A Proposal to be Submitted to the Joint Fire Science Program

A NATIONAL STUDY OF THE CONSEQUENCES OF FIRE AND FIRE SURROGATE TREATMENTS

Principal Investigators—Members of Project Steering Committee:

Phil Weatherspoon
(project coordinator)
USDA, FS, PSW Station

Jim Agee
University of Washington

Phil Aune
USDA, FS, PSW Station

Jim Baldwin
USDA, FS, PSW Station

Jamie Barbour
USDA, FS, PNW Station

Frank Beall
University of California,
Forest Products Laboratory

Julio Betancourt
USDI, USGS, Tucson, AZ

Ralph Boerner
Ohio State University

Matt Busse
USDA, FS, PSW Station

Carl Edminster
USDA, FS, RM Station

Gary Fiddler
USDA, FS, Region 5

Carl Fiedler
University of Montana

Sally Haase
USDA, FS, PSW Station

Kathy Harcksen
USDA, FS, PSW Station

Mick Harrington
USDA, FS, RM Station

Ron Hodgson
California State University,
Chico

Sue Husari
USDA, FS, Region 5

Jon Keeley
USDI, USGS, BRD,
Sequoia-KC NPs

Mike Landram
USDA, FS, Region 5

Bill Laudenslayer
USDA, FS, PSW Station

Jim McIver
USDA, FS, PNW Station

Dan Neary
USDA, FS, RM Station

Bill Otrosina
USDA, FS, SO Station

Roger Ottmar
USDA, FS, PNW Station

Martin Ritchie
USDA, FS, PSW Station

Kevin Ryan
USDA, FS, RM Station

Patrick Shea
USDA, FS, PSW Station

Carl Skinner
USDA, FS, PSW Station

Scott Stephens
California Polytechnic State
University,
San Luis Obispo

Nate Stephenson
USDI, USGS, BRD,
Sequoia-KC NPs

Elaine Kennedy Sutherland
USDA, FS, RM Station

Bob Vihnanek
USDA, FS, PNW Station

Dale Wade
USDA, FS, SO Station

Tom Waldrop
USDA, FS, SO Station

Dan Yaussy
USDA, FS, NE Station

Andy Youngblood
USDA, FS, PNW Station

Steve Zack
Wildlife Conservation Society
(New York);
Humboldt State University
(California)

EXECUTIVE SUMMARY

Introduction

Many U.S. forests, especially those with historically short-interval, low- to moderate-severity fire regimes, are too dense and have excessive quantities of fuels. Widespread treatments are needed to restore ecological integrity and reduce the high risk of destructive, uncharacteristically severe fires in these forests. Among possible treatments, however, the appropriate balance among cuttings, mechanical fuel treatments, and prescribed fire is often unclear. For improved decisionmaking, resource managers need much better information about the consequences of alternative management practices involving fire and mechanical/manual "fire surrogates."

Long-term, interdisciplinary research thus should be initiated to quantify the consequences and tradeoffs of alternative fire and fire surrogate treatments. Ecological, economic and social aspects must all be included as integral components. The research needs to be experimental, rather than retrospective or correlative, to permit stronger inferences about cause-and-effect relationships. Only through such research will it be possible to determine which ecosystem functions of fire can be emulated satisfactorily by other means, which may be irreplaceable, and the implications for management. The human dimensions of the problem are equally important. Treatment costs and utilization economics, as well as social and political acceptability, strongly influence decisions about treatment alternatives. Such research must be a cooperative effort, involving land managers, researchers, and other interested parties.

A team of scientists and land managers has designed an integrated national network of long-term research sites to address this need, with support from the USDA/USDI Joint Fire Science Program (http://www.nifc.gov/joint_fire_sci/index.html). The steering committee and other participants in this national "Fire/Fire Surrogate" (FFS) study represent a number of federal and state agencies, universities, and private entities, as well as a wide range of disciplines and geographic regions. The study will use a common experimental design to facilitate broad applicability of results.

Objectives

The overall goal of the proposed research is to quantify the ecological, economic, and social consequences of fire and fire surrogate treatments in a number of forest types and conditions in the United States. Priority is given to forests with low- to moderate-severity natural fire regimes.

Objectives of the FFS study are:

1. Quantify the effects of fire and fire surrogate treatments on a number of specific core response variables within the general groupings of (a) fuel and fire behavior, (b) vegetation, (c) soils and forest floor/hydrology, (d) wildlife, (e) entomology, (f) pathology, (g) treatment costs and utilization/economics, and (h) social sciences.
2. Provide an overall research design that (a) establishes and maintains the study as an integrated national network of long-term interdisciplinary research sites utilizing a common "core" design to facilitate broad applicability of results, (b) allows each site to be independent for purposes of statistical analysis and modeling, as well as being a component of the national network, and (c) provides flexibility for investigators and other participants responsible for

each research site to augment—without compromising—the core design as desired to address locally-important issues and to exploit expertise and other resources available to local sites.

3. Develop and validate models of ecosystem structure and function, and successively refine recommendations for ecosystem management.
4. Within the first five years of the study, establish cooperative relationships, identify and establish network research sites, collect baseline data, implement initial treatments, document treatment costs and short-term human and ecological responses to treatments, report results, and designate FFS research sites as demonstration areas for technology transfer to professionals and for the education of students and the public.
5. Develop and maintain an integrated and spatially-referenced database format to be used to archive data for all network sites, facilitate the development of interdisciplinary and multi-scale models, and integrate results across the network.
6. Identify and field test, in concert with resource managers and users, a suite of response variables or measures that are: (a) sensitive to the fire and fire surrogate treatments, and (b) both technically and logistically feasible for widespread use in management contexts. This suite of measures will form much of the basis for management monitoring of operational treatments designed to restore ecological integrity and reduce wildfire hazard.

<u>Research Approach</u>

Experimental Design

The benefits of an integrated study with multiple experimental sites located around the country clearly can be enhanced if a common or "core" experimental design is utilized. The core experimental design for the FFS study—i.e., those elements of the design common to all research sites in the network—consists of common (1) treatments, (2) replication and plot size, and (3) response variables.

1. **Treatments.** The following suite of four FFS treatments will be implemented at each research site:
   1. untreated control
   2. prescribed fire only, with periodic reburns
   3. initial and periodic cutting, each time followed by mechanical fuel treatment and/or physical removal of residue; no use of prescribed fire
   4. initial and periodic cutting, each time followed by prescribed fire; fire alone also could be used one or more times between cutting intervals

   These four treatments span a useful range both in terms of realistic management options and anticipated ecological effects. The non-control FFS treatments (treatments 2, 3, and 4) must be guided by a desired future condition (DFC) or target stand condition. The DFC will be defined mainly in terms of the tree component of the ecosystem—specifying such targets as diameter distribution, species composition, canopy closure, and spatial arrangements—and live and dead fuel characteristics. The following fire-related minimum standard will serve as a starting point for DFCs throughout the FFS network:

   > Each non-control treatment shall be designed to achieve stand and fuel conditions such that, if impacted by a head fire under 80th percentile weather conditions, at least 80 percent of the basal area of overstory (dominant and codominant) trees will survive. (See full proposal for further details.)

Given that this starting point is met for a given research site, however, the DFC can and should incorporate any additional management goals appropriate to the site and stand conditions and the expectations of resource managers and other stakeholders. Beyond the fire-related minimum standard for DFCs and the general treatment definitions given above, it is neither feasible nor desirable to prescribe detailed definitions of a core DFC or detailed treatment specifications that would apply across all research sites. Participants at each research site must provide this detail to ensure consistent application of treatments at that site.

2. **Replication and Plot Size.** Each treatment will be replicated at least 3 times at each research site, using either a completely randomized or randomized block design as appropriate to the research site. The core set of 4 treatments thus will be represented in 12 treatment plots at a research site. Each of the 12 core treatment plots at a research site will consist of a 10-ha measurement plot, within which core variables will be measured, surrounded by a buffer. The buffer, which is to be treated in the same way as the measurement plot it surrounds, will have a width at least equal to the height of a best site potential tree. Where feasible, the replicated plots will be supplemented by much larger (200 to 400 ha or more), generally unreplicated areas treated to the same specifications, to facilitate the study of larger-scale ecological and economic/operational questions.
3. **Response Variables.** A major aspect of the common design proposed for this study is a set of core response variables to be measured at all the research sites. Core variables encompass several broad disciplinary areas, including fuel and fire behavior, vegetation, soils and forest floor/hydrology, wildlife, entomology, pathology, treatment costs and utilization/economics, and social sciences. A corresponding set of disciplinary groups has had the responsibility for developing the core variables and associated measurement protocols, including coordinating across groups to ensure consistency, compatibility, and non-duplication of data collection efforts. Intraplot sampling of all variables will be keyed to a 50-m square grid of permanent sample points to be established and maintained in each measurement plot. Spatial referencing of all data to the grid will facilitate both spatial and cross-disciplinary analyses.

As suggested in Project Objective #2, the overall study is designed to balance the values of an integrated national network of research sites having a common design against the needs for each site to retain flexibility in addressing important local issues and in exploiting expertise and other resources available to that site. Accordingly, at the discretion of investigators, managers, and other participants involved in a given site, the core design may be augmented (provided it is not compromised) at that site by adding FFS treatments, adding one or more DFCs, adding replications, increasing treatment plot size (by increasing buffer width; the 10-ha measurement plot and core data collected within it would remain unchanged), and/or adding response variables. Except where additions to the core design are specifically justified for a given research site, we are requesting support through the Fire Science Program only for implementing the core design at each site.

Research Site Locations

In selecting research sites we developed and used the following set of criteria:

1. Site is representative of forests with a historically short-interval, low- to moderate-severity fire regime and a currently high risk of uncharacteristically severe fire.
2. Site is representative of widespread forest conditions (site characteristics, forest type and structure, treatment history) that are in need of, and likely to benefit from, fire or fire surrogate treatments, and in which such treatments are feasible.

3. Site contributes significantly to balancing the overall network in terms of regional representation and/or land ownership type.
4. Partners and cooperators are committed to and capable of participating in the program. This involves several factors, including: active support and interest in involvement on the part of partners/cooperators; available land base for the study; ability and willingness of land managers to implement the full suite of experimental treatments successfully within required time frame, repeat treatments over time as appropriate, commit selected sites for long-term research uses, and document these commitments in amendments to long-term land management plans.
5. On federal lands, treatment costs are borne by lead agency or partner.
6. Partnerships exist across agencies and with universities, and between researchers and managers.

The proposed initial network comprises 10 main sites and 1 satellite site (satellite will have less than the full suite of core treatments):

1. Mission Creek, north-central Washington, Wenatchee National Forest.
2. Hungry Bob, Blue Mountains of northeast Oregon, Wallowa-Whitman National Forest.
3. Lubrecht Forest, University of Montana, northern Rockies, western Montana.
4. Klamath Province, northwestern California, one or more national forests, possibly other ownerships.
5. Kings District Administrative Study Area, Sierra National Forest, southern Sierra Nevada, California.
6. Sequoia-Kings Canyon Satellite, Sequoia National Park, southern Sierra Nevada, California (satellite to Kings District Administrative Study Area site).
7. Flagstaff and Williams Arizona, Coconino and Kaibab National Forests, northern Arizona.
8. Jemez Mountains New Mexico, Santa Fe National Forest, northern New Mexico.
9. Ohio Hill Country, lands managed by the Wayne National Forest, the Ohio Division of Forestry, Mead Paper Corporation, and The Nature Conservancy, southern Ohio.
10. Southeastern Piedmont, Clemson Experimental Forest, northwestern South Carolina.
11. Florida Coastal Plain, Myakka River State Park, southwest Florida.

All of these initial sites represent forests with a historically short-interval, low- to moderate-severity fire regime. Eight sites are in western coniferous forests, ranging from the Pacific Northwest to the Southwest. These sites all share the fact that ponderosa pine is an important tree component, but sites vary in composition of other conifers and differ substantially in topographic and soil parameters. Two sites are in the southeastern U.S.—one in the Piedmont and one on the Coastal Plain—and are dominated by mixtures of southern pines with hardwood understories. Rounding out the network is a site in the midwestern oak-hickory type of Ohio. Collectively, these sites comprise a network that is truly national in scope. Depending on the level of interest and support available, future sites in the same or other fire regimes may be added to the network.

For more information about the study, see: **http://ffs.psw.fs.fed.us/**

BACKGROUND AND JUSTIFICATION

Introduction

Current forests in many fire-dependent ecosystems of the United States are denser and more spatially uniform, have many more small trees and fewer large trees, and have much greater quantities of forest fuels than did their presettlement counterparts (Bonnicksen and Stone 1982; Chang 1996; Harrod et al. 1998; Parker 1984; Parsons and DeBenedetti 1979). Causes include fire suppression, past livestock grazing and timber harvests, farm abandonment (especially in the south), and changes in climate (Arno et al. 1997; Skinner and Chang 1996). The results include a general deterioration in forest ecosystem integrity and an increased probability of large, high-severity wildfires (Dahms and Geils 1997; Patton-Mallory 1997; Stephens 1998; Weatherspoon and Skinner 1996). Such conditions are prevalent nationally, especially in forests with historically short-interval, low- to moderate-severity fire regimes (Agee 1991, 1993, 1994; Arno 1980; Barden 1997; Caprio and Swetnam 1993; Cowell 1998; Dieterich 1980; Guyette and Cutter 1997; Kilgore and Taylor 1979; Mutch and Cook 1996; Phillips 1999; Swetnam 1990; Taylor and Skinner 1998; Sutherland 1997; Touchan et al. 1996; Van Lear and Waldrop 1989; Waldrop et al. 1987; Wills and Stuart 1994; Wright 1996; Yaussy and Sutherland 1993). The report of the Sierra Nevada Ecosystem Project highlighted these problems and explained the need for large-scale and strategically-located thinning (especially of small trees), fuel treatment, and use of prescribed fire (SNEP 1996; Weatherspoon and Skinner 1996). A recent speech by Interior Secretary Babbitt (1997) pointed out that similar problems and the need for similar solutions are now being acknowledged by national policymakers.

