Ecological Consequences of Alternative Fuel Reduction Treatments in Seasonally Dry Forests: The National Fire and Fire Surrogate Study

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THIS special issue of *Forest Science* features the national Fire and Fire Surrogate study (FFS), a multisite, multivariate research project that evaluates the ecological consequences of prescribed fire and its mechanical surrogates in seasonally dry forests of the United States. The need for a comprehensive national FFS study stemmed from concern that information on the ecological effects of restoration treatments designed to improve current, unsustainable conditions in seasonally dry forests was lacking. Current conditions are the result of climate change and forest management practices over the past 150 years that together have resulted in conditions that are undesirable and unsustainable, especially in forests that have an annual dry season (Stephens and Ruth 2005). In particular, the structure and tree-species composition of forests that once experienced frequent, low-to-moderate intensity wildfires have been altered by fire suppression or exclusion, grazing, and the preferential harvest of large-diameter trees. These practices, in the context of climate change, have resulted in increased tree density, decreased overall tree size, changes in tree-species composition, and increased fuel loads. Conservative estimates place >10 million hectares of forests in the United States in an elevated fire hazard condition class and much of this land area is widely thought to need some form of fuel reduction and ecological restoration (Agee and Skinner 2005).

The primary goal of the FFS study was to measure the economics, effectiveness, and ecological consequences of commonly used fuel reduction treatments. Our intent was to apply treatments that reduced potential fire risk at each of 12 sites (seven sites in the western United States and five sites in the eastern United States). The seven western FFS study sites, although differing in elevation, tree-species composition, and productivity, are located in seasonally dry conifer forests, all of which include some representation of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.). The five eastern FFS study sites include two sites dominated by hardwood trees, and three dominated by pines (McIver and Weatherspoon 2009). The treatments were conducted in cooperation with local experts, including fire management personnel, fuel specialists, and silviculturists, and included an untreated control, prescribed fire only (surface fire), mechanical treatment only (usually thinning from below), and a mechanical plus prescribed fire treatment. At each of the 12 FFS study sites, treatments (exclusive of the untreated control) were designed and implemented to achieve stand conditions such that if impacted by a head fire under 80th percentile weather conditions, at least 80% of the basal area represented by dominant and codominant trees would survive (80/80 rule). Treatments were assigned randomly to at least three replicate units, each measuring at least 10 ha. The effects of these treatments were measured on a wide variety of response variables, including the structure and composition of trees and understory vegetation, fuel beds and coarse woody debris, soils, bark beetle activity, and small mammal and avian species abundance. For a complete description of the FFS study, we refer the reader to our website (NBII 2009). The 11 contributions in this special issue include a lead-off article that describes the history, development, and organization of the FFS study; three articles that document treatment responses on stand structure, fuels, or fire behavior; two articles on the abundance and impacts of bark beetles; and five articles on vertebrate and invertebrate responses to the FFS treatments.

The FFS is one of the largest and most comprehensive forestry research projects ever undertaken, and thus required that several scientists work closely together throughout its development, implementation, and operation. In this issue, McIver and Weatherspoon describe the challenges faced by the FFS team of scientists, and discuss seven key features that contribute to the success of a comprehensive, multidisciplinary experiment.

A primary goal of any fuel reduction project is to change the structure of the fuel bed and of the standing woody vegetation, to increase resistance to stand-replacement wildfire. Working at the Northern Rocky Mountains site, Fiedler et al. demonstrate that thinning and burning have complementary effects, with thinning promoting individual tree growth while reducing canopy cover and crowning hazard, and burning reducing torching hazard and increasing height to live crown. They suggest that the combination treatment, thinning followed by fire, is the most effective way to increase stand resistance to wildfire. Similarly, in describing results from the hardwood Southern Appalachian site, Waldrop and Phillips showed that the combined mechanical plus burning treatment was most effective in reducing all measures of fire behavior and in achieving short-term restoration goals, but cautioned that treatments, especially prescribed fire, needed to be applied at frequent intervals to sustain desirable conditions. Finally, applying a meta-analysis to seven western FFS sites, Youngblood shows that, although all active treatments shifted live tree diameter distributions toward larger trees, no single treatment was capable of mitigating nearly a century of fire suppression and fuel accumulation in these seasonally dry forests. Mirroring Fiedler and Waldrop, the results from Youngblood

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call for repeat application of fuel reduction treatments over the long-term, to sustain forest conditions that would be expected to resist stand-replacement wildfire.

Bark beetles, a large and diverse group of insects consisting of approximately 550 species in North America, are commonly recognized as important mortality agents in coniferous forests, particularly in western North America. This special issue features two publications documenting the response of bark beetles and associated levels of bark beetle-caused tree mortality to FFS treatments. At the Southern Cascades site in northern California, Fettig et al. observed that burning resulted in higher levels of delayed tree mortality attributed to bark beetle attack, mostly within smaller diameter trees. However, overall mortality was low, never rising to more than 10% of available trees. Similar burning effects were observed by Hessburg et al., who report that burning (with or without prior thinning) increased the number of snags at the Northeastern Cascades site, which had been disproportionately attacked by red turpentine beetles. However, the number of the largest snags was reduced by treatment, especially for those experimental units that had previously high numbers of large snags.

For managers interested in sustaining biodiversity, it is important to understand patterns of treatment response in various animal taxa, because animals are likely to be influenced by treatment-induced changes in habitat. For the most part, the five faunal response studies in this collection show that treatment impacts tended to be subtle and transient. For example, working at the Northeastern Cascades site in central Washington, Gaines et al. report that, although burning alone tended to lower daily survival rates of bird nesting guilds, overall species composition of the avian community was unchanged by treatment. Similarly, working at five western FFS sites, Farris et al. report no overall negative effects of treatment on the bark-foraging bird guild, although individual bird species varied in how they selected microhabitat after treatment. Unique individual species responses, coupled with a high degree of site-specificity, indicates that managers will have to take an adaptive approach toward managing bird habitat as they apply these treatments in different places. Greenberg et al. discovered that the abundance and biomass of ground-dwelling macroinvertebrates were relatively unaffected by FFS treatments, with results showing only occasional treatment effects, such as a slight increase in ant biomass in mechanical + burning units. Reptiles and amphibians were common at four eastern FFS sites, including Southeastern Piedmont, Gulf Coastal Plain, Florida Coastal Plain, and the Southern Appalachians. Their response to the FFS treatments at these sites is described by Kilpatrick, who used structural equation modeling to determine that reptile abundance tended to be higher in burned units due to increased native herbaceous cover. Finally, working at the Southwest Plateau site, Hurteau shows that fuel reduction treatment, both thinning and burning, increases nest density of western bluebirds by 50%, but caution that snag reduction in burned units may lead to decreased nesting habitat quality for bluebirds in the intermediate future.

In recent years, unusually large and catastrophic wildfires burning in seasonally dry forests have heightened public concern. Such events emphasize the need for well-designed treatments in these forests to reduce their extent and severity. Under the National Fire Plan and Healthy Forests Restoration Act of 2003, federal and state hazardous fuel reduction programs have increased substantially (US Department of Agriculture 2001, US Public Law 108-148). The national FFS study is providing answers to many of the important questions that surround the issue of hazardous fuel reduction and ecological restoration in seasonally dry forests of the United States.

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