Final report, Joint Fire Science Program AFP3-2003

Project Title: Ecosystem effects and propagation of the Biscuit fire across the large-scale plots of the long-term ecosystem productivity experiment

Project Location: Biscuit Fire, Siskiyou National Forest, southwestern Oregon

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This final report details findings to date and proposed and accomplished deliverables. Details on the study background, objectives, methods, and evidence to support these findings are presented on our recently updated web page (http://www.fsl.orst.edu/ltep/Biscuit/Biscuit05_files/frame.htm), which can be considered a contribution to the final report.

SUMMARY OF FINDINGS TO DATE

Simplistic rules sometimes belie inherent ecosystem complexity.

- The Biscuit Fire has important lessons for us, about the effects of wildfire on forest ecosystems. Our study—above all else—demonstrates that interactions of wildfire with ecosystem processes and conditions can create very complex patterns of response. Complex responses from previous fires likely created much of the high small-scale spatial variability described we previously described for these sites (Homann et al. 2001). We also have documented important temporal complexities. For example, many legacies from the last fire, about 110 years ago, persisted until fire returned. Legacies include hardwood mid-canopy trees (tanoak, madrone, and others), over-mature knobcone pines (with serotinous cones), and apparent seed banks in the soil. We expect that Biscuit legacies, by extrapolation, will likely last to the next fire. Spatial and temporal complexities are extended by other uncertainties and surprises about ecosystem processes (such as possible plume-driven soil loss and a damping effect on fire by mid-canopy hardwoods, discussed later).
- These general conclusions are supported by results from our study. We found that the degree that ecosystems were affected by the fire was determined in part by pre-fire management, and that these various outcomes hold different consequences for future ecosystem development, including future fire risks. Some widely held views on the magnitudes and even directions of management effects were not well supported. The most extreme effects of fire on soils that we observed at stand scales should be long-lasting, suggesting that special interest should be paid to pioneering plants that can help rebuild nutrient pools. Soil development itself was substantially affected in many places. New insights into soils, forest productivity, and diversity in forests with frequent fire-return intervals are likely with continued investigation.

Having unburned controls changes interpretations.

- Trends before and after fire in vegetation, woody debris, tree mortality, and even soils can be easily misinterpreted without understanding background changes in unburned stands. In some cases what appears to be distinct fire effects turn out to be lacking or overshadowed by background changes already underway.

Past management changed how the fire burned.

- Past management, created as experimental manipulations in the LTEP study—of 110-yr-old, fire-origin, Douglas-fir-dominated stands—appears to have changed how the fire burned. The thinned and underburned stand had the least mortality (36%); the two burned control stands had intermediate mortality (63 and 77%); thinned, low woody debris stands had moderately high mortality (91 and 94%); while thinned high woody debris and 6-yr-old pioneer and Douglas-fir stands had 100% mortality. The relatively low mortality in the controls was most unexpected, and not predicted by the fire models (Raymond 2004, Raymond and Peterson 2005). The relative similarity among pairs in replicated treatments (controls and thinned, low woody debris) gives us limited confidence in these conclusions. We must also consider, however, that fire behavior is influenced by more than fuels. Even though most stands burned on the same day, how they started, what was adjacent to them, and other factors may have come into play. Potential explanations for observed patterns of mortality—including a possible role for mid-story hardwoods removed in the thinning of these stands—deserve future attention.

Tree mortality and fire temperatures are significantly related.

- Although not surprising, tree mortality averaged across individual treatments explains about 50% of the variation in average temperature as measured by the degree that aluminum tags melted along our grid system. Future work will examine relationships between caloric consumption, temperature, fuel distribution, hardwood distributions, slope, woody debris, and other variables

The effects of the fire on some soils were extreme.