The need for widespread use of restorative management practices is clear (e.g., Hardy and Arno 1996). Less clear, however, is the appropriate balance among cuttings, mechanical fuel treatments, and prescribed fire (SNEP 1996; Stephens 1998; van Wagtendonk 1996; Weatherspoon 1996). Economic and technical feasibility of various treatments across different stands and landscapes, as well as social and political acceptability, are important considerations in managers' decisions about tools to use. However, to achieve goals for ecosystem integrity and sustainability, we also need much better information about the ecological consequences and tradeoffs of alternative management practices. The frequent, low- to moderate-severity fires that characterized presettlement disturbance regimes in many of our forests affected not only overall forest structure, composition, and fuel levels, but also a wide range of other ecosystem components and processes (Agee 1993, Chang 1996). What components or processes are changed or lost, and with what effects, if "fire surrogates" such as cuttings and mechanical fuel treatments are used instead of fire, or in combination with fire? For the most part, information necessary to answer such key questions is anecdotal or absent.

Long-term, interdisciplinary research thus should be initiated to quantify the consequences and tradeoffs of alternative fire and fire surrogate treatments. Ecological, economic and social aspects must all be included as integral components. The research needs to be experimental, rather than retrospective or correlative, to permit stronger inferences about cause-and-effect relationships. Only through such research will it be possible to determine which ecosystem functions of fire can be emulated satisfactorily by other means, which may be irreplaceable, and the implications for management. The human dimensions of the problem are equally important. Treatment costs and utilization economics, as well as social and political acceptability, strongly influence decisions about treatment alternatives. Such an effort must be collaborative, involving land managers, researchers, and interested public.

We propose to establish and maintain a national "Fire/Fire Surrogate" (FFS) study to quantify the ecological, economic, and social consequences of alternative fire and fire surrogate restorative treatments in a number of forest types and conditions in the United States. The study is designed as an integrated network of long-term interdisciplinary research sites utilizing a common "core" design to facilitate broad applicability of results.

Fire Effects and Fire Regimes

This study proposes to examine alternative treatments in forests at high risk of uncharacteristically severe fires—those fires that produce effects outside the historic range of variability. First order fire effects are a direct result of exposure to fire, including both the initial flaming front of a fire and smoldering combustion after the fire has passed. The severity of fire effects is not necessarily linked to the apparent intensity of the fire, such as the height of the flames, and is rarely linked to the rate at which the fire moves. In forests having short-interval, low- to moderate-severity fire regimes, historic fire behavior was variable, but mostly consisted of surface fire that burned dead leaves, twigs, limbs and other small fuels on the surface of the ground along with herbaceous and woody vegetation. Under current conditions, which generally include altered arrangements of fuels and vegetation, many of these same forests are likely to burn with extreme fire behavior (involving torching, spotting, and crown fire), as well as higher intensity surface fire and consumptive ground fire (involving often-prolonged smoldering of accumulations of litter, duff, and large diameter fuels). Like fire behavior, fire effects have changed from those of historic fire regimes to greater severity, with excessive mortality of overstory trees and damage to soils more common. As compared with forests having long-interval, high-severity natural fire regimes, forests with low- to moderate-severity regimes experience more adverse ecological effects from high-intensity and/or highly-consumptive wildfires because these forests are not adapted to such fires. In general, such forests have been more adversely affected by fire suppression and other human influences since European settlement than forests in other fire regimes, and are in greater need of treatments to restore ecological integrity and reduce wildfire hazard.

The proposed study thus has a focus on short-interval, low- to moderate-severity fire regimes as a matter of priority. A series of recent large-scale analyses and policy papers (SNEP, Sierra Nevada RDEIS, Columbia River Basin, various WO papers, federal wildland fire policy) have asserted that the most marked changes in fire behavior and fire effects have been in forests characterized historically by frequent fire. These areas have missed more fire cycles than longer interval fire regimes. Not only do wildfires in these areas cause more detrimental ecological effects, as discussed earlier, but they also pose hazards to fire fighters and the public. Analyses of expenditures indicate that recent wildfires in forests of these types are large and costly, and are difficult or impossible to control under extreme weather conditions or during periodic droughts. Active fire seasons occur at more frequent intervals than in long-interval types, due to longer fire seasons, greater drying of fuels during the fire season (higher average temperatures) and exposure to more potential ignitions during a given fire season.

For these reasons, all of the research sites in our proposed initial FFS network represent forests with a short-interval, low- to moderate-severity natural fire regime. We feel that these are strong reasons for continuing to give these forests highest priority in the study. We recognize, however, that there may be other reasons to include some sites with long-interval fire regimes in the FFS network.

Such an expansion should not be done at the expense of research sites in the high-priority fire regime.

We have also considered the possibility of further enlarging the FFS study to include non-forested vegetation types. The general approach and some aspects of the design of the FFS study might be useful if a comparable study in other vegetation types is established. However, a study in non-forested types would involve such fundamental differences in key elements to be addressed—e.g., nature of management issues and problems, nature of treatments to be evaluated, and nature of many of the response variables—that combining it with the FFS study would be difficult.

OBJECTIVES

The overall goal of the proposed research is to quantify the ecological, economic, and social consequences of fire and fire surrogate treatments in a number of forest types and conditions in the United States. Priority is given to forests with low- to moderate-severity natural fire regimes.

Objectives of the FFS study are:

1. Quantify the effects of fire and fire surrogate treatments on a number of specific core response variables within the general groupings of (a) fuel and fire behavior, (b) vegetation, (c) soils and forest floor/hydrology, (d) wildlife, (e) entomology, (f) pathology, (g) treatment costs and utilization/economics, and (h) social sciences.
2. Provide an overall research design that (a) establishes and maintains the study as an integrated national network of long-term interdisciplinary research sites utilizing a common "core" design to facilitate broad applicability of results, (b) allows each site to be independent for purposes of statistical analysis and modeling, as well as being a component of the national network, and (c) provides flexibility for investigators and other participants responsible for each research site to augment—without compromising—the core design as desired to address locally-important issues and to exploit expertise and other resources available to local sites.
3. Develop and validate models of ecosystem structure and function, and successively refine recommendations for ecosystem management.
4. Within the first five years of the study, establish cooperative relationships, identify and establish network research sites, collect baseline data, implement initial treatments, document treatment costs and short-term human and ecological responses to treatments, report results, and designate FFS research sites as demonstration areas for technology transfer to professionals and for the education of students and the public.
5. Develop and maintain an integrated and spatially-referenced database format to be used to archive data for all network sites, facilitate the development of interdisciplinary and multi-scale models, and integrate results across the network.
6. Identify and field test, in concert with resource managers and users, a suite of response variables or measures that are: (a) sensitive to the fire and fire surrogate treatments, and (b) both technically and logistically feasible for widespread use in management contexts. This suite of measures will form much of the basis for management monitoring of operational treatments designed to restore ecological integrity and reduce wildfire hazard.

RESEARCH APPROACH

The first two sections that follow, which explain the benefits of two key elements of the proposed study—the experimental approach and the national network—set the stage for the subsequent sections on Experimental Design and Research Sites.

Benefits of the Experimental Approach

A long-term experimental study, especially one with the scope and complexity of the proposed FFS study, is expensive and time-consuming. A logical question is, "Why not learn what you need to know by examining previously-treated areas?" In other words, why not do a retrospective study?

We can and should exploit opportunities for learning from retrospective and anecdotal observations. Such observations can provide first approximations of needed information, and can help to fine-tune hypotheses and approaches for experimental studies. In some disciplines (e.g., paleoecology), retrospective research is the only option. However, for most of the kinds of questions being considered here—especially ecological effects of fuel management and other restorative treatments—an experimental study has significant advantages over a retrospective approach.

A retrospective study typically will involve choosing a set of treatment levels, or different treatments, at some time after treatment, and matching after the fact untreated areas to serve as a "control". Usually there is little evidence that the controls were in fact similar to the treated areas before they were treated. Likewise, different treatments may have been applied because of initial differences in site or stand conditions, thereby confounding treatment effects. Sometimes different treatments will have been applied at widely varying times, and this can further confuse apparent treatment effects, particularly in ecological studies, if there are temporal variations in population dynamics or climate. Legitimate treatment replications are seldom available, and treatments may be largely undocumented. The lack of randomness in study design also leads to questionable inferences from parametric statistical analysis.

An experimental approach matches all potential plots before treatment, and assigns treatments randomly, or with acceptable and defined restrictions on randomization. The experiment is synchronized across space and time, and much stronger inferences can be made about cause-and-effect relationships. An additional advantage of the experimental approach within a national network is that a number of simultaneous studies are being completed within and among sites, enabling scientists to make quantitative comparisons with other studies within sites and qualitative comparisons with similar studies across sites. This is further explained in the following section.

In brief, retrospective studies are often not as rigorous as well-designed experimental studies and may reach equivocal conclusions. Considering the immense importance and likely debate over the questions addressed in this study, there is a need for rigorous experiments that offer the hope of drawing firm scientifically-based conclusions.

Benefits of a National Network of Interdisciplinary Research Sites

Network Products

Each of the study sites proposed here as part of the FFS network will address managerially important sites and forest conditions, and will use desired condition prescriptions and treatment definitions that are meaningful regionally. Each of these sites will be able to stand on its own statistically, so that valid conclusions can be reached concerning these regionally-important issues.

However, the great strength of the national network of FFS research sites is being able to draw broad inferences that transcend the boundaries of individual sites. An additional crucial value of the network approach is the synergy created by the interaction of scientists from many disciplines, backgrounds, and geographic areas. This benefit accrues at several levels, including project planning, implementation of site installations, and reporting of results. The synergistic effect of the national network is already apparent in the output of the ensemble of scientists who designed this project, but the best evidence of the value of a truly integrated network is the kind of products proposed here. At least four distinct kinds of products will result, three of which can be described as "integrated," in that they are either interdisciplinary or interregional. Such integration would not be possible from analysis of a disarticulated group of studies (Figure 1).

The simplest product is non-integrated, being publications or other outputs from disciplinary studies at individual sites. The remaining three products are integrated, but in different ways. First, results from disciplinary studies across sites can be compared more effectively and confidently because sites share common core variables and protocols. These comparisons are most important for disciplines in which a national or regional perspective is desired. Second, results from the various disciplinary studies at each site can be analyzed together because all data at each site will be collected from a common sampling grid, at both the plot and sub-plot level. This interdisciplinary product is essential for identifying interactions among key ecological variables, such as the functional linkages among fire, bark beetles, dead trees, and cavity nesting birds. Interdisciplinary products also allow us to evaluate the effectiveness of alternative fuel reduction treatments, their ecological effects, associated costs, and consequent tradeoffs. Finally, the commonality of treatments and core variables across sites allows the periodic review, interpretation, and synthesis of all information. This will facilitate opportunities to identify and characterize emerging interdisciplinary patterns common across all sites. The network structure permits a more powerful synthesis at the national scale than cobbling together results from a group of independent studies.

Value of Interdisciplinary Analysis at the Site Scale—Examples

This section provides examples for one of the four products described above—interdisciplinary analysis at a given site. At the site scale, we know that numerous ecological links will be found among variables, and so we expect that treatments will cause changes not only in the individual variables, but in their relations to other variables as well. Hence for a complete elaboration of treatment effects, it will be essential to conduct interdisciplinary analysis at the site scale.

A simple example is the effect of fuel reduction treatments on down woody material used by various organisms. While fuel reduction may lower fire hazard and risk, removing down woody material will also reduce foraging habitat for birds and numerous macroinvertebrate species. Measuring both the extent of fuel reduction and its effect on biodiversity may help identify thresholds that would be useful for fine tuning management to achieve more holistic objectives. In addition, measuring belowground variables within a fuel reduction context should help us better understand the interplay between rotting wood and the soil environment. Because decomposing wood plays an obvious role in ultimately providing nutrients for plants, measuring the extent of fuel reduction, as well as soil chemistry and plant growth, should help identify ecological tradeoffs inherent in the application of management activities.

Another example that illustrates the interplay of differences in temporal effects is the expected response of bird communities to treatment. As trees are killed or injured through thinning or burning, immediate changes can be expected to occur in the quality of habitat for foraging and nesting birds. Root death or injury due to the same treatment can be expected to set into play a cascade of belowground effects including changes in N-mineralization through microbial activity, which may affect nitrogen availability and, ultimately, understory composition, density and biomass. Changes in the complexion of the understory habitat will tend to influence bird feeding and nesting in the intermediate term, and these may run counter to the immediate changes in bird habitat relations set up by the original treatment itself.

These examples illustrate only a small subset of potential links that are bound to emerge as we simultaneously investigate the response of numerous variables to fuel reduction and thinning treatments. The common core treatment and variable design of the FFS network will provide critical information on how generally applicable ecological linkages are across many similar but distant sites.

Experimental Design

The benefits of an integrated study with multiple experimental sites located around the country clearly can be enhanced if a common or "core" experimental design is utilized. The core experimental design for the FFS study—i.e., those elements of the design common to all research sites in the network—consists of common (1) treatments, (2) replication and plot size, and (3) response variables.

Treatments

The proposed FFS treatments consist of various combinations of the most common manipulative management activities utilized in forested ecosystems: cutting trees or other vegetation, using prescribed fire, and mechanically treating residues or scarifying the soil. Treatments include those that address widely-shared concerns about forest health and wildfire hazard, those that deal with environmental concerns, and those most practical from an operational standpoint. Consistent with the long-term focus of the study, treatments will be repeated periodically to represent real management approaches.

The following suite of four FFS treatments will be implemented at each research site:

1. Untreated control
2. Prescribed fire only, with periodic reburns
3. Initial and periodic cutting, each time followed by mechanical fuel treatment and/or physical removal of residue; no use of prescribed fire
4. Initial and periodic cutting, each time followed by prescribed fire; fire alone also could be used one or more times between cutting intervals

These four treatments span a useful range both in terms of realistic management options and anticipated ecological effects.

