupies an equal area). The patchiness component is based on the size and interspersion of the community types.

Procedures

Fire history was reconstructed with the method outlined by Arno and Sneck (1977). Fire-scarred trees are located and sectioned, and fire years are determined by counting the annual rings from the cambium back to the scar. Reproduction of shade-intolerant species (in this case *Pinus contorta*) following fires is documented by taking increment cores from dominant individuals of all age classes present within a stand. Fuels were sampled with the planar intersect method (Brown 1974) in stands ranging from very young to very old in the two predominant habitat types (Steele et al. 1977) on the watershed. Other parameters of stand structure and site conditions that may influence fuel accumulation were also measured, such as infestation by insects or mistletoe and site productivity. The data were examined for correlations between fuel accumulations and parameters of stand age, structure, and site. In addition, the fuels data were used in a fire behavior model to further explore the relationships between stand age and flammability.

Using the data on stand age and extent, a 1978 vegetation map of the 73-km^2 Little Firehole River watershed was constructed. Each stand was classified according to vegetation type and successional stage. To recreate the vegetation mosaic on the watershed in 1778 we subtracted 200 yr from the age of each existing stand. On the resulting 1778 map of stand ages we then determined the successional stage of each stand, based on observations of the relationship between stand age and successional stage on the watershed today. We assumed that rates and patterns of succession in the recent past were similar to those of today. Our approach to landscape reconstruction was straightforward except in two types of situations which are described in the final report (Romme 1979). A computer simulation model was developed to predict changes in landscape diversity through time under 1) the natural fire regime, 2) total fire exclusion, and 3) selective fire control (permitting only small fires to burn).

Results

Evidence was found for 15 fires since 1600, of which seven were major fires that burned ≥ 4 ha, destroyed the existing forest, and initiated secondary succession (Table 1). Two major fires in the middle and late 1700's together burned half of the watershed, the other fires being comparatively small (Fog. 1). Fire frequency in this area is controlled by changes in the fuel complex during succession. Fuels capable of supporting a major fire usually do not develop until a stand is 300-400-yr fire cycle in which large areas burn during a short period, followed by a long, relatively fire-free period during which a highly flammable fuel complex again develops during forest succession. The 73-km^2 study area currently appears to be about midway between major fire events in this cycle. This, rather than human fire suppression, apparently accounts for the small number and size of fires in the Little Firehole area during the last 150 yr.

Based on the fire history data, the sequence of vegetation mosaics covering the Watershed during the last 200 yr was reconstructed. Indices of landscape diversity were computed for each reconstruction, treating forest types and successional stages as taxa and incorporating components of richness, evenness, and patchiness. Landscape diversity was highest in the early 1800's following the two large fires in the 1700's, then declined in the late 1800's and early 1900's during a 70-yr period when no major fires occurred and the landscape was dominated by even-aged forests developing on the areas burned in the 1700's (Fig. 2). Landscape diversity has increased somewhat during the last half-century as a result of two small fires and the effects of the mountain pine beetle.

Table 1. Fire years since 1600 on the 73-km^2 Little Firehole River Watershed. Major fires burned >4 ha, destroying the existing forest and initiating secondary succession.

FIRE YEAR	MAJOR FIRE	Pico/Cage** HABITAT-TYPE	Abla/Vasc** HABITAT-TYPE	FIRE SCAR SAMPLE DATES
1949	X		X	1949, 1949, 1949, 1949, 1949
ca 1932		X		ca 1932
1905	X		X	1905, 1907, ca 1912
ca 1890		X		ca 1888, ca 1889
ca 1881			X	ca 1881
ca 1860		X		ca 1858, ca 1859
ca 1851			X	ca 1851
1834	X	X		1834
ca 1827		X		ca 1827
1795	X	X	X	1792, 1793, 1794, 1794, 1795, 1795, 1795, 1795, 1795, 1795, 1795, 1795, 1796, 1797, 1797, 1797, 1797, 1797, 1797, 1798, 1798, ca 1802
1755	X		X	1755
1739	X	X	X	1739, 1739, 1739, 1739, 1740, 1741, 1741, 1742, 1742, 1743, 1743, 1744, ca 1746
ca 1659		X		ca 1659
ca 1643		X		ca 1643
ca 1630	X	X	X	*

*Evidenced by extensive 350-yr-old lodgepole pine forests.

