Principal short-term findings of the national Fire and Fire Surrogate study by discipline and ecosystem components

All of the numbers in this table represent publications.
To find the citation for any number, refer to the Look-up Table for Publication Numbers and Citations.

Discipline and ecosystem component	Finding	Key papers
Overstory vegetation	At all 12 FFS sites, all active fuel reduction treatments changed forest structure, with burning treatments leading to greater reduction in surface fuels, and thinning treatments leading to greater reductions in tree density. Complementary effects of thinning and burning made the combination mechanical + burn treatment the most effective at meeting short-term fuel reduction objectives. But although each of the active treatments was effective in shifting diameter distributions toward larger trees, no single entry is sufficient to restore historical structure.	22, 81, 86, 138, 169, 171, 204
Understory vegetation	Although all FFS treatments tended to increase cover and richness of herbaceous plants, treatments that included fire favored more xeric species, through decreases in litter and increases in exposure of mineral soil. Most threatened endangered and sensitive plant species were favored by fire, probably because fire suppression over the years has been the primary mechanism for their decline. Mechanical + burn treatments had the greatest short-term effects at multiple scales, increasing the dominance of both herbaceous natives and exotic “transformer” species; there will often be tradeoffs between the desire for rapid restoration of historical native conditions and the need to limit establishment and rapid growth of weedy species. Landscape context, or the proximity of proposed treatments to nearby roads, wildland-urban interface, or previous plant invasions, will influence exotic plant invasion and thus the effectiveness of treatments.	37, 55, 110, 172
Fuels and fire behavior	Most sites met short-term fuel reduction objectives, as measured by posttreatment stand structure and fuel bed variables. Burns had little influence on live stand structure, but increased small snag density and decreased fuel mass. Mechanical treatments had nearly the opposite effect, decreasing live tree density, basal area, and snag density with little change or an increase in woody fuel mass. The combination mechanical + burn treatments were the most effective at meeting stand structure and fuel objectives, having generally additive effects. Fire performance analyses conducted at six western sites strongly indicated that mechanical + burn treatments was most effective in reducing short-term fire risk. For two eastern sites at which potential fire behavior analyses were conducted (Central Appalachian Plateau and Southeastern Piedmont), the most effective treatment was burn alone, because slash created by the mechanical treatment was not consumed or had not sufficiently dried by the time burns were applied. Repeat entries of both mechanical and burn treatments will be necessary to meet long-term restoration objectives.	8, 26, 52, 68, 98, 174

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Soils	Soils varied considerably among the 12 FFS sites, representing six soil orders and over 50 named soil series. Eastern and western sites responded differently to fuel reduction treatments in terms of nitrogen and carbon storage, suggesting different management approaches; strategies that maximize carbon gain by minimizing nitrogen loss may be more applicable in western forests where carbon and N are tightly linked but not in those eastern forests where atmospheric N deposition has decoupled carbon and N cycles. While burning tended to decrease total ecosystem C, these losses were offset by increasing carbon uptake in the years following fire. Mechanical + burn treatments tended to generate the highest fire severity, and produced the greatest magnitude of effects, although overall treatment effects were generally modest and transient for most variables, including soil microbes, microarthropods, soil enzyme activity, soil nitrogen, soil carbon, cations, and soil compaction. Mechanical treatments did not serve as surrogates for fire in terms of soils, owing to distinctly different primary effects, and also the tendency for fire to produce more spatial heterogeneity in fuels, which leads to patchiness in soil variables. Few long-term experimental studies exist to help understand links among fire, the soil, microbes, plants, and ecosystem function.	176, 177, 178, 179, 180, 200
Vertebrates	Effects of fuel reduction treatments on vertebrate species varied among species, but were generally subtle, transient, and different for fire versus mechanical treatments. Fire-adapted birds including many cavity-nesters and bark-foragers tended to respond most favorably to treatments including fire, and tended to forage on larger than average trees. Mechanical + burn treatments had the greatest effect on smaller and more sedentary vertebrates such as reptiles and amphibians through decreases in litter and increases in mineral soil exposure and herbaceous vegetation. Because effects tended to be site-specific, adaptive management at the local level may be most useful in understanding vertebrate responses to treatments.	165, 181, 182, 183, 184
Invertebrates	Short-term impacts of treatments on litter arthropods were subtle, but treatments that included burning altered feeding guild composition and increased richness in the two western sites at which they were studied. Burning increased within-stand heterogeneity in arthropod habitat through decreased litter depth and increased mineral soil exposure and herbaceous vegetation cover, all of which were patchy at small scales. Compared to burning, mechanical treatments had lower impacts and favored species similar to controls.	64, 73, 159, 160

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Discipline and ecosystem component	Finding	Key papers
Bark beetles	Four western sites exhibited bark beetle effects after treatment. In each case, incidence of bark beetles was directly related to the application of fire, and to fire severity, with tree mortality generally restricted to smaller trees. Mortality of larger trees occurred after mechanical + burn treatments where cured logging slash was concentrated and resulted in increased fire intensity. There was no evidence at any site of bark beetle attacks spreading to adjacent green trees, which was probably owing to a combination of high tree vigor in residual stands and low background populations of bark beetles.	33, 46, 51, 74
Fungi and pathology	At each site at which fungi were studied, researchers reported high fungal species richness, including many previously unreported species, and species of potential importance for biological control. At the Blue Mountains site, ectomycorrhizal fungi associated with plant roots responded negatively to fire in the short term, with greater effects in stands where logging slash left in the woods increased fire severity. At the Southeastern Piedmont site, incidence of the forest pathogen *Leptographium* was reduced by treatments, but rebounded within 5 years. At the Northeastern Cascades site, the mechanical + burn treatment caused the greatest reduction in incidence of dwarf mistletoe, and modeling suggested that the effect may last 20 years.	15, 19, 28, 167
Operational economics	In general, the lower the value of harvested product in a fuel reduction project, the more advantage there was to use “purpose-built” machines designed specifically for a particular operation. On federal lands, giving contract officers more flexibility to decide on the details of a fuel reduction operation (e.g., whether to remove small trees, or whether to treat slash on site) makes senses given market volatility. Financial analyses of costs and revenues of fuel reduction treatments provided only a partial picture; a complete cost-benefit analysis involves both short- and long-term ecological effects and monetary values assigned to nonmarket issues.	29, 31, 187
Sociology and outreach	Surveys conducted at the Central Sierra Nevada site indicated that while most respondents understood the need for fuel reduction, fewer individuals found mechanical treatments to be as acceptable as fire for fuels management. Forest managers tend to favor the use of existing electronic platforms within which to place information, favored the synthesis of technical papers by topic, and emphasized the value of one-on-one contact with researchers. Multisite, multivariate studies like the FFS are challenging to execute, and success depends on several key features: adequate funding, design, partnerships, collegiality among researchers, standardization, data management, and outreach.	189, 190, 199