Cuttings in treatments 3 and 4 will be repeated at intervals appropriate to the forest type and site conditions—e.g., 20 years. Periodic prescribed burns in treatments 2 and 4 normally will be based on the best available information about presettlement fire intervals on the kinds of sites represented by the research site. Irregular rather than fixed burn intervals are preferable where supported by fire history evidence, since it seems likely that important elements of ecosystem diversity were promoted historically by natural variability in fire intervals (Agee 1993; Skinner and Chang 1996).

Definitions of the 4 FFS treatments are necessarily rather generic, and can encompass considerable variability in both cutting/mechanical and fire treatments that may significantly affect ecological responses of interest. More precise definitions would be helpful from the standpoint of reducing treatment variability among research sites. Applying uniform treatment specifications across so diverse an array of sites, however, is neither feasible nor desirable. The real world of forest ecosystems and resource management would not be represented appropriately with such a "one-size-fits-all" approach. This does, however, increase the need for (1) local replication to allow each research site to stand on its own statistically, and (2) good characterization of treatments actually applied at each research site to help explain observed differences among sites.

The non-control FFS treatments (treatments 2, 3, and 4) must be guided by a desired future condition (DFC) or target stand condition. The DFC will be defined mainly in terms of the tree component of the ecosystem—specifying such targets as diameter distribution, species composition, canopy closure, and spatial arrangements—and live and dead fuel characteristics. As with the FFS treatments, it is not feasible to prescribe a core DFC with any level of specificity that would apply across all research sites. We have, however, set a fire-related minimum standard or "least common denominator" that will serve as a starting point for DFCs throughout the FFS network. That standard is based on predicted effects of a hypothetical wildfire occurring on the site after treatments have been implemented:

> Each non-control treatment shall be designed to achieve stand and fuel conditions such that, if impacted by a head fire under 80th percentile weather conditions, at least 80 percent of the basal area of overstory (dominant and codominant) trees will survive. The definition of 80th percentile weather conditions will be based on an analysis of fire season conditions, calculated for mid-afternoon, over a period of 10 to 20 years at the closest fire weather station. The prescription to implement the treatment will be developed based on fire behavior modeling (e.g., FARSITE) and predicted fire effects. Effects will be predicted using techniques such as FOFEM (First Order Fire Effects Model) and/or other modeling efforts that may include expert opinion.

The standard presumes the retention of a viable residual stand following treatment. Thus, clearcutting would not be an acceptable treatment option. In many cases, early treatments may take the form of some variation of thinning from below (or the equivalent via a series of burns), since this often addresses the greatest short-term restoration need. In the long-term, however, provisions will need to be made for recruitment of tree regeneration and development of a sustainable age-class structure.

Because of vegetation growth and fuel accretion, treatments will need to be repeated periodically for the standard to continue to be met. In most cases, surface fuels will require retreatment—by fire or mechanical techniques, as appropriate to the treatment type—more often than stand structure.

Participants at each research site will define a DFC (and associated treatment prescriptions and retreatment schedules) that meets this fire-related standard. Given that this standard is met, however, the DFC can and should incorporate any additional management goals appropriate to the site, to stand conditions, and to the expectations of resource managers and other stakeholders. For sites that employ a randomized block design with blocks that differ significantly in site or stand conditions, DFC could vary somewhat among the experimental blocks within a research site. It is important for a DFC to be well-defined, and implemented using a specific prescription to ensure consistency among treatment plots.

Assuming the same starting point of stand and fuel conditions, moving toward a given DFC using FFS treatment 2 (fire only) clearly will be a much less precise process than using FFS treatments 3 and 4 (cuttings) and will also require a number of successive burns. Some desired changes in stand structure—e.g., "thinning" relatively large trees without doing excessive damage to the overall stand—may not be feasible. However, skilled and innovative use of prescriptions, firing techniques, and other methods such as stage burning should, over several successive burns, permit considerable progress toward most DFCs using prescribed fire alone. It should be noted that opportunities for significant reshaping of stand structure—e.g., killing groups of trees to create openings—may be greater with initial relatively heavy fuel loads than after most fuels have been consumed.

Replication and Plot Size

Replication at each research site is necessary to allow each site to be analyzed independently. As part of the core experimental design, each treatment will be replicated 3 times at each research site, using either a completely randomized or randomized block design as appropriate to the research site. The core set of 4 treatments thus will be represented in 12 treatment plots at a research site.

Each of the 12 core treatment plots at a research site will consist of a 10-ha measurement plot, within which core variables will be measured, surrounded by a treated buffer. The 10-ha size is a compromise between advantages of smaller plots (e.g., reduced costs, reduced intraplot variability) and those of larger plots (e.g., need to represent natural variability in stands and in DFC(s) at a more nearly operational scale, need to accommodate some larger-scale ecological responses). Size of measurement plots and appropriate core response variables are closely related and interdependent. To keep the perimeter-to-area ratio low and reasonably consistent, the length-to-width ratio should not exceed 1.5.

The buffer, which is to be treated in the same way as the measurement plot it surrounds, will have a width at least equal to the height of a best site potential tree. A 30-m treated buffer, for example, would bring the total size of the treatment plot to about 14 ha. Local participants may decide to adopt wider buffers than the minimum specified. Furthermore, it is left to participants at each research site to determine appropriate separation of treatment plots and the nature of treatment (or nontreatment) in the matrix between plots.

We recognize that many aspects of wider-ranging wildlife species, fisheries, watershed-scale hydrology, other landscape-level responses, and some economic and social questions can be studied at the 10-ha scale only indirectly—e.g., via habitat attributes and modeling methods. Where feasible at a given research site, two additional approaches may help in addressing larger-scale issues: (1) Larger replicated treatment plots (i.e., larger buffers) can be used, provided that the core

10-ha plots are embedded within them and are utilized for measurement of core response variables. Additional, larger-scale variables could then be measured on the larger treatment plots. (2) The core 10-ha replicated plots can be augmented with much larger (200 to 400 ha or more), generally unreplicated areas nearby treated to the same specifications. These large treatment areas could provide useful information concerning operational-scale economics and practicability, as well as larger-scale ecological responses, especially if linked to the smaller replicated plots via appropriate models.

Response Variables

A major aspect of the common design proposed for this study is a set of core response variables to be measured at all network sites, using common measurement protocols to the extent possible and a consistent intraplot sampling approach. Other responses certainly can be studied at one or more sites, depending on interests and available expertise and resources. The proposed research is designed to be open-ended in terms of scientific disciplines and associated response variables that can be accommodated.

Several members of our steering committee have been serving as disciplinary group leaders with responsibility for developing major groups of response variables (Table 1). Each group leader has worked with a team of people with appropriate expertise to identify a core set of response variables that would be measured consistently across all research sites. Their activities also have included cross-group coordination to ensure consistency, compatibility, and non-duplication of data collection efforts. We anticipate that their responsibilities will continue into the implementation phase of the project to ensure that data collection protocols are followed consistently at all the sites. (Where deviations from common measurement protocols are necessary for specific variables, they will be documented and justified.) This may include training, oversight of field crews, or other measures as appropriate.

Table 1. Disciplinary groups and group leaders.

Fire and fuels (including emissions measurements and modeling)
Sally Haase, PSW Station, and Bob Vihnanek, PNW Station

Vegetation
Jon Keeley, USGS, Sequoia-Kings Canyon National Parks

Soils and forest floor/hydrology
Ralph Boerner, Ohio State University

Wildlife
Steve Zack, Wildlife Conservation Society

Entomology (primarily bark beetles)
Patrick Shea, PSW Station

Tree pathology
Bill Otrosina, SO Station

Treatment costs and utilization/economics
Jamie Barbour, PNW Station

Social sciences
Ron Hodgson, California State University Chico

Details of the core response variables and measurement protocols are included as Appendices A-1 and A-2, respectively.

Intraplot sampling of all variables will be keyed to a 50-m square grid of permanent sample points to be established and maintained within each measurement plot. Any number of grid points in a measurement plot may be utilized for a given variable depending on the nature and appropriate intensity of sampling for that variable. Spatial referencing of all data to the grid will facilitate spatial analyses in conjunction with planned acquisition and analysis of high-resolution digital orthophotography and utilization of a GIS-based data base. Co-location (or consistent proximity) of multi-disciplinary data facilitated by use of the grid also will promote analyses that should elucidate cross-disciplinary relationships and suggest interdisciplinary hypotheses.

Augmenting the Core Design

As suggested in Project Objective #2, the overall study is designed to balance the values of an integrated national network of research sites having a common design against the needs for each site to retain flexibility in addressing important local issues and in exploiting expertise and other resources available to that site. Accordingly, at the discretion of investigators, managers, and other participants involved in a given site, the core design may be augmented (provided it is not compromised) at that site by adding FFS treatments, adding one or more DFCs, adding replications, increasing treatment plot size (by increasing buffer width; the 10-ha measurement plot and core data collected within it would remain unchanged), and/or adding response variables. Except where additions to the core design are specifically justified for a given research site, we are requesting support through the Fire Science Program only for implementing the core design at each site.

Research Sites

Criteria for Site Selection

As discussed earlier, a network of research sites using a common experimental design has the potential for synergistic output far exceeding what could be accomplished by a series of separate, uncoordinated studies. In selecting research sites we have developed and used a set of criteria (Table 2). All sites identified in this proposal—the initial sites in the network—have met or will meet the criteria given in Table 2.

Table 2. Criteria used in site selection.

1. Site is representative of forests with a historically short-interval, low- to moderate-severity fire regime and a currently high risk of uncharacteristically severe fire. (See Appendix B: Representative Land Base, Fire History.)
2. Site is representative of widespread forest conditions (site characteristics, forest type and structure, treatment history) that are in need of, and likely to benefit from, fire or fire surrogate treatments, and in which such treatments are feasible. (See Appendix B: Contemporary Fire Hazard.)
3. Site contributes significantly to balancing the overall network in terms of regional representation and/or land ownership type. (See Appendix B: Introduction to Site Descriptions.)
4. Partners and cooperators are committed to and capable of participating in the program. This involves several factors, including: active support and interest in involvement on the part of partners/collaborators; available land base for the study; ability and willingness of land managers to implement the full suite of experimental treatments successfully within required time frame, repeat treatments over time as appropriate, commit selected sites for long-term research uses, and document these commitments in amendments to long-term management plans. (See Appendix B: Prior Work, Level of Long-Term Interest.)
5. Partnerships exist across agencies and with universities, and between researchers and managers. (See Appendix B: Partnerships.)

Proposed Initial Sites

The network comprises 10 main sites and 1 satellite site (Table 3). Summary descriptions of all sites are provided in Appendix B. The main sites are all located on forest types with a prior cutting history and will implement the full suite of treatments (see Experimental Design section). The satellite site is in "old growth" forest with no historical cutting, and will limit treatments to different seasons of prescribed burning plus untreated control. The satellite site, Sequoia-Kings Canyon, is linked to the Kings River Administrative Study Area site, which is implementing the full experiment on a similar forest type.

Seven of the main sites plus the satellite site are in western coniferous forests, ranging from the Pacific Northwest to the Southwest. These sites all share the fact that ponderosa pine is an important tree component, but sites vary in composition of other conifers and differ substantially in topographic and soil parameters. Two sites are in the southeastern U.S.—one in the Piedmont and one on the Coastal Plain—and are dominated by mixtures of southern pines with hardwood understories. Rounding out the network is a site in the midwestern oak-hickory type of Ohio. Collectively, these sites compose a network that is truly national in scope. Represented in this network is a mixture of land ownerships, including federal, state, university experimental forests, and private holdings.

All sites are similar in that the lead agency and site coordinator are committed to interdisciplinary research of the type proposed here and have expressed enthusiasm for continuing the program beyond the expected timeframe of JFSP funding.

The status of planning and implementation vary significantly among sites. One site (Hungry Bob, Oregon) is already established, and is compatible in design with this proposal. Some sites are prepared to implement (or begin) treatments in 2000, whereas others will be phased in 1 to 3 years later. This has important budget implications as it will stagger the initial and annual costs for the sites, thereby reducing average per-site costs over a 5-year proposal period and increasing the breadth of forest types that can be represented by the network. (See timeline on p. xx.) **[Reviewers, this timeline is not yet available. Necessary information is still being developed as part of ongoing site workshops.]**

We recognize that the proposed initial network does not represent all forest types and conditions with serious fire hazard and forest health problems. However, its composition is a reasonable compromise considering the widespread need for the information, anticipated availability of funding, and available expertise and commitment. It is our expectation that the network will provide us with widely applicable results. We see the possibility that additional sites will be included in the network as other agencies or landowners see the value of this approach. Possibilities for using the FFS study as a model for similar international studies have been discussed.

Table 3. Proposed initial research sites and principal contacts.

Mission Creek, north-central Washington, Wenatchee National Forest.
Contact: James K. Agee, University of Washington.

Hungry Bob, Blue Mountains of northeast Oregon, Wallowa-Whitman National Forest.
Contacts: James McIver, Andy Youngblood, PNW Research Station.

Lubrecht Forest, University of Montana, northern Rockies, western Montana.
Contacts: Carl Fiedler, University of Montana; Michael Harrington, RM Research Station.

Klamath Province, northwestern California, one or more national forests, possibly other ownerships.
Contacts: Gary Fiddler, Carl Skinner, and Phil Weatherspoon, PSW Research Station.

Kings District Administrative Study Area, Sierra National Forest, southern Sierra Nevada, California.
Contacts: Scott Stephens, California Polytechnic State University, San Luis Obispo; Mark Smith and Alan Quan, Sierra National Forest.

Sequoia-Kings Canyon Satellite, Sequoia National Park, southern Sierra Nevada, California (satellite to Kings District Administrative Study Area site).
Contacts: Jon E. Keeley and Nathan L. Stephenson, USGS, Sequoia-Kings Canyon Field Station; Anthony C. Caprio, NPS, Sequoia-Kings Canyon National Parks.

Flagstaff and Williams Arizona, Coconino and Kaibab National Forests, northern Arizona.
Contact: Carl Edminster, RM Research Station.

Jemez Mountains New Mexico, Santa Fe National Forest, northern New Mexico.
Contact: Carl Edminster, RM Research Station.