**Pico/cage = _Pinus contorta-Carex geyeri_; Abla/Vasc = _Abies lasiocarpa-Vaccinium scoparium_

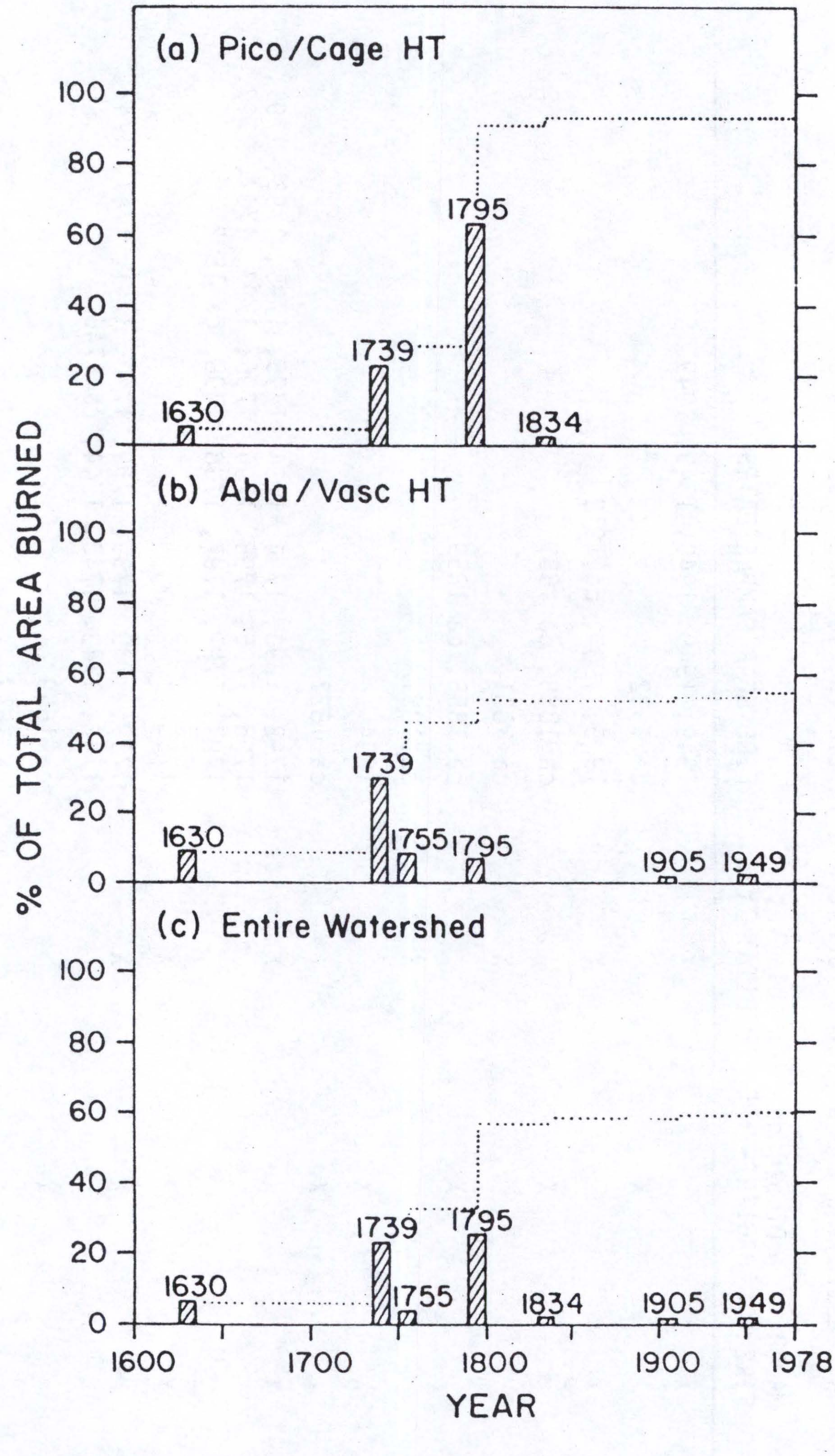

Figure 1. Sizes of documented major fires since 1600 in the Pico/Cage habitat-type (HT), Abla/Vasc HT, and entire Little Firehole River Watershed, expressed as percent of total area in the habitat-type or Watershed, respectively. The dotted line shows the cumulative area burned since 1600.