- Our quantitative-pit soil sampling across 2-ha area grids, before and after the fire allows us to determine fire effects quantitatively at the stand scale. Some soils were greatly affected by the fire, and soil effects appear related to stand conditions before the fire as well as temperatures during the fire. Stands with less mortality appear to have less soil effects (for example, surficial rocks are positively related to mortality on an averaged stand basis).
- The most affected soils appear to have lost their entire organic horizon, all of the top mineral horizon (A), as well as over 10% of the upper B horizon. More than 5 kg/m^2 of soil (organic and fine mineral components) are now missing, changing particle size distributions (for example, many rocks at the surface), soil bulk densities, charcoal content, and many other factors.
- Nitrogen associated with these losses and changes in remaining soil add up to about 400 kg/ha. Combined with vegetative losses (not yet quantified) we expect that up to 18 years of typical N uptake in vegetation was lost. Losses of other elements know to volatilize at lower temperature (S, P, K) have yet to be quantified.
- Taken together, changes in soil organic matter, bulk density, particle size, and nutrient content are likely to impact forest productivity for some time to come. Tracking new growth against that observed before the fire, and that in unburned treatments will reveal direct measures of wildfire on productivity. Of particular interest will be to follow the nitrogen-fixing plants that may or may not come to dominate burned stands. The LTEP program is considering growth plots of uniform seedlings to evaluate fires of different intensities. Unlike background changes in vegetation, soils appear relatively unchanged in unburned stands. Thus, observed changes are easily attributable to the Biscuit Fire.

Rain-driven erosion was large but local.

- Erosion was large on burned soil relative to unburned soil, at least at small scales. Evidence indicating large short-distance transport included controlled erosion boxes and pins. Boxes showed a relation between slope and transport for burned soil as expected. Pins demonstrated fluctuating soil surface heights (relative to the top of rebar grid-point posts). We failed to see significant movement at the base of hotly burned units. Little soil accumulated in ditches along the road. Microtopography from old windthrow mounds, stumps, and decaying logs appeared to sharply limit long-distance transport.
- Needles that fell from fire-damaged conifers formed numerous needle dams in the first and second year after the fire, trapping large amounts of ash in stands that had large conifers left standing. Needles appeared to decompose by the 3rd year and ash may be moving again, so any nutrient or soil trapping effects may not differ from initially treeless areas over time.

Wind-driven erosion appears large.

- The mineral components of missing soil can be considered as eroded, unlike most of the organic components combusted in the fire. Mechanisms for this erosion include water transport (there's little evidence of long-distance transport), soil infilling, and aolian or wind transport during or after the fire. Many decaying stumps, roots, and logs combusted leaving deep holes in the ground. Short-distance transport would likely fill these holes. Our sampling did not indicate this process was important across the entire stands (but our sampling was not designed to test for this). The most probable mechanism we have surmised is fire-driven winds. Smoke is mostly made of particles including larger, but light burned organic matter as well as small mineral particles. As the upper soil burns, some soil particles disaggregate into smaller fractions. Winds at the soil surface in hot fires can reach over 100 mph, easily picking up such particles. The satellite photos of the plume extending more than 50 miles across and, on some days, nearly to Hawaii are suggestive of significant particle movement.

Added large woody debris did not significantly affect fire temperature.

- Observed temperatures were hotter on the high-wood treatment in only 1 of 3 pairs—and no significant differences were found. Woody debris, added in 1996 in some LTEP stands, contributed little additional combusted material in the fire. About 3 times more fine wood was consumed than larger-diameter wood. Older larger-diameter woody debris was more important than recently added woody debris. Decayed wood was more consumed (85%), compared to less-decayed wood (41%).

Past management changed how fire affected species composition

- Vegetative succession, already influenced by the LTEP treatments, changed again after the fire. Tree mortality ranged from 5 to 100% and tree species composition will change as knobcone pine and shrubby hardwoods initially dominate young stands.
- At first glance, the numbers of understory species found appear to radically increase after the fire (compared to pre-fire frequencies on burned plots), but because we have similar treatments that were not burned, we can evaluate elements of change caused by the fire. When background changes are taken into account, the fire had positive, negative, or little effect depending on the LTEP treatment. Small increases were seen in the burned compared to unburned control plots; large decreases were seen in the burned compared to unburned Douglas-fir plots; and no or minor changes were seen in the Late-successional, Pioneer, and Underburned plots.