Ohio Hill Country, lands managed by the Wayne National Forest, the Ohio Division of Forestry, Mead Paper Corporation, and The Nature Conservancy, southern Ohio.
Contacts: Daniel A. Yaussy, Todd Hutchinson, NE Research Station; Elaine Kennedy Sutherland, RM Research Station.

Southeastern Piedmont, Clemson Experimental Forest, northwestern South Carolina.
Contact: Thomas A. Waldrop, SO Research Station.

Florida Coastal Plain, Myakka River State Park, southwest Florida.
Contacts: Thomas A. Waldrop, SO Research Station; Robert Dye, Park Manager; Dale D. Wade, SO Research Station.

Site and Plot Location

Given that the criteria in Table 2 are met, several factors have been or will be considered in selecting specific locations for long-term research sites and treatment plots. Land managers, scientists, and other collaborators involved with a particular site have the responsibility for deciding specifically where it should be located. The process of coming to agreement on the characteristics and location of the research site, in fact, should be a major opportunity for the various stakeholders to initiate a productive partnership.

The first step in the process is to describe the area and range of conditions to which inferences from that site are desired—the *target population.* The target population, which will be defined uniquely for each research site, generally should consist of widespread forest conditions (site characteristics, forest type and structure, treatment history) that are in need of fire or fire surrogate treatments, and in which such treatments are feasible (Table 2). The target population will be defined in terms of acceptable ranges of site and forest attributes such as slope, aspect, elevation, geology and soils, and vegetation condition. Riparian zones as defined locally should be excluded to the extent (e.g., for various stream classes and riparian zone widths) that they would not be (presently or in foreseeable future) available in that region for at least a modified version of all of the FFS treatments. Formally designated roads should be excluded, although poorly defined tracks, skid trails, etc. probably would be included.

The subset of the target population that is actually available for installing experimental treatments is the *sampled population.* One reason that the sampled population normally will be much smaller than the target population has to do with commitment and capability of land managers and other partners (Table 2). Potential treatment plots (see Experimental Design section) will be identified within the sampled population. Each potential plot must be capable of accepting any of the proposed treatments, not just a particular treatment and not just a control. Finally, plots will be randomly drawn from the available pool of potential plots, and then randomly assigned to treatments. If plot locations need to be balanced with respect to some factor such as aspect, blocking should be considered. If blocking is used, plot selection and treatment assignment will be done randomly within blocks, and subsequent data analyses must account for the blocking factor.

Where the target population is characterized by a preponderance of submerchantable, low-value trees needing treatment, site and plot locations should not be biased toward less common stand conditions in which removal of merchantable trees will pay for the overall treatment. Similarly, research sites in physiographic provinces characterized mainly by steep slopes should be located on such slopes, despite the additional costs and complexities involved. Treatments and site locations should reflect "real world" constraints that often include treatments with a net negative financial return. Land managers for most sites (Table 3) have agreed to contribute the costs of planning and implementing treatments. On federal lands, appropriated fuel treatment funds (the better-informed use of which the Fire Science Program is designed to support) may be nationally earmarked to cover the costs of treatments with a net negative financial return. In this regard, the study will include a component to investigate utilization options, treatment costs, and overall economics.

Statistical Analysis

The basic analysis for the experiment is the oneway analysis of variance using an F-test for overall treatment differences. Tukey's test for all possible pairwise comparisons could be used irrespective of the outcome of the F-test. Presenting confidence intervals will allow readers to make their own decisions about interpretation of results.

The whole treatment plot, not the subplot, is the unit of replication for making inferences about treatments. However, grid system-based subplots may provide opportunities for evaluating effects of "degrees of severity" of treatments—e.g., differences in localized severity of prescribed burns—assuming such treatment severity is characterized for each grid point or subplot. Having many variables from several disciplines keyed to the same grid points may also facilitate cross-disciplinary analyses and may help to account for effects of local site variability. Spatial referencing of all data offers many possibilities for analyses using the still-developing techniques of spatial statistics. Use of more advanced statistical techniques needs to be carefully thought out and reviewed on a case-by-case basis.

Network Management

Oversight and Administration

Given the substantial benefits of a national FFS network, it is essential that the network be maintained over time and that its integrity not give way to a collection of separate, uncoordinated studies. A network-wide oversight and management function is needed for this purpose. We propose the following two-tiered structure.

The project will be managed under a structure comprising two committees. The first is the Science/Management Integration Committee (SMIC), which consists of site managers and disciplinary group leaders. The second is a five-member Executive Committee, selected by the SMIC, which consists of a network manager, two disciplinary group leaders, and two site managers. The Executive Committee is responsible for project oversight, distribution of funds, and reporting to the Joint Fire Science Program Governing Board. The Science/Management Integration Committee is responsible for ensuring that: (1) site-level studies are progressing according to project guidelines, (2) data collection protocols and analysis remain consistent and state-of-the-art, (3) data are properly archived and managed, and (4) integration is occurring at all levels.

This organizational structure reflects the integrated nature of the proposed network. The responsibilities outlined above are critical to guaranteeing that the network functions as a whole, in terms of both interactions among participants at all scales, and in terms of the three types of integrated products planned (Fig. 1). Furthermore, this structure ensures continuity of the network through time, as participants come and go.

Quality control is the province of all participants in the study. Disciplinary group leaders and field personnel have the responsibility to develop and implement standardized methods across sites and across time based on appropriate study plans. Site managers have the responsibility to ensure that data are collected appropriately and are effectively entered and maintained in local databases. Oversight of data collection may be entirely by the site manager or through interaction with disciplinary team leaders if national data teams are used by a discipline. The SMIC and Executive Committee ensure final oversight to the data collection and storage process. They also have the responsibility to recruit replacement personnel as necessary to ensure the viability of each discipline and site through the life of the experiment.

Database Management

As with network-wide project management, database management is also a requirement for the long-term integrity and viability of the project. A database manager will be designated to coordinate development of a common, uniform, corporate database structure to be used at all sites. This structure will include definition of necessary metadata. The SMIC (previous section) will have oversight responsibility for the work of the database manager and the integrity and management of the corporate database.

All data entered into the database will be spatially registered. Spatial referencing of data facilitates multi-scale spatial and temporal analyses to reveal important relationships not otherwise detectable at the scale of the core plot size. Using a spatial database will allow integration of data and findings across scientific disciplines. The use of a spatially referenced database also makes additional low-cost data such as orthophotos, satellite imagery, and digital elevation models more readily accessible. Relocation and remeasurement of plots will be facilitated with geo-referenced coordinates.

Site managers will be responsible for updating the database within one year of data being collected. The SMIC will control access to the data within the database. Public access will be limited until there has been opportunity for site-specific and network-wide analysis of the data. Network access to the data will be handled by the site managers. The site managers will make summary statistics available to the network as they become available or are requested by the executive committee. All data will be released to the network within five years of collection and be made available for network-wide analysis and modeling. Source code for models developed under the FFS network will be treated like data for purposes of release to the network.

BUDGET

[Reviewers: Much of the budget is still in the process of coming together, in part by means of ongoing site workshops. Aside from some relatively small network-wide costs, the budget will consist of site-related costs and discipline-related costs. We do not anticipate the need for treatment implementation costs to be included in this budget (a final determination will emerge from the site workshops). We plan to submit a 5-year budget. We expect the impact of startup costs during that period to be buffered by a planned phase-in of sites over the first few years of the project. A rough overall estimate of the average annual cost (including 15% overhead) for the FFS network over the 5-year period is $3 - $3.5 million. We anticipate that subsequent needs for JFSP funds for the proposed network—i.e., assuming no additional sites—will decrease because (1) data collection frequency for core variables will lessen, and (2) the network should be in a position to attract more non-JFSP funds.]

DELIVERABLES

Deliverables are derived from the project objectives identified earlier. Some key deliverables for the short-term (≤3 years post-treatment) and mid- to long-term (3-10 years post-treatment) are indicated below:

Short-Term

Within three years of implementation of treatments across all sites, the disciplinary groups and site representatives will meet to share data at a workshop centered on main treatment effects detected in the short-term. At this point each of the disciplines will have summarized core variable information from each site and so have the opportunity to compare and contrast patterns across sites and with other disciplines. This workshop will allow the team to identify those emerging interdisciplinary patterns common across all sites. It will also represent an opportunity to recognize those issues (variables) that are not amenable to generalization, and instead are affected more by the particulars (e.g., latitude, topography, site conditions, plant communities) of each site. Examples of potential general patterns might include correlations between bark-beetle infestation and woodpecker community response, common effects on ground-nesting bird productivity following prescribed fire relative to controls or fire surrogates, change in the relative cover of grass and forbs as a function of treatment, and efficiency of alternative fuel treatments in meeting stated objectives.

Other short-term deliverables include: (a) establishment of collaborative relationships, (b) identification and establishment of network research sites, (c) collection of baseline data, (d) application of initial experimental treatments, (d) documentation of treatment costs and short-term human and ecological responses to treatments (see workshop described above), (e) reporting of results, and (f) designation of research sites as demonstration areas for technology transfer to professionals and for the education of students and the public. We expect treatment cost data and the demonstration value of plots with alternative fire and fire surrogate treatments (linked closely to study of human responses to treatments) to be particularly useful short-term outputs.

Mid- to Long-Term

Within this time frame a wide range of ecological, economic, and social consequences of fire and fire surrogate treatments will emerge. All four kinds of network products discussed earlier (Fig. 1) will be produced, including a range of models elucidating ecosystem structure and function. Relevance of the research results to resource managers will be emphasized in these products, and successively refined recommendations for ecosystem management will be provided as appropriate. This information will be documented and provided to users in publications, workshops, and a variety of other technology transfer modes.

Monitoring of operational treatments designed to improve forest health and reduce wildfire hazard is necessary for evaluating their effectiveness in meeting management objectives and identifying other changes in ecosystems brought about by the treatments. Developing standard monitoring protocols that can be used across agencies, geographic areas, and vegetation and fuel types would facilitate regional or national assessments of responses to fuel treatments. One of the planned products of the FFS study is the development of such monitoring protocols, in cooperation with managers and users, for forested areas to which the FFS network is applicable. We will derive monitoring protocols from a suite of field-tested response variables or measures that are: (a) sensitive to the fire and fire surrogate treatments, (b) cost-efficient, and (c) both technically and logistically feasible for widespread use in management contexts.

The FFS network will provide a unique integrated set of experimental studies whose value may increase with time. The sound, common experimental design, together with a geo-referenced database of many layers of interdisciplinary, interrelated data, should attract the participation of a variety of future scientists and managers. Once the study is established and productive, these same factors also should attract funding from a variety of sources, thereby multiplying the early investment by the JFSP.

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APPENDIX A-1
Core Variables

Introduction

The overall goal of this project is to establish a national network of research sites in which the ecological, economic, and social consequences of different forest fuel treatments (fire and fire surrogates) would be determined. For such a network to function in a manner that facilitates cross-ecosystem, integrated research, a common set of core variables must be measured at each site using a common sampling protocol and set of methods. In this section, we list and justify the core variables to be measured in each of the seven disciplinary areas we have identified.

Vegetation

The vegetation component of the larger project has been designed for the long term because forest response to treatments generally exhibit four characteristics that demand long-term research and monitoring (Franklin 1989): (i) slow processes, such as forest succession; (ii) sensitivity to rare episodic events, such climatic extremes and insect outbreaks; (iii) high intra- and interannual variability, such as changes in reproduction, growth, and death driven by both "normal" and changing climatic regimes; and (iv) complex phenomena where multivariate analysis is required to separate pattern from noise, a consequence of the interactions of the preceding three characteristics. Within this context, each network site team will measure and project the consequences of the different treatments on the following:

Stand Structure and Composition, both because trees are keystone life forms which create or greatly influence habitat for all other forest organisms, and because trees have great amenity and commodity value to humans.

Stand Function (e.g., aboveground productivity) because productivity tells us the rate at which future forest products are produced, the rate at which carbon and other elements are being sequestered, and the rate at which new fuels are being generated.

Stand Stability and Resilience, because forests have great amenity and commodity value to humans. Forest stability and resilience can be viewed as a component of the vaguer term "forest health." Stability and resilience are more easily inferred from stand structure and function than directly measured.

Shrub and Herb Layer Structure and Composition, because understory vegetation is important habitat and food source for other forest organisms, and because the understory plants are important components of the aesthetics for which humans often visit such sites.

Shrub and Herb Layer Function, because the plants that comprise these understory strata are important in the fuel complex and in fixing atmospheric nitrogen that subsequently supports productivity in the tree layer.

The specific core variables that will be sampled in order to meet those needs will be

Stand structure
- Tree demographics (in the broadest sense)
- Spatial pattern of gaps and subsequent patches (horizontal and vertical)
- Snag and log distribution
- Bole scarring and crown condition
- Repeated photographic images from permanent photopoints

Stand composition
- Shifts in abundance and diversity

Stand function
- Tree radial growth rates (both from cores and diameter changes)
- Seed production (in the context of food for wildlife)

Shrub and herb layer structure
- Cover and frequency by species and life form

Shrub and herb layer composition
- Shifts in abundance and diversity

Shrub and herb layer function
- Productivity
- Nitrogen fixation potential

NOTE: For practical reasons, species-level resolution of shrub and herb layer plant taxa usually will be limited to vascular plants. Taxonomic expertise in non-vascular species is usually more difficult to come by, and non-vascular species are a minor component of many forested ecosystems. However, non-vascular plants may be important components of the understory of some forested ecosystems, requiring identification to the species level when possible.

