America creating concern for the long-term sustainability of forest ecosystems. Much of the focus has been centered on the need to reduce fuels in areas containing high human and ecological values. These include homes in the wildland-urban interface, community watersheds, and threatened and endangered species habitat. Vast areas of fuel hazards exist or are constantly being created on forest lands being managed for multiple-uses including timber commodities. On these lands fuel reduction and silviculture site-preparation objectives can typically be met at 2 stages in forest development: the initial stand establishment stage following harvest, and possibly again at a more mature stage when understory burning can be safely and effectively carried out without damaging the future crop trees. The period between these 2 can be one of high to extreme hazard depending on the intensity and frequency of intermediate stand tending treatments such as juvenile spacing and pre-commercial thinning. Slash resulting from these treatments can constitute a hazard for many years. In 1989 the "Grav" fire burned 5 ha of dry ponderosa pine and Douglas-fir in the Squamish Forest District, B.C. The area was salvage logged, and planted to 1200 stems/ha. In 2001 the stand density at age 11 was >8,000 stems/ha. Simply spacing the stand to a lower target stocking of 900 stems/ha would have resulted in a high fuel hazard in an area of high to extreme wildfire threat. An experimental treatment regime of spacing and prescribed fire was applied to 1.4 ha of the plantation in the spring of 2002. The study site was divided evenly and half was spaced to 700 stems/ha and half to 500 stems/ha. Target species for retention were ponderosa pine first, followed by western larch, and Douglas-fir. The fuel reduction objective focused on significantly reducing fine fuels (1-hr and 10-hr timelag categories) and retaining the larger fuels remaining from the salvage operation. The spacing was completed in December in 2001 and the site was burned in April 2002. Fine fuels were reduced by 70% (1-hr) and 40% (10-hr), while larger fuels (>3") were reduced by <15%. Tree mortality by the fall of 2002 was 13% for Douglas-fir, 3% for western larch, and 2% for ponderosa pine. The treatment was successful for meeting the stated objectives however further work is needed in determining follow-up fuel reduction treatments and devising ways to make the treatment cost-effective.

2B.1

STEM MORTALITY IN SURFACE FIRES. PART I, TISSUE RESPONSE TO ELEVATED TEMPERATURES

Matthew B. Dickinson
USDA Forest Service, Delaware, OH
email: mbdickinson@fs.fed.us

It is typically assumed that the vascular cambium (or any tissue) is killed at a threshold temperature (e.g., 60°C). In fact, the vascular cambium is killed at some combination of exposure time and temperature as surface flames pass a tree and heat transfer into the stem causes a rise and fall of temperatures. Here, I use two temperature-dependent rate-process models to describe data on tissue impairment at elevated temperatures. At fixed temperatures, one of the models describes a simple negative-exponential decline thorough time in tissue viability (single-hit model) and the other includes a mechanism by which a lag, commonly seen in data, occurs before the onset of rapid rates of tissue impairment (multiple-hit model). The temperature-dependence of tissue-impairment rates is exponential and the models assume that temperatures are high enough and last for a short enough time that cellular acclimation and repair processes play an insignificant role. Thus, the models are appropriate for the rapid heating of the vascular cambium during forest fires. I apply the models to data on mortality within populations of aspen (*Populus tremuloides*), Englemann spruce (*Picea englemannii*), Douglas-fir (*Pseudotsuga menziesii*), and lodgepole pine (*Pinus contorta*) live bark cells showing that differences among species are small (a result reflected in other studies). As well, I use data from the Central Hardwoods to confirm the expectation that the relatively rapid rise and fall of tissue temperatures and an exponential dependence between temperatures and rates of tissue impairment causes the inward propagation of a tissue-necrosis threshold in tree stems during fires. Given appropriate thermal tolerance parameters, the modeling approach described here can be applied to any tissue heated relatively rapidly in fires and is well suited for coupling with a heat-transfer model as described by Jones and Webb for stems heated by flames (Stem Mortality in Surface Fires: Part III, Linking Stem Heating with Tissue Response for Planning Prescribed Burns).

2B.2

STEM MORTALITY IN SURFACE FIRES. PART II, EXPERIMENTAL METHODS FOR CHARACTERIZING THE THERMAL RESPONSE OF TREE STEMS TO HEATING BY FIRES

D. M. Jimenez
USDA Forest Service, Missoula, MT
email: bwbutler@fs.fed.us

B. W. Butler, J. Reardon
USDA Forest Service, Missoula, MT

Current methods for predicting fire-induced plant mortality in shrubs and trees are largely empirical. These methods do not exhibit a wide range of applicability and are not readily linked to duff burning, soil heating, and surface fire behavior models. A detailed model predicting the temperature distribution through a tree stem as a function of time for a time varying heat pulse has been developed (see Stem Mortality in Surface Fires. Part III, Linking Stem Heating with Tissue Response for Planning Prescribed Burns by J. Jones and B.W. Webb). Evaluation of model accuracy has required the development of new techniques for quantifying the heat flux at the bark surface and change in temperatures within plant stems. The techniques must work for a range of heating regimes, stem diameters, and tree species. Here, we describe the experimental methodology used for this effort. Data were collected in field and laboratory studies, the methodology used for each varied. Representative cambial temperatures and surface heat fluxes from four species are presented for a range of stem diameters. Typical surface heating fluxes measured in the field studies ranged from 15 to 80 kW-m 2, magnitude and duration depended on fuel type and loading. Fluxes measured in laboratory studies ranged from 15 to 40 kW-m-2. It is anticipated that the methods developed in this study will be used to obtain data for additional species.

2B.3

STEM MORTALITY IN SURFACE FIRES. PART III, LINKING STEM HEATING WITH TISSUE RESPONSE FOR PLANNING PRESCRIBED BURNS

Joshua L. Jones
Brigham Young Univ., Provo, UT
email: jlj62@et.byu.edu

Brent W. Webb
Brigham Young Univ.

A one-dimensional model for predicting stem heating during wildland fires has been developed. The numerical model includes the dependence of wood/bark thermophysical properties on temperature and moisture. A key aspect of the model is the implementation of an imposed heat flux condition at the boundary of the stem. Such a boundary condition lends itself more readily to coupling with fire behavior simulators. Additionally, the thermal aspects of desiccation, bark swelling, devolatilization, and charring are treated in an approximate fashion for the first time in such a model. With predicted local temperature/time behavior, the simulations can be coupled to the tissue thermal response/mortality model of Dickinson (Stem Mortality in Surface Fires. Part I, Tissue Response to Elevated Temperatures. This coupling provides a tool for predicting depth-of-kill and/or stem mortality. A model evaluation exercise was carried out for four species including two western conifers (Douglas fir and Ponderosa pine) and two central hardwoods (Chestnut oak and Red maple). Model evaluation was carried out in

SECOND INTERNATIONAL WILDLAND FIRE ECOLOGY AND FIRE MANAGEMENT CONGRESS AND FIFTH SYMPOSIUM ON FIRE AND FOREST METEOROLOGY

16—20 November 2003 Orlando, Florida

Cover image: Prescribed burn in cutthroat grass (Panicum abscissum) and south Florida slash pine (Pinus elliottii var. densa) at Archbold Biological Biological Station, Florida.

Photo by R. Myers, The Nature Conservancy

AMERICAN METEOROLOGICAL SOCIETY
45 BEACON STREET, BOSTON, MASSACHUSETTS USA 02108-3693