DELIVERABLES

Proposed	***Accomplished/Status***
Annual progress reports	Annual progress reports completed
Series of 3 or more journal papers describing changes in our plots relating to initial conditions, pre-fire experimental manipulations, fire intensity and severity, and our interpretation of the implications of combined effects on long-term productivity and biodiversity (focus on changes in plants, soils, nutrients, and erosion).	Publications examining fire-effects have been produced in several formats: o Bormann, B.T., R. Darbyshire. 2005. Ecosystem effects of the Biscuit Fire. Conference proceedings, Mixed severity fire regimes: ecology and management symposium, Spokane, WA. ONLINE [http://www.emmps.wsu.edu/fire/secondary/PROCEEDINGS.html] o Raymond, C.L. 2004. The effects of fuel treatments on fire severity in a mixed-evergreen forest of Southwestern Oregon. Master of Science thesis, University of Washington, Seattle, WA. o Raymond, C.L., D.L. Peterson. 2005. How did prefire treatments affect the biscuit fire? Fire Management Today 65: 18-22. Additional publications that provide context for post-fire evaluation and plant-soil productivity relations o Homann, P.S., S.M. Remillard, M.E. Harmon, and B.T. Bormann. 2004. Carbon storage in course and fine fractions of Pacific Northwest old-growth forests. Soil Science Society of America Journal 68: 2023-2030. o Homann, P.S., M.E. Harmon, S.M. Remillard, E.A.H. Smithwick. 2005. What the soil reveals: Maximum ecosystem C stores of the Pacific Northwest region, USA. Forest Ecology and Management. *In press*. Planned future journal articles comparing post- and pre-fire conditions: o Wildfire effects on soils and long-term productivity o Wildfire effects as influenced by pre-fire stand structures, downed woody debris, and species composition (including role of sclerophyllous-tree mid stories) o Utility of Lidar to characterize stand structures and species composition of burned and unburned forests o Evaluation of stand-scale soil sampling approach, looking at magnitude and causes of spatial and temporal variability.

Proposed	*Accomplished/Status*
Publish on the post-LTEP and post-fire changes in mycorrhizal morphotypes and fruiting fungi.	Work was completed under cooperative agreement with Dan Luoma at Oregon State University. We have been given some preliminary findings but are awaiting a final report.
Publish on changes in bird populations. This element was dropped when the budget was reduced.	Although funding was removed for this part, other funds were found to support work by C.J. Ralph. The work was completed and we are awaiting a report.
Pursue opportunities to link this study to other ongoing wildfire-effects research—mainly that funded by the Joint Fire Science Program and the PNW Station—and especially where we share similar data, such as in the fire-surrogate study, work by Dave W. Peterson, and Marilyn Walker (Institute of Northern Forestry, Fairbanks, AK). We will also seek to link with other work being considered in this competition that we are aware of, including re-measurement of inventory plots. We will also explore linkages with major assessment efforts the OSU College of Forestry is currently exploring. We can help to extend interpretations from broader, but shallower inventory or remote-sensing datasets because the fire effects in our study area cover a range of fire intensities and severities.	o Link to Seattle Fire Lab—we developed a close and mutually beneficial arrangement with the Seattle Fire Lab (D. Peterson and others). They provided a field crew to make many above-ground measure and have taken the lead on several publications. We expect this collaboration to continue. o Link to Rogue-Siskiyou National Forest—we continued and expanded our collaboration with the Forest, including volunteering to be the research liaison and team member for the Biscuit Fire EIS (Darbyshire) and to develop a 36,000-acre landscape management experiment (see below; Bormann and Darbyshire). o Link to NCSSF biodiversity program and OSU—we wrote and were awarded a small grant from the National Commission on Science and Sustainable Forestry to develop methods to evaluate lidar methods of predicting biodiversity indicators by using our LTEP ground data from the Biscuit Fire. This study is underway. o Link to the PNW Research Station Director's Office and the Silviculture and Forest Models team in Seattle, WA, who contributed funds to fly $80,000 of lidar over the LTEP plots and the landscape experimental area on the Biscuit Fire. We are collaborating with Steve Reutebuch and his UW collaborators in this ongoing project. o Link to JFSP project on Biscuit retrospective study (Spies et al.). We are actively collaborating with this group, and have been advising them, providing them with aerial photos, and helping to interpret their data. Several other proposed links did not materialize. For example, Marilyn Walker moved from the Fairbanks lab, and Dave W. Peterson did not have the time to work with us. These deficiencies were countered with other links described above.