Soils and the Forest Floor

The forest floor and soils component of the larger study has been designed to determine the consequences of different fuel management treatments on key aspects of forest floor and soil structure, function, biogeochemistry, and biodiversity. Fuel accumulates on the forest floor as a consequence of the rates of and balance between primary production by the vegetation and decomposition/mineralization by organisms in the soil. The chemical, physical, and biological status of the soil determines to a great extent the rate of primary production, and feedbacks among vegetation, forest floor, and soil processes determine the rates at which dead plant materials are recycled. Thus, one cannot expect to predict the long term effects of various fuel reduction treatments on the forest ecosystem without understanding the direct effects of those treatments on the forest floor and soil as well as the manner in which the feedbacks among vegetation and soil components are altered. Within this context, each network site team will measure and project the consequences of the different treatments on the following:

Forest Floor Mass, Depth, and Organic Matter/Nutrient Capital: Not only does the organic matter comprising the forest floor mass supply a significant part of the fuel for wildfire, this organic material plays a number of other keystone roles in the forest ecosystem, including: insulating the soil from extremes of moisture and temperature, storage and recycling of essential macronutrients (e.g. Ca, P, Mg, K, N), sequestering C and N derived from the atmosphere through primary production, determining the potential range of "safe site" conditions for seed germination and seedling growth, and supplying habitat for a range of vertebrate and invertebrate animals.

Mineral Soil C, N, and Macronutrients: Nutrient availability is one of the major controls on plant productivity. Understanding how the various fuel treatments will affect both standing pools of key nutrients and the rates at which they are made available through the activities of the soil biota are both critical to the prediction of the long term effects of the fuel treatments. The quantity and quality (e.g. C:N ratio) of soil organic matter regulates many of the microbial processes that determine nutrient availability, either directly or through its effect on other soil organisms. Finally, in many cases, a significant proportion of the organic C and N in soils are found in compounds that are highly recalcitrant. Thus, these pools may represent important and long term mechanisms for the sequestering of C and N from the atmosphere.

Mineral Soil Physical and Hydrologic Properties: The physical properties of surface soils help determine whether precipitation that penetrates the canopy will infiltrate into the soil and be available for biological processes or run off the surface and impact on water quality. The physical properties of the soil also affect root growth, seedling germination, microbial activity, and soil faunal activities, and an understanding of how the treatments affect these properties is important to understanding the long term impact on the vegetation. In particular, the degree of compaction of the soil surface (and its impact on soil bulk density), the proportion of the mineral soil surface that is directly exposed to the atmosphere by the treatments, and the degree of development of hydrophobicity after fire must be measured to determine the impacts on soil physical properties.

Forest Floor and Soil Biodiversity: It is clear that soil microbes (e.g. bacteria, fungi, actinomycetes) and soil fauna (e.g. microarthropods, nematodes) play key roles in the organic matter and nutrient dynamics of the forest floor and soil, and thereby, help regulate primary production and fuel accumulation. Although some insights into how the abundances of these broad groups affect ecosystem processes, little is known about the importance of their biodiversity to ecosystem function. Biodiversity can be determined either from a functional approach or from a taxonomic viewpoint. As taxonomic studies are expensive in terms of time, effort, and funds, and as few links have been established between taxonomic biodiversity of soil organisms and ecosystem processes, we will adopt a functional approach to the measurement of soil biodiversity.

Fine Root Production: One of the goals of the vegetation sampling is to determine aboveground net primary production. We anticipate measuring fine root growth and decay in parallel so that a complete estimate of ecosystem primary production can be assembled.

Initial Site Characterizations: In addition to those core variables directly related to the fuel management treatments, we must also conduct initial site characterizations in each of the plots within each study area, including the full range of standard taxonomic and morphological measurements.

The specific core variables that will be sampled in order to meet those needs will be:

Forest floor and soil organic matter and nutrient capital
- Mass
- C, N by fuel class
- Macronutrients (Ca, Mg, P, K, Al, S) by fuel class;

Mineral soil chemistry

C, N by depth
macronutrients by depth

Soil Nutrient Availability
Nitrogen mineralization in forest floor and mineral soil
Nitrification in mineral soil

Soil Physical Properties
Alteration in Porosity, as measured by bulk density or compaction
Exposure of mineral soil
Hydrophobicity

Soil BiodiversityAssessment
Biolog analysis of the functional diversity of microbes

Root Production
Fine root productivity and turnover measured by sequential and ingrowth cores

Initial Site Characterization
Standard morphological and taxonomic survey methods
Texture measured by depth

Note: Many other soil and forest floor variables could be measured in order to gain greater insight into the ecological effects of the fuel treatments on these ecosystems. Those which were discussed seriously, but which did not make the core variable list because of financial or logistic constraints inlcuded •soil water movement and leaching, using lysimetric analysis; •semi-permanent instrumenting for soil moisture and temperature; •direct analysis of microarthropod and nematode biodiversity •analysis of microbial taxonomic diversity using fatty acid methyl ester profiles •analysis of microbial functional diversity using soil enzyme analysis •decomposition of forest floor materials •measurement of mycorrhizal diversity and/or abundance

Pathology

The primary goal of the pathology component of the larger study is to determine below-ground pathological dynamics and its impact on forests resulting from fuel management treatments. Fire can affect the soil fungal community and forest pathogens in a number of ways. Fire influences on pathogen epidemiology range from direct effects on inoculum density, inoculum viability, and wound/fire scar infection to indirect effects such as influences on stand composition, vigor, changes in soil microbial communities, and changes woody debris and litter accumulation. Reintroduction of fire or fire surrogate treatments to fire driven forest ecosystems may result in novel pathological and entomological problems due to what is defined as an "exotic ecosystem" effect (Otrosina 1998). Such an effect arises from disturbances, previous cultural practices, soil degradation, or altered fire periodicity (suppression). Pathologically, exotic ecosystems are characterized by increased mortality associated with root infecting fungi not normally regarded as primary pathogens. Because forest tree root pathogens are powerful drivers of forest ecosystems, influencing stand dynamics and succession in various forest types, knowledge of fire effects on below ground pathological processes are essential for predicting long-term effects of various fuel reduction treatments on forest ecosystems (Piirto et al. 1998). Within this context, each network site team will measure and project the consequences of the different treatments on the following:

1) Assessment of root disease incidence and impact: Root disease fungi, being key drivers of conifer forest ecosystems, can influence productivity and stand composition both directly and indirectly. Some information is beginning to emerge relating prescribed burning to increased incidence of root infecting fungi (Otrosina 1998). Fungi involved in root disease and associated mortality and productivity losses belong to diverse taxonomic groups. These taxa have various modes of pathogenicity, ranging from opportunistic colonizers to primary pathogens. Some root infecting fungi, such as the Ophiostomoid complex fungi, may be indicators of stress or abnormal ecosystem function (Otrosina et al. 1997). This group of fungi is isolated with increasing frequency in longleaf pine ecosystems where prescribed burning is conducted following longer than normal periods of fire absence (Otrosina, 1998). Another aspect of importance relative to Ophiostomoid fungi is they are generally associated with insects, which directly vector them or are incidentally associated with infection by these fungi through wounding. A devastating root disease in east-side ponderosa and Jeffrey pine ecosystems is caused by a fungal species, *Leptographium wageneri,* belonging to this group. Little is known of fire effects on this disease and the insects associated with its spread. It is therefore essential to assess presence of poorly understood insects such as root feeding bark beetles (e.g., *Hylastes* sp.) that may vector this and similar fungi. Understanding these relationships will enable a pro-active approach to be taken relative to fuel treatment effects in various ecosystems, both from a disease risk assessment perspective and from its use as indicators of ecosystem function. Study of these insects and the fungi they may carry can be coupled to the Entomology Sub-component. Other fungi, such as *Heterobasidion annosum,* are woody root pathogens that cause mortality in conifer ecosystems worldwide (Otrosina and Cobb 1989). In most ecosystems, effects of fire and other disturbances on incidence of root disease caused by these fungi are unknown. Because root diseases predispose trees to bark beetle attack, it is especially imperative we gain an understanding of the effects fuel treatments have on the fungi that cause root diseases.

2) Fine root damage assessments: There is increasing evidence that fine root (< 3 mm diameter) damage occurs in certain conifer ecosystems even with fires of low intensity, particularly when litter has been accumulating for some time. Fine root damage is thought to play a role in predisposing trees to attack by certain root pathogenic fungi and root feeding insects (Otrosina 1998). Energy expended to regenerate damaged roots, reestablish mycorrhizal associations, and defend against fungal and insect invaders would theoretically divert energy resources that would otherwise be used for growth. Thus, assessment of root damage would provide insights into predisposition of trees to various insect and fungi that may cause mortality or productivity losses. Such assessments can be linked to fine root turnover evaluations as outlined in the Forest Floor/Soils Sub-component, and may provide additional information relevant to both sub-components.

3) Fungal Biomass: Profound changes in fungal communities can take place following fuel treatments, including fire, because of substrate conversion. These changes are dynamic and are embedded in natural seasonal fluctuations. Imposing treatments such as fire may alter patterns of live fungal biomass which, in turn, are coupled to nutrient turnover. For example, mycorrhizal fungal biomass measurement can provide carbohydrate source/sink relationships affected by treatments (Sung et al. 1995), and may be related to pathogen and insect susceptibility. Measurement of this component would therefore provide information that will be useful for predicting fire effects on productivity. Fungal biomass determination relating to fuel treatments can be coupled to the Forest Floor/Soils Sub-component issues relating to forest floor and soil biodiversity, fine root turnover, and nutrient pool turnover rates. These studies will compliment aspects of that sub-component and increase the inference space relative to data interpretation and application.

Fuel and Fire Behavior

The primary goals of the fuel and fire behavior analysis are to characterize the changes in fuel loading resulting from fire and/or fire-surrogate treatments at each research site, and to document fire behavior during the fire treatment applications. Elements that will be measured include the ground, surface, understory, and overstory fuels. These will be measured before treatment and after treatment and at specific times throughout the length of the study. In addition, fuel moisture content, fire behavior measurements, and fire weather will be collected at the fire treatment application sites.

The fuel components to be measured are:

Ground Fuels: These are the L, F and H forest floor layers often called litter and duff. The forest floor is a vital element in relating effects of the fire treatment on soil, vegetation, smoke production, and other components of the study. Fire severity and behavior are directly related to the consumption of this fuel.

Surface Fuels :This includes the down dead woody fuels, grass, and dwarf shrubs. They are significant contributors to the affects of the applied treatments outlined in this study. They constitute a large component of the biomass available for fire consumption. The down dead woody fuel component will also be generated by the fire surrogate treatment. A measure of success of the surrogate treatment will be the amount of woody fuels remaining on the site after the application of the treatments and how that change will reduce wildfire risk.

Understory Fuels: This includes the standing live and dead shrubs, and saplings. The significance of the live fuel contribution to fire spread and amount of fuel consumption will vary from ecosystem to ecosystem.

Overstory Fuels: This includes the standing live and dead trees, and tall shrubs. They are in important element in determining crown fire potential. Changes within this fuel component between surrogate treatments will determine the success or failure of the treatment application in reducing wildfire risk.

Other Fuel-related Variables: Fuel moisture content, fire behavior, and fire weather parameters are not fuel bed components, but have a direct relationship to potential fire effects on the fire treatment sites

The specific fuels variables to be measured are:

Ground Fuels.

- L-layer (newly cast foliage),
- F-layer (foliage beginning to break down yet still identifiable)
- H-layer (humus consisting of unidentifiable organic material).

Surface Fuels

- Coarse woody debris
- Ground-level plant biomass

Understory Fuels

Live and dead shrub and sapling ibomass

Overstory Fuels

Standing live and dead biomass of trees and tall shrubs

Vertical distribution of overstory fuels

Fire Behavior

Fuel moisture

Fire weather

Flame height, rate of spread, and smoldering duration

Wildlife (Vertebrates)

It is important to the overall goal of this project to complete a qualitative and, where possible, quantitative assessment of the effect of fire and fire surrogates on the bird and mammal fauna across the network. Evaluating potential general patterns of the avian, small mammal, and herpetofaunal community responses to fire and fire surrogate treatments is especially central to the needs of National Forests when undertaking environmental impact assessments in support of plans for active management of forests. Further, evaluating the fire and fire surrogate treatments in relation to snag generation and sustainability is critically important to wildlife management concerns in coniferous forests.

We are particularly interested in how populations respond numerically (the abundance issue from above) and, among birds, how a particular foraging guild responds functionally ("bark-gleaners" and how they forage on trees in response to the treatments). Among the birds, our emphasis will be on the foraging "guilds" (woodpeckers, "bark-gleaners", "leaf-gleaners", etc.) that seem to have phylogenetic coherence across the coniferous forests of North America. We will evaluate possible cause-effect relationships of abundance, diversity, nest productivity, and the functional response of bark-gleaners to the fire and fire-surrogate treatments relative to controls.

Among the mammals, *Tamias* chipmunks, *Tamiasciurus* tree squirrels, *Sciurus* squirrels, and *Spermophilus* ground squirrels should be regular diurnal species interacting directly (in cavities, in coarse woody debris, feeding on mast) with forest trees across all sites. The nocturnal mammals should be dominated by *Peromyscus* (and in particular *P. maniculatus*) deer mice. We expect the abundance and diversity of these groups to reflect closely the effects, indirect and direct, of fire.

The herpetofauna is not expected to be phylogenetically consistent among the network sites, nor do we anticipate strong community fidelity among this group of organisms. At this time, it is less clear how this group of animals will respond to the fire and fire surrogate treatments.

Within this context, each network site team will measure and project the consequences of the different treatments on the following:

Species diversity: Emphasis will be on species which colonize sites in response to fire/fire and those that tend to disappear following treatment

Changes in abundance:: Shifts in abundance of each species in response to the treatments will be assessed both over the short term (1-2 yr) and longer term (5+ yr).

Nest productivity: Knowing how the production of avian young/nest changes in response to the fire/fire surrogate treatments is key to predicting longer term demographic effects.

Avian Functional responses: How will the "bark-gleaners" respond to trees as foraging substrates as a response to treatments? Fire will inevitably contribute to mortality in some trees. Evaluating how woodpeckers respond to fire (and how other bark-gleaners choose among trees) is one direct way of evaluating wildlife response to prescribed fire across coniferous forests. As dying and dead trees are those excavated for cavities by woodpeckers, understanding the spatial and temporal aspects of this process of decay and cavity-generation by woodpeckers is important for sustainable management of wildlife in forests.