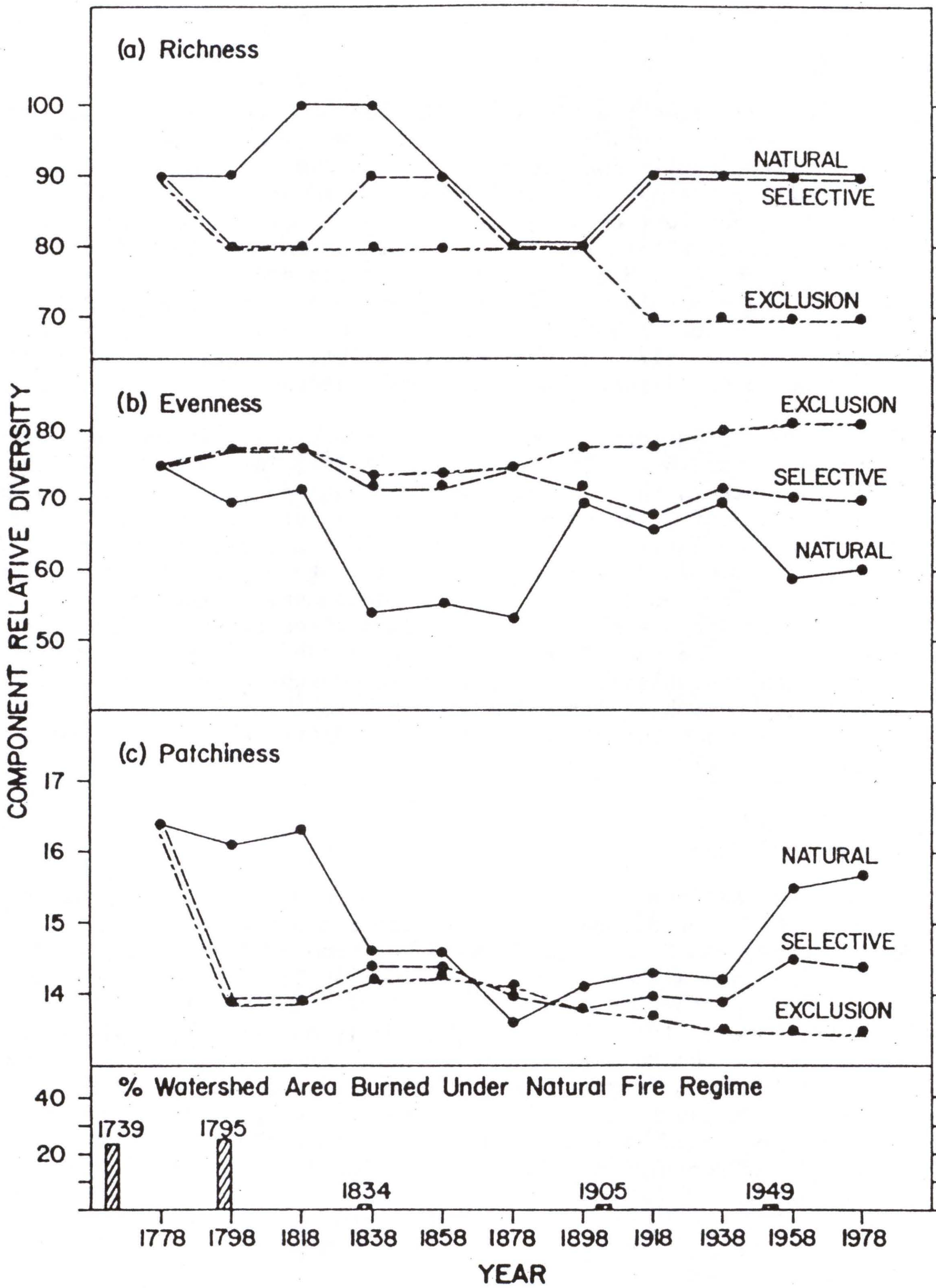

Figure 2. Relative richness, relative evenness, and relative patchiness on the Little Firehole River Watershed since 1778 under three different simulated fire regimes: natural fire — all fires allowed to burn; selective fire control -- large fires excluded, small fires allowed to burn; total fire exclusion (see text).

Discussion

The landscape reconstructions for the last 200 yr suggest that the Little Firehole Watershed is a "non-steady-state" system characterized by long-term, cyclic changes in landscape composition and diversity. Such cyclic patterns may significantly influence wildlife habitat, streamflow, nutrient cycling, and other ecological processes and characteristics within the Park, and may be an important consideration in judging whether recent ecological changes are natural or man-induced (see Romme 1979). There may be some level at which subalpine forests in Yellowstone National Park can be viewed as a steady state system. However, if such a condition exists the area must be very large, certainly larger than the 73-km^2 watershed that we studied.

The observed long-term patterns in landscape composition and diversity underscore the exhortations of Wright (1974), Sullivan and Shaffer (1975) and others that in the establishment and management of natural areas for conservation of biotic diversity care must be taken (1) to set aside a large enough area to include a mosaic of all normal stages in community development, and (2) to allow natural processes of perturbation and recovery to occur unchecked. Otherwise species and ecological processes restricted to particular successional stages may be lost. The very large-scale patterns of perturbation and recovery characteristic of the Yellowstone subalpine ecosystem probably necessitate a much larger natural area here than might be required in some other ecosystems where individual perturbations are more frequent and affect a smaller area.

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