Proposed	Accomplished/Status
Additional technology transfer: advising on an administrative study testing effectiveness of mulching that was implemented by the Forest; revising the LTEP program web page, participating in the Joint Fire Science workshops, writing a popular publication we envision, "Do fires really sterilize the soil?", perhaps submitted to Natural History or a similar outlet; and presenting initial findings at the planned Umpqua-Siskiyou-Rogue Forests workshop on disturbance ecology as an alternative to the Northwest Plan.	o Advised on a Siskiyou NF mulching study—finished advising and have preserved records after employee retired. o Revised the LTEP Biscuit web page—a revision was just completed to complement this final report [http://www.cfsl.orst.edu/ltep/biscuit05] o Attended Joint Fire Science workshop (March 18-19, 2003 in Corvallis, OR) o Wrote a popular article—for Fire Management Today, another is planned on fire effects on soil. o Presented at the disturbance ecology workshop—completed by presenting an invited paper at the Mixed Severity Fire Regime workshop in Spokane, WA [http://www.emmps.wsu.edu/fire/secondary/PROCEEDINGS.html] as well as a popular talk at the Marys Peak Natural Resources Interpretive Center [http://www.orww.org/MPIC/] Several additional products (not specifically proposed): o Designed a 36,000-acre landscape experiment comparing 3 different approaches to managing late-successional reserves after fire. This experiment was adopted in the Biscuit EIS and is being implemented. o Participated in an Oregon Public Broadcasting broadcast. The popular Oregon Field Guide invited us to be the focus of a show on the Biscuit Fire. The show highlighted aspects of our JFSP work. The producer remarked that it was one of their most highly rated shows, and they rebroadcast it a second time. We have various forms of the broadcast and can disseminate it for educational purposes. o Presented to a Congressional field tour (2003). "Biscuit Fire: how can managers and researchers work better together to learn at the landscape scale?" Invited presentation to congressional staffers sponsored by the Northwest Forestry Association. Siskiyou National Forest, Cave Junction, OR. o Presented to the R6 Regional office (2004) "Landscape experiments at Five Rivers and on the Biscuit Fire as a model for a new cooperative relationship between regional managers and the PNW Station." Invited presentation to the Regional Forester, Station Director, and staff. o Assisted entrants in the State Science Fair. Robyn Darbyshire worked with several area high school students on a project on effects of the fire on seedling survival and growth. They won the State Fair, and were funded to compete in the national science fair.

Proposed	***Accomplished/Status***
New items (not initially proposed) being pursued, partly attributable to JFSP funding	o Expanding work into cation losses and rock fragmentation using X-ray fluorescence (total elemental content) and X-ray diffraction (mineral composition) measures, with additional funding from the PNW Research Station (long-term studies program). o Expanding work into the role of mid-story hardwoods, and how they affected mortality of 110-yr-old Douglas-fir. We will perform a spatial analysis to assess the role of hardwoods. o Updating out LTEP sample archive (including samples collected under the grant) to maintain options for long-term tracking of soil recovery. o Replanting parts of the burned LTEP stands to evaluate effects on forest tree productivity. o Continuing more detailed work on micro-topographic erosion effects using the 1-m DEM from lidar, other field methods, and sequential photos. o Continuing the digital photo points (1400) across the LTEP treatments that date back to 1992. o Developing methods to better assess biomass before the fire on young stands, using unburned stands, and evaluate potential nutrient losses from burned vegetation. o Exploring burn severity and seedling establishment in whitebark pine communities