Note: The approach used for analyzing the avian functional responses will be coordinated with that used for assessing bark beetle dynamics (detailed in the next section). The sampling protocol will be designed to match the status (time since infection, source of infection) of bark beetle-infected trees with woodpecker foraging patterns and drilling patterns in order to closely correlate tree mortality with onset of cavity excavation. For woodpeckers and the other bark-gleaners, the tag number of the individual tree utilized during foraging observations to later correspond bird utilization patterns with tree characteristics will be noted. Sampling for micro-habitat variables associated with nest-site choice in birds and the micro-habitat near our small mammal and herp trapping sites will be coordinated with those designed to establish overall plant community composition and structure on a per site basis.

Wildlife (Invertebrates)

Invertebrates are also key elements in the forest ecosystem, and have what are typically considered as positive factors (e.g. facilitating wood decay, pollinator service) and negative factors (e.g. bark beetles) for forest management. Prescribed fire is commonly viewed as the most commonly-used management tool for improving forest health and reducing wildfire risk. Although wildland fires have been shown to predispose residual trees to attack by bark beetles (Miller and Peterson 1927; Hall and Eaton 1961; Furniss 1965; Swain 1968; Gara et al 1984), little research has been done the effect of different types of prescribed fire or on combinations of fire and other treatments on predisposition to attack by bark beetles and secondary insects. In addition, virtually no detailed research has been done on the effect of prescribed fires and/or thinning on populations of insect (numbers of species or individuals) inhabiting coarse woody debris (CWD). Thus, the goal of the segment of the overall fire and fire surrogates study is to develop an understanding of how the various treatments are likely to affect both the positive and the negative roles that these insects play in ecosystem processes.

To achieve this goal, each site team will measure the following:

Bark beetle-caused tree mortality: Determine whether there is a significant increase or decrease in percent mortality/ha/year, by insect species and tree species. This will also involve determining the degree of cambial injury/bark scorch, because of the importance of these as indicators of susceptibility of trees to infestation.

Iinteractions between bark beetles and secondary insects, and between bark beetle activity and cavity dependent wildlife species: This involves determining the suitability and acceptability of fire killed trees and bark beetle killed trees to cavity dependent wildlife species

Abundance and Diversity of entomofauna that utilize down coarse woody debris (CWD): We need to determine if the various treatments induce an increase or decrease in populations (numbers of individual or numbers of species) of insects dependent on CWD, as well as the effect on biodiversity of entomofauna in CWD. We will also evaluate possible interactions between CWD entomofauna and birds and small mammals

Treatment Costs And Utilization Economics

There are economic costs and benefits associated with reducing fuel loadings, whether this happens through uncontrolled wildfires, prescribed natural fire, prescribed burning, mechanical removals of coarse fuels, or some other means. If silvicultural cutting (thinning, improvement cuts, regeneration harvest, etc.) is part of the management strategy then materials removed might help offset treatment costs. Efficient utilization of the small-diameter wood removed during initial treatments may require specialized harvesting equipment and processing facilities. As a result, questions about the economic viability of treatments can only be partially answered at the stand level. To fully analyze the problem, simulations need to aggregate treatments across larger land areas and perform analyses at the sub-regional or regional level.

As part of this project, we will coordinate develop a national/regional modeling effort to provide information useful to managers and policy makers who must evaluate economic tradeoffs associated with different management actions intended to reduce fire hazard and improve forest health. We anticipate that the needs of these groups will differ. Managers are expected to need more specific information about smaller land areas, e.g., site, watershed, national forest level, while policy makers will typically focus on cost/benefit analyses for larger land areas.

The goal of the treatment and utilization efforts is to help managers evaluate economic costs and benefits associated with a range of treatment options. Analysis will center on the key issue of potential trade-offs among the costs and economic benefits associated with fire, mechanical removals, and combinations of the two. The analyses that support this effort are designed to develop information on costs and benefits both at the time of treatment and into the future at both the stand and regional levels, and analysis will proceed in six topic areas designed to help managers and policy makers evaluate the costs and potential economic benefits associated with treating large numbers of stands that are at risk for stand replacement fires: treatment methodology and costs, quantity of removed materials, value of and potential uses for removed materials, projection of future stand conditions and treatments, costs of future treatments and values of materials removed, and risk of and costs associated with escaped fire.

Within this context, each network site team will measure the variables necessary to achieve the following site and regional level objectives:

Site-level objectives:

Validate existing harvest treatment cost simulation model with compartment-level data. Compartment-level harvest productivity data will be collected for each function e.g., felling, skidding, forwarding, etc. Where feasible, information will be collected on multiple operational compartments at each site so that more data points will be available. The data will include operating hours for each compartment, and scale (volume and/or weight) information for all products removed from each compartment. The between-compartment variation of factors such as average tree size and slope will provide more information than would a single data point for each unit. In many cases, the area served by a single landing would make an easily identified compartment.

Estimate amount (volumes or weight) and value of materials removed by diameter and species. The pre-treatment inventory of the overstory and understory vegetation at each site and will allow the estimation of removal proportions to be incorporated into the prescription.

Estimate the effects of burning on tree mortality and wood quality as related to salvage value. This will be done as part of the post-treatment vegetation sampling.

Regional level objectives:

Use regional inventory data to identify and develop composite stands representing widely occurring forest conditions. Analysis of the economic benefits and costs of a large-scale treatment program requires an understanding of the problem in a regional context.

Develop prescriptions to address high risk conditions in major forest types, and use existing forest growth models, such as the Forest Vegetation Simulator (FVS), to project stand conditions over time. This work will provide an understanding of the scope the of problem at the regional level and generate information on the amount and types of materials that will be generated by silvicultural cuttings over time, as well as the magnitude of potential burning programs.

Use an expert opinion survey approach to develop harvest and treatment costs applicable to the forest types and conditions needing treatment. This process will develop regional estimates of costs associated with implementation of a large-scale silvicultural cutting and/or prescribed burning program.

Use detailed regional forest industry databases and simulation models to determine product uses and values by species and diameter. This analysis will evaluate the capability of the existing industry to process materials removed during treatments and highlight different kinds of processing facilities that could increase the value and utilization of this material. It will also provide information useful for planning new facilities to efficiently process materials removed during future treatments.

Human Social Dimensions

Primary goal of the social dimensions subcomponent is to describe human emotional and behavioral responses to wildfire, prescribed fire, fire surrogates, and their effects on environments. In addition this portion of the larger project will describe the impact of fire and fire surrogates on the non-market value of landscapes for selected uses, and describe the structure of attitudes and opinions about fire and fire surrogates, including the association between those attitudes and opinions and knowledge, information, intentions, and behaviors.

Ultimately the feasibility of any ecosystem management program depends on public support. Public support depends on perceived impacts of the program on people's values and the values assigned to the ecosystem management activities themselves. Understanding what values are influenced by fire and fire surrogates and how the fire and ecosystem management activities cause the impacts will permit managers to alter their activities to enhance desirable impacts and minimize negative impacts. Failure to adequately consider social dimensions of fire and fire surrogates may lead to organized opposition and lack of general support for fire and fire surrogates, which will in turn influence policy and funding of such activities.

Landscape modifications by fire and fire surrogates will alter the value of those landscapes for various market and non-market uses. Modifications that enhance the desirability of landscapes increase the value of the resource while those that cause undesirable changes reduce resource values. Changes in values for given uses will change demand for those resource characteristics and alter use patterns. Those alterations will have consequences for land use decisions and social and economic structures at the local level.

The current landscapes present in the ecosystems that comprise this network have a high risk of uncharacteristically severe fire because of past management practices. As a consequence, the potential for loss of life, property and natural resources is high under present conditions. We anticipate that the landscapes that will result from fire and fire surrogate treatments will be have significantly lesser risk of such fires. If the post-treatment landscapes are or can be made attractive to those who influence their management, positive safety and property protection benefits can be expected. If, on the other hand, resulting landscapes are unattractive, it will be more difficult to promote widespread adoption.

To achieve the goals of the social dimensions subcomponent, the following variables have been selected for measurement during the initial stages of the project: Emotional responses, attitudes, perceptions and beliefs (cognitive responses), behaviors and perceived value (willingness to pay), and the environmental context in which they are measured. These variables have been chosen because they are thought to have the most immediate impact on resource values and human behaviors.

Emotional response. Human emotional responses to environments can be characterized as combinations of the basic emotional components: pleasure, arousal, and dominance. Each of these can be measured using the Emotional Response Inventory. Environmental and situational characteristics have been identified associated with each of the fundamental emotions. Significant changes to the landscape resulting from fire and fire surrogates will alter emotional responses to that landscape. There will also be important emotional responses to fire and its alternative ecosystem management methods. It is possible, within limits, to predict the effect of certain landscape changes on emotional responses and to influence those responses through modification of the landscape and other variables. Emotions influence behaviors and are fundamental to the value placed on a landscape. Expectations of emotions are at the root of attitudes and opinions.

Attitudes. The importance of attitudes can be judged by the amount of money spent collecting such data in marketing and politics and on persuasive efforts to change them. Simply put, an attitude is a personal probability that association with some person or thing will result in certain emotions, positive and negative. The attitude object and even the names and symbols for the object can arouse emotions. People generally attempt to maintain and support those things toward which they have positive attitudes and to avoid or oppose those that elicit negative attitudes. People can be expected to have attitudes about fire in the forest. Fire prevention campaigns have worked for years to establish certain attitudes. People will also have attitudes toward agencies and activities of different kinds that might be used to manage ecosystems. Understanding what attitudes people hold about fire and fire surrogates will provide a better understanding of their intentions and actual behaviors.

Perceptions and beliefs. As used here, perceptions describe how a person experiences an event through the senses and how those experiences are organized into images. Beliefs are those things that people think are true or false about a thing. Perceptions and beliefs are treated here as free of emotions but, of course, perceptions and beliefs will trigger emotions. What is believed about a thing will influence how one feels about it.

Behaviors. Both actual behaviors and intentions to behave in certain ways cam be measured. Approach behavior can be observed as such things the length of time spent in different settings. Exploration can be observed. Affiliation is the desire to interact with others and can be observed. All these and the feelings that the behavior is easy or difficult in the setting can also be measured using paper-pencil scales.

Value (willingness to pay). There are market values expressed in the prices one might get if things were offered for sale. Market values in those cases where the market is working well should describe relative worth of a thing when compared to all other things exchanged in the market. It is also possible to measure individual willingness to pay for goods and services that are not exchanged in the market place. Several valid and reliable methods for doing so are in common use by resource economists. One of these is contingent valuation methodology.

The changes to landscapes resulting from fire and fire surrogates will change their characteristics and make them more or less useful for a variety of purposes, That will change the instrumental or resource value of the landscape. Some of those instrumental values might be expressed in the market. They can be measured using contingent valuation. Other changes may alter the final value of the landscape for such purposes as aesthetics. Such changes may be only imperfectly expressed in the markets but they, too, can be measured. People will also be willing to pay to avoid the losses from wildfire, smoke, and the disruption of social and economic life associated with a large destructive wildfire. The willingness to pay to avoid some of these costs can be measured to a degree by the insurance market. Other dimensions are poorly reflected even in the market but their value can be measured using contingent valuation.

Environmental Context. A number of environmental variables have been shown to be associated with emotional and behavioral response to settings. Among those that are associated with emotions include brightness, wind speed, relative humidity, temperatures, sounds, and odors.

Note: The human dimensions to be studied here are measures of individuals and not of groups or social systems. As such, they are only a part of the social dimensions of fire and fire surrogates. If they are measured without linking changes in these variables to group and system variables or the impacts of group membership and roles on perception and emotional response, for example, understanding of the social dimensions will be incomplete.

Other effects such as changes to community economic structure resulting from adjustments in resource management practices and the impacts on status and local social structure are as real and important as the effects on attitudes and beliefs. However, resource limitations prevent studying the whole system at all levels at the same time. The selected variables are comprehensible and the consequences for individual behavior more obvious so studies of these variables make at least an admirable starting place for understanding the social dimensions of human beings in relationship to fire and fire surrogates.

The selected variables also are less costly in time and money to measure. That is not always a good argument for selecting topics for study. However, there are very limited resources available to support data collection and analysis. It would be wise first to tackle those parts of the puzzle that can be worked out with available resources and then to leverage other resources based on the knowledge developed in the first stages. It must always be kept in mind, of course, that the variables studied are different in scale and systems levels from other important variables. It would be unwise to limit human dimension studies in the long run to this initial set of variables.

These variables also tend to have been those that have been studied in related resource areas and for which validated measures and study designs are more available. It is expected that the literature and theory will be, at least initially, more productive here.

Relatively small scale landscape changes can be studied for their effects on the psychological level variables described here. Experiments, surveys and qualitative studies with relatively low budgets are possible. Much larger and longer lasting changes will need to be observed to determine effects on such things as the economic structure of resource based community economies. Although experiments at that scale are conceptually possible, they are usually impractical. In some cases, modeling would provide useful answers but the complexity argues against such studies being done early in the project. They may sooner or later rise in priority and possibility, however.

The core variables that will be measured in support of this component are:

Emotional Response

- Arousal
- Dominance
- Pleasure
- Emotional Response Inventory

Attitudes

- Strong-weak
- Active-passive
- Good-bad
- Appropriate-inappropriate
- Compatible-incompatible
- Semantic differential
- Ranking
- Adjective checklists
- Content analysis
- Social distance scales

Perceptions

- Mystery/deflected vistas

- Coherence
- Information rate
- Depth
- Harmony/composition
- Focality and ordering
- Ground surface texture
- Threat/tension

Phenomenology
- Focus groups
- Content analysis
- Semantic differential
- Likert scales

Beliefs
- Natural/artificial
- Durable/fragile
- Permanent/temporary
- Cyclical/linear
- Scarce/plentiful
- Comprehensible/unknowable
- Useful/useless
- Potential/exhausted
- Dependable/fickle

Behaviors
- Approach/avoid
- Effortless/difficult
- Exploration
- Affiliation
- Ranking
- Likert scales
- Content analysis
- Behavior observation

Value
- Willingness to pay
- Final/instrumental
- Central/peripheral
- Contingent valuation
- Ethnography

Environmental
- Brightness

Windspeeds
Wind directions
Relative Humidity
Temperatures
Sounds
Odors

APPENDIX A-2
Sampling Protocols and Methodology

Overall Study Design and Site Characterization

Spatial scale plays a tremendous role in defining which tools and approaches we will use to measure our core variables. Thus, in our presentation of study design tools and approaches are organized by spatial scale, from broadest to finest. For the purposes of this project, "plot" refers to a full 10 ha area receiving a treatment application. "Sub-plot" refers to smaller areas nested within the larger 10 ha plot for the purpose of spatial organization of the sampling.

