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Responses of Boreal-Forest Fire Regimes to Holocene Climatic Change in Alaska: The Key Role of Vegetational Composition

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Area burned in boreal forests is projected to increase with climatic warming over the next century. This projection is based upon observational data of the past several decades showing that fire occurrence is controlled primarily by mean summer temperatures and precipitation. However, the climate-fire-vegetation relationships during this period may not capture the range of variability that has occurred over longer time periods and that may occur in the future. We conducted paleoecological analyses and computer simulations to assess Holocene fire-regime responses to vegetational and climatic variations in Alaskan boreal ecosystems.

The most robust feature of our paleoecological records is an increase in fire occurrence with the establishment of boreal forests dominated by *Picea mariana*: estimated mean fire-return intervals (FRIs) decreased from $\geq$300 yrs to as low as $\sim$80 yrs at some sites. This fire-vegetation relationship occurred at all sites in interior Alaska with charcoal-based fire reconstructions, regardless of the specific time of *P. mariana* arrival. The establishment of *P. mariana* forests was associated with a regional climatic trend toward cooler/wetter conditions. Because such climatic change should not directly enhance fire occurrence, the decrease in FRIs most likely reflects the influence of highly flammable *P. mariana* forests, which are more conducive to fire ignition and spread than the preceding vegetation types. The importance of species composition as a direct control of fire occurrence is further illustrated by the virtual absence of fire in the early-Holocene *Populus* woodlands, when warmer and drier climatic con-

ditions should have been favorable for burning. Decreased fire occurrence probably resulted from the low flammability of deciduous trees that reduced fire spread across the landscape.

Computer simulations using ALFRESCO, a spatially explicit ecosystem model of boreal forests, were applied to evaluate alternative explanations that the mid-Holocene decrease in FRIs was caused by climatic change, changes in vegetation flammability, or a combination of climatic and vegetational effects. Results clearly indicate the overriding effects of vegetation, as none of the climate-alone scenarios resembled the paleorecords. In contrast, all vegetation-change scenarios were similar to paleocharcoal records, and two were statistically similar.

Thus species composition appears to have played a key role in modifying the impacts of Holocene climatic change on boreal-forest fire regimes. Recent warming has led to vegetational changes across northern high-latitudes. Our results imply that in these regions, vegetational variables may greatly alter the direct effects of climate. This possibility highlights the need for improved understanding of vegetation-climate-fire interactions in northern high latitudes.