Aerial photography will allow us to determine changes in the forest mosaic much more cheaply than ground-based measurements. Determination of changes in the forest mosaic will be useful for several reasons, not the least of which are documenting changes in forest potential as wildlife habitat and addressing the long-simmering "structure vs. process" debate (see Stephenson 1996 and in revision). Regarding the latter, structural restorationists have argued that fire suppression has led to more uniform forest conditions, thus blurring the boundaries between formerly distinct forest patches. This increased uniformity, they have argued, will be perpetuated by fire which erases the original character of the forest mosaic. Thus, a silvicultural restoration is a necessary precursor to reintroduction of fire. Process restorationists, in contrast, have argued that a simple reintroduction of fire is likely to restore the forest mosaic. Both sides have been arguing in a near-vacuum of evidence. As in so many cases, either argument may be correct depending on local circumstances. Examination of broad-scale treatment effects on forest structure by aerial imagery can help address this issue.

As a consequence of its lower spatial resolution, satellite imagery cannot adequately address our questions of interest regarding changes in forest structure. Likewise, to obtain aerial digital multi-spectral images for determining changes in productivity at a resolution also useful for determining changes in forest structure is more expensive than separately obtaining satellite images (for determining changes in productivity) and aerial color-infrared photographs (for determining changes in forest structure).

We will obtain color infrared photographs at a resolution (approximately 1:4000) that allows individual trees and objects on the ground to be discerned easily. Images will be georeferenced to treatment plots by a combination of (1) on-board GPS, and (2) ground markings set up for the purpose. Sets of images will be taken pre-treatment and twice during or post-treatment. Since treatments are likely to take several years to complete, planning for three sets of images will allow analysis to begin before all treatments are completed. Analysis will proceed as described in Skinner (1995) and references therein.

Plot Design

The key to plot design is that it be nested, since different ecosystem components will best be measured at different spatial scales. Decades of experience by many scientists have demonstrated the value of a plot-based approach to addressing many of the questions listed earlier. A standard established by Whittaker in the 1950's and now commonly used in North America is the tenth-hectare plot (20 x 50 m). Plots of this size form the core of many forest vegetation studies that find a reasonable balance between intensive and extensive, and precision and accuracy. In some studies the Nature Conservancy has adopted 25 x 50 m (0.125 ha) plots. For all practical purposes, the two plot sizes (0.100 and 0.125) are comparable, and there is no obvious need for any group already using one size to switch to the other. For groups establishing sub-plots for the first time, however, tenth-hectare sub-plots should be used.

There will be six tenth-hectare (20 x 50-m) sub-plots per 10-ha treatment plot, arrayed systematically at pre-determined grid points. This number amounts to 6% of the treatment area and is considered a compromise between accurate sampling and personnel constraints. In forest types where local site managers perceive this is insufficient to adequately sample the smaller size classes of trees, they can compensate by decreasing the minimum size of trees to be censused in the 10-ha treatment plot. If local site conditions merit, subplot locations may be determined by site stratification.

Tenth-hectare subplots will have nested within them, ten 10x10-m subplots, and nested within them will be two 1x1-m quadrats located in opposite corners (to reduce spatial autocorrelation between these quadrats, those on the inside corner will be offset from the corner one meter towards the outside. This is the base design but it will be flexible to the extent that the 10x10-m subplots will be modular and site managers will have the option of sampling fewer if vegetation density warrants. The smallest quadrats will have a minimum size of 1x1-m and sites have the option of increasing their size as needed.

Vegetation

In the 10-ha plots the largest standing trees (95^{th} percentile in dbh, determined from subplot samples) will be censused and individually identified. For each tree, species, dbh, status (live, dead, harvested), height, and height to base of the live crown.

Complete species lists of all woody and herbaceous plants will be recorded for both the 0.1 ha subplots and the 10 x 10m subplots. In the 10 x 10m subplots, each tree will be identified and the following attributes recorded: dbh, status (live, dead, harvested), height, height to base of the live crown, and crown condition (foliage transparency and branch dieback). In addition, each sapling in the 10 x 10m subplot will be identified and its dbh class (small <3 cm, medium 3 - ≤ 6 cm, large > 6 cm) and status (live, dead, damaged) noted. For each live shrub in the 10 x 10m sampling plots, species and cover (% GSC class: (trace <1, very low 1-10, low 11-25, moderate 26-50, high 51-75, very high >75) will be recorded.

In each 1 x 1m quadrat, a complete species list will be recorded and the following vegetation data taken: species and number in height classes (small <10 cm, medium 10-50 cm, large > 50 cm) for all tree seedlings and saplings (< 1.4 m), species and estimated number for all shrub seedlings, species and cover (% GSC: trace <1, very low 1-10, low 11-25, moderate 26-50, high 51-75, very high >75) for each herbaceous species, whether present as seedlings, vegetative sprouts, or both.

All variables will be measured pre- and post-treatment and again in Year 5, except overstory tree DBH, crown class, and height, which will only be measured in year 5. The initiating year is the first pre-treatment sample year. Post-treatment sampling should take place during the growing season (as appropriate) after treatment. In some network sites, herbaceous sampling must be performed twice per growing season to account for the phenology of the herbaceous flora (i.e., spring ephemeral and summer flora). In other locales, one growing-season sample may be sufficient

Soils and the Forest Floor

We anticipate measuring the soil and forest floor core variables during year 0 (the pretreatment year), year 1 (the immediate post treatment year), and either year 3 or 4. The spatial pattern of the soil and forest floor sampling will be guided by the design of the subplots for vegetation analysis, whereas the degree of replication within and around each subplot will be determined by the magnitude of underlying variability in each site.

To determine the C, N, and macronutrient content of forest floor and mineral soil we anticipate taking 6-12 samples per subplot. In sites in which six samples is sufficient, we will take one at each corner and one at the midpoint of each long side. For sites in which the underlying variability dictates a larger number, samples will be taken at regular intervals along the long sides of the plots. Forest floor samples will be sorted by fuel class, and mineral soils samples by depth in 10cm increments. Wherever possible, given the underlying variability, samples from a given subplot will be composited prior to chemical analysis.

Analysis of nutrient availability will be done for four samples per subplot during the spring of each year using aerobic, laboratory incubations for measurement of N mineralization and nitrification. Aerobic laboratory incubations are preferable over *in situ* incubations because of the high loss rate of samples in *in situ* experiments and greater control over environmental factors in the laboratory. The moisture content of the incubating samples should be adjusted during the incubation period following a regime that mimics changes in soil moisture in the field, and incubations should be done on fresh samples, not on stored, dried, or frozen samples. Ideally, Biolog analyses of soil biodiversity will be done on the same samples.

Each subplot will be searched each spring for areas of exposed mineral soil greater than 30 cm^2 in area. Each exposure will be measured and marked for resurvey on a biannual basis. Compaction will be measured along transects just outside the long boundaries of the subplots. The preferred method will be to take penetrometer readings at 5 m intervals along the two long boundaries, thus yielding 20 measurements per subplot per year. For sites in which bulk density or tile spade penetration must be used, sample size will be adjusted to a level which generated an equivalent mean:variance ratio.

Root production will be determined by sieving live and dead roots from two types of soil cores: (1) sequential cores: cores taken on a periodic basis and destructively harvested (monthly during the early part of the growing season, bimonthly over the latter part, and one five month interval over the non-growing season), and (2) ingrowth cores; aliqouts of freshly sieved, root free soil that are placed into holes made by the taking of sequential cores and allowed to remain for one-two months before being reharvested. These cores determine net root production over the interval of ingrowth. Root litter bags will be used to determine decay rates of roots that are sloughed.

Pathology

It will first be necessary to survey each plot prior to the initiation of treatments. Depending upon the whole plot size in a given location, a 100% cruise to determine pretreatment condition will be conducted on at least a 2 ha central portion of each treatment plot involved in root disease assessments. If the plot size is less than 2 ha, then a 100% cruise will be conducted on the existing plot area. Symptomatic trees will be tagged and recorded. Crown symptom severity will be rated following a rating scale previously devised (Bannwart 1998). Root tissue samples will be taken from symptomatic trees and transported to a laboratory for fungal isolation and identification. Occurrence of fungal species will be catalogued and correlated with above-ground symptoms. At this time, at least four permanent subplots will be established on each treatment plot. Configuration will be determined after site visits, however, similar current studies are utilizing the forest health monitoring field design employing fixed radius plots located at cardinal directions and fixed distances from whole plot centers (Otrosina, unpublished study plan). All permanent sub-plot trees will be tagged and diameter, condition, and growth data taken prior to treatment along with samples for assessment of root/fungal biomass and post-treatment damage estimates.

Following treatment, cruises will be conducted on entire whole plots (or inner 2 ha), as described in the pretreatment survey section, at least twice per year for the first three years post treatment to measure symptom/mortality dynamics. New symptomatic trees will be tagged and data on diameter, crown symptom ratings, crown and stem scorch ratings, and root condition will be collected after excavation of at least two lateral roots > 3 cm in diameter. From these trees, samples of root tissue will also be collected to isolate and document occurrence of fungal pathogens. The presence, frequency, and identity of these fungi will be compared with any crown symptoms, root damage, and mortality observed.

Potential root feeding bark beetle vectors will be enumerated via standard entomological trapping methods. Trapped beetles will be identified and quantified so that findings can be compared to treatment, fungal pathogen incidence, symptom severity, and root, bole, or crown damage data. Selected sub-samples of trapped beetles will be retained for isolation of fungal associates. Counts of colony forming units (CFU's) appearing on isolation plates as well as their identification will be garnered. Representative isolates of each fungal species obtained will be kept in permanent culture for pathogenicity studies. These studies on root feeding bark beetles can be integrated with the Entomology Sub-section.

In situ inoculation experiments will be conducted to determine pathogenicity of isolated root infecting fungi and to determine treatment effects on pathogenicity. Randomly selected trees within whole treatment plots will be selected for inoculation with fungi isolated from insects and or root tissues. Large woody roots will be inoculated by introducing sterile segments of wood (checks) or wood infested with pure cultures of the fungi in question. At least three roots per tree will be inoculated at points within 1 m of the root collar. Inoculation will be performed in Spring, Summer, and Fall to examine seasonal variation in virulence and or host response relative to treatment. After four weeks, infection response will be measured by length of lesions and amount of resinosis observed. Portions of lesions will be excised and placed in pentane to quantify host defensive byproducts such as terpenoids and other phenolic compounds. This will provide information of potential risk of infection due to treatment.

Sucrose synthase activity, along with related enzymes, will be determined monthly during the first two growing seasons following treatments in randomly selected trees in treatment plots (Otrosina et al. 1996; Sung et al. 1993). Assay of this enzyme has been shown to indicate of stress in conifers by determination of activities in certain stress sensitive carbohydrate mobilizing enzymes. These assays will determine stress due to treatment effects and will contribute to the development of predictive models with respect to fire and fire surrogate effects on disease and insect incidence.

Fine root damage assessment: The general method employed involves selection of sample trees within plots and obtaining root samples via coring or fixed volume excavations from the drip line zone around selected codominant sample trees within permanent sub-plots. Fine roots are harvested via sieving and immediately fixed on site in FAA or are placed in coolers on site and shipped to the laboratory within two days. Both visual damage estimates and microscopic (histological) analyses will be performed using standardized staining procedures (Walkinshaw & Otrosina 1999). The sampling intensity will be determined by site characteristics after initial pilot tests to estimate variability. Pretreatment sampling will be performed to establish baselines. Sampling and field experiments can be carried out by utilization of plot designs of the Vegetation Sub-component.

Fungal biomass estimates: Analysis of ergosterol content in mineral soil, organic matter, and root/mycorrhizal and rhizosphere substrates will be used to determine fungal biomass. Ergosterol is a surrogate for living fungal biomass because it only occurs in living fungal membranes and is a more reliable indicator of mycorrhizal status than visual estimation (Sung et al. 1995). Fine root and soil samples will be obtained from selected sample trees as described in fine root damage assessment above. Detailed sample protocols will be developed after site evaluations. Pretreatment pilot studies will be initiated to determine variability and experimental sample intensity and specific design. Post treatment samples will be obtained at least every two months during the growing season or post growing season depending upon site characteristics and accessibility (snow cover, etc.).

Note: Specific and detailed protocols for variables to be measure will be determined after appropriate site visits or preliminary information and data are obtained from the various study sites. Linkage to and reliance on other sub-components mentioned are critical for certain assessments and studies as outlined in the preceding proposed work plan. The specific protocols required to carry out various phases of the Pathology Sub-component studies are well established. It is anticipated that on site cooperators will be able to carry out the sampling protocols after a brief orientation and training period. Non of the methodologies employed for obtaining field data are particularly difficult but do require some attention to detail, not unlike any other critical field data collection stratagem. The training required will be conducted by personnel of the Tree Root Biology Team of RWU 4154, Athens, GA. As stated in the Forest Floor/Soils Sub-component, sampling intensity and replication are site specific and will be determined by conditions on site. In all cases, sufficient replication will be performed in all phases of the pathology study that is within constraints of good science on one hand and manpower and budgetary limitations on the other.

Fuels and Fire Behavior

The L- and F-layers are more influential to the fire behavior of the fire treatments and the H-layer affects more of the severity and below ground events of the prescribed fire. The amount of this fuel component must be measured or accounted for on each treatment plot if it is agreed that it is a significant fuel condition on the study site.

The amount of forest floor material can be determined by destructively sampling the forest floor material or by estimating the weight by developing a regression equation for forest floor weight and forest floor depth. It would be expected that destructive sampling would be required to characterize the forest floor on the thinned treatment plots due to the relatively higher level of disturbance anticipated in thinned vs burned plots.

It is also expected that some study sites may not have a well-defined forest floor component due to species composition or as a consequence of past management activities. These sites would also need to be destructively sampled. The destructive forest floor samples would be taken in conjunction with the woody fuel transects. A corresponding sample would be taken after the prescribed burning on the fire treatment plots.

In order to develop a forest floor prediction equation, the site needs to have an undisturbed, well-developed forest floor. A forest floor with little humus and mostly L- and F layer material will not produce a reliable prediction equation. Being able to use this method of predicting forest floor weight allows the use of duff spikes to estimate the average forest floor weight over the burn treatment plot or in a particular area where specific fire effects are measured. It creates less disturbance in these sensitive areas where disturbance may affect the fire behavior in that small area of concern.

Samples used to develop the prediction equation are randomly selected in areas that have the full range of forest floor depth on the plot. If blocks are used in the design of the study site, a different prediction equation may be necessary for each block if there appears to be significant differences. Fifty samples (each 1.0 ft^2 = 930 cm^2) is the minimum number of samples needed to produce the predictive equation. Each sample is collected by layer (L, F, and H) and bagged separately. A depth for each layer is measured in the center of each side of the square foot sample and the depths are then averaged for that sample. Procedures for processing samples have been developed by Stephen Sackett and others and will be available

The amount of forest floor material removed by prescribed burning is critical for defining vegetation and soil responses as well as smoke production potential. A series of eight duff pins will be used to determine the amount of forest floor material removed. The eight steel pins will be located on two perpendicular axes located at each grid point and marked with engineering flags to aid in relocating. Each pin will be pushed into the forest floor and mineral soil until the head of the pin is flush with the top of the litter layer. The location of the pins will have to be determined once other activities around the grid points are defined so that they are located in undisturbed areas. After the fire, each pin is relocated and the distance from the top of the pin to the top of the remaining forest floor is measured and record. The total distance from the top of the pin to mineral soil is also recorded for each pin. These duff pin protocols have been developed by Roger Ottmar and others and will be made available.

The down dead woody fuels will be measured using Brown's (1974) planar intercept method. This will classify the fuel by size class (0-1/4"=0-6mm, 1/4-1/2"=6-12mm, 1/2-1"=12-25mm, 1-3"=25-75mm, and 3^{+}"=75^{+}mm), decay class condition (sound and rotten), and the number of intercepts and diameters of 3^{+}" diameter material by species. This fuel inventory will need to be done prior to treatment application, after thinning activity is completed and after the application of the prescribed fire treatments. It is expected that at least 4,000 ft (1220m) of transect will be measured on each treatment plot. The recommended number of samples would consist of two 20m transects randomly placed at each of the 36 grid points. These transects need to be permanently marked with reinforcement rod so that the same transects are measured for post burn sampling.

The number of pieces of different decay classes than those mentioned previously can be estimated from the information collected from the woody fuel transects if these decay classes are more relevant to some of the treatment effects. They would have to be defined prior to the woody fuel sampling process. Only the diameter at the point of the intersection is recorded. The actual volume (including length) and distribution would not be adequately determined by the transect method.

If biomass of grass, forb, and dwarf shrub vegetation is considered to be an important contributor to fire behavior or effects then biomass measurements must be collected. The grass and forbs would be destructively sampled before and after treatment applications. If allometric equations exist for the dwarf shrub species present then measurements taken during the vegetation sampling can be used to estimate biomass. If no equations exist, then destructive sampling must be done to quantify the biomass of the dwarf shrub fuel component. If biomass of the large shrubs and saplings is a major contributor to fire behavior or effects, then it must be determined by using shrub measurements applied to allometric equations or by using destructive sampling procedures.

The overstory fuels are critical in estimating fire risk and crown fire potential on a site. Species, tree density, d.b.h., ladder fuel height, number of canopy layers, height to live crown, total height, and percent canopy closure are critical variables and are needed to calculate fire risk and crown fire potential. These variables will be changing during the applications of the treatments within each study site and they will reflect the differences between the different study sites. The collection of these data will be part of the basic vegetation sampling and will be incorporated into the overstory plot descriptions for each plot and sub-plot. After the application of the burn treatments, we recommend crown scorch data also collected on the overstory plots

Samples for the measurement of fuel moisture will need to be collected just prior to the application of the burn treatments. Forest floor samples need to be collected by layer to represent the plot condition. Woody fuel moisture content samples need to also be collected by size class. Moisture content must also be determined for the live fuel component. This should be done by vegetation class (grass, forb and shrub) and should be sampled to represent the entire plot. The moisture content is determined on an oven dry basis. We suggest that a site team collect this information prior to burning with instruction from the fuels team

It will be necessary to document fire behavior at each burn treatment plot to be able to qualify the fire intensity between fire treatment plots. Flame length should be measured and done as an ocular estimate on the flame front. Rate of spread is estimated by timing the movement of the flaming front to cover a known distance. This should be down for both heading and backing fire fronts. Flaming and smoldering stage duration should be measured during the course of the burn. The flame length and rate of spread should be taken as sets of measurements at regular intervals (i.e. every 15 minutes), throughout the lighting phase at selected grid points. In addition, flaming and smoldering duration should be ocularly estimated at the same selected grid points. We suggest the site team collecting fuel moisture content samples also collect this information with instruction from the fuels team.

Prior to and during the burning operations on the fire treatment plots, ambient temperature, relative humidity, and wind speed and direction should be collected as fire parameters. This should be done for each burn treatment plot and should be done by the site team or teams under the direction of the fuels team.

Table 2. Summary of information being measured by the fuels team.

Fuel Variable	Data collected:
Ground fuels (litter and duff)	(1) Destructive sample of forest floor material to develop a depth/weight prediction equation to estimate tons/acre of material present on the study sites. Reinforcement rod can then be used to estimate consumption of forest floor material in relation to specific fire effects being investigated by other groups. This also can be used to relate the depth measurements taken from the woody fuel transects to a tons/acre estimate of fuel loading. Forest floor biomass and the average of four depth measurements of each layer (L, F, and H) will be collected for each square foot sampled. (2) Consumption of forest floor material at eight pins located at each grid point for each burn plot.
Down dead woody fuel	(1) Number of intercepts of woody fuel by diameter size class: 0-1/4" diameter size class in first 6' of transect ¼-1/2" diameter size class in first 6' of transect 1/2-1" diameter size class in first 6' of transect 1-3" diameter size class in first 12' of transect (2) Actual diameter of woody material that is in the 3+" size class of the entire transect length by species. (3) Duff depth at two points in the first 5 feet of the transect line to the nearest 0.1 inch. (4) Dead fuel depth at three 1-foot wide vertical partitions in the first 3 feet of the transect line. (5) Slope estimate of the transect line.

Table 3. Summary of data collected by other teams but shared with the fuels team.

Variable	Needed by fuels	Collected by:
Overstory Fuels		
Ladder fuel height	X	Vegetation
DBH	X	Vegetation
Species	X	Vegetation
Tree density by diameter	X	Vegetation

Crown cover	X	Vegetation
Number of crown layers	X	Vegetation
Height to live crown	X	Vegetation
Crown scorch	X	Vegetation
Understory Fuels		
Live fuel biomass if alloiometric equations are not available to estimate biomass	X	Vegetation
Surface Fuels		
Grass/Forbs	X	Vegetation
Other Variables		
Mineral soil exposure		Soils
CWD-dimensions and distribution		Entomology
Fuel moisture	X	Site crew
Flame length and rate of spread	X	Site crew
Flaming and smoldering duration	X	
Fire weather: Ambient temperature Relative humidity Wind speed/direction	X	Site crew

Wildlife (Vertebrates)

We propose will assess the diversity and abundance to the treatments of birds in the study through the use of point count censuses. We will monitor nest productivity (number of young fledged per nest initiated) of nesting birds in a subset of sites. We will evaluate the functional response of foraging woodpeckers and other "bark-gleaners" to the treatments.

Point counts are a standardized method of assessing the diversity and abundance of birds by counting birds at grid points based on either hearing or sight. As the network study sites will have grid points at every 50m, we will assess birds at every 100m, with 50m radii of detection. Depending on the shape of each study site, we hope to have 10 points/plot assessed for five minutes per point. Each site will be assessed three times (three replicates per sites) during the two-month spring-summer breeding season. The main output of this method will be an assessment of the diversity and abundance of birds detected as a function of treatment.

Nest productivity can also be assessed by standardized methods. We will randomly assign two replicates of each treatment (including controls) to be thoroughly searched for bird nests and monitored until the fate (fledging young or failure) has been determined. The data will be analyzed in terms of overall productivity, and analyzed by categories (cavity vs. cup-nesters vs. ground nesters) and by species.

Evaluating the "functional" response of woodpeckers and other "bark-gleaning" birds (chickadees, titmice, nuthatches, creepers) means observing their foraging patterns on trees in each site. Methods for this have been developed in research at Blacks Mountain Experimental Forest in Northern California **(citation needed here)**. This method emphasizes tree condition (including "risk rating"), dbh, and a measure of fire scaring. As woodpeckers forage on larval bark beetles and other insects infecting tree tissue and ultimately create cavities essential for wildlife from several taxa, we will emphasize the response of woodpeckers to the proposed treatments. Microhabitat measurements will be made near each nest (substrate measures, cover, etc.) and each woodpecker or barkgleaner tree chosen for foraging. We hope to correlate these vegetative data with those of the plot data taken by the vegetation team. All of our observations will be referenced to the nearest grid point.

It is generally quite costly and difficult to effectively sample populations of small mammals and the herpetofauna. There are, however, methods being developed that may provide better sampling reliability at lesser cost. We propose to use Y-shaped arrays of 10 pitfall traps and drift fences (Kirkland and Sheppard 1994) combined with two Sherman XLK and one Tomahawk #201 at each pitfall trap. Traps will be spaced at 25m intervals. Pitfall traps are to be kept dry as our objectives are to have a minimum impact on the mammal and herpetofaunal population, and population estimates will need to be based on marking and recapturing animals.

Traps will be inspected morning and night for 10 day/night periods at each experimental area. This will reduce mortality and ensure that traps are available in both daylight and night hours to afford the greatest potential for capturing specimens of all species present. Trapping will be completed after the juvenile mammals appear within an approximately one month period. To the extent possible, especially in areas where late spring and early spring rainfall is expected, each mammal trapping period should include a rainy night to increase the potential of capturing shrews. These methods should do a reasonably good job on the ground-dwelling small mammals/herpetofauna; this method probably will not suffice for arboreal or fossorial mammals and no cost-effective methods are available.

For the more abundant taxa, estimates of absolute abundance or at least relative abundance will be developed. For less abundant taxa, presence vs. absence information may be the most quantitative analysis possible. Taxa will be aggregated as appropriate to develop analyses of population differences among functional groups. Microhabitat measurements will be made near each trap setting. The use of drift fences will confound information from individual trap settings so the microhabitat measures will be evaluated across the area occupied by each trap array. We hope to correlate these vegetative data with those of the plot data taken by the vegetation team. All of trap settings will be referenced to the nearest grid point.

Table 4. Summary of Wildlife Methods:

Measurement	**Season**	**Scale**	**Effort**	**"Output"**
Bird Point Counts	May-August Annually	Every 100 m	All plots 3 repeat visits	Density and diversity
Bird Nest Productivity	May-August Annually	Where found on sampled plots	2 plots each treatment (= 8 plots total)	Young/nest per nesting species
Bird "Functional	May-August Annually	Sampling foraging "bark	2 plots each treatment (= 8	Foraging response to

Response"		gleaners"	plots total)	"treated" trees
Mammal Capture-Recapture	May-August Annually	Y-array, 25 m trap interval for 10 points	All plots, sampled one time/yr (10day-night periods)	Density and diversity (productivity?)
Herpetofauna Pitfall Trapping	May-August Annually	Y-array, 25 m trap interval for 10 points	All plots, sampled one time/yr (10day-night periods)	Density (?) and diversity

Wildlife (Invertebrates)

At least one year before the applications of the treatments the study plots will be censused for bark beetle mortality. At each successive grid point we will scan 180° for trees that are clearly in decline or devoid of needles. As such trees are found, the direction and distance from the grid point will be determined. For each tree, the tree species, bark beetle species responsible for mortality, tree diameter, fading stage (color i.e. lime or light green, straw colored, yellow, red, or grey {old dead}) will be recorded. These data will be collected at each grid point on each study plot. This will allow for bark beetle mortality to be spatial referenced for GIS analysis.

These data will also be collected at 1,2 and 4 years post-treatment. The variables of interest to be used to detect treatment effects include, but are not limited to, percent mortality/tree species/bark beetle species/year, percent of mortality represented by group kills, mean number of trees per group kill, distribution of morality by diameter class/bark beetle species, incidence (percentage) of bark beetle attacked trees also attacked by secondary insects, percent of tree mortality caused by secondary insects acting alone, and DHB distribution of tree mortality caused by secondary insects.

methods for CWD insects???

Treatment Costs and Utilization Economics

The site-level and regional-level objectives each require a distinct set of measurement methods. At the site-level, the validation of existing harvest treatment cost simulation model with compartment-level data first requires that each site team determine the per unit area costs of associated activities at the site level, such as slashing, prescribed burning, etc. To insure accurate estimates, operational times for all equipment will be monitored with Servis recorders and collected by study personnel on each site. Study personnel will also record times for the associated activities. Agreements to allow monitoring of operating times and to provide scale records by compartment need to be built into contracts (or formally agreed upon in advance with purchasers) at the site level. To provide realistic estimates of costs, information will need to be collected from areas where an efficient operations layout is used and the treated area is large enough to be cost efficient. The compartment-level harvest productivity data will be used to validate estimates from a harvesting cost simulation model and when appropriate to validate expert opinion data collected for individual sites.

Harvesting costs depend on a number of factors including tree size, removal density, skidding distance and slope, among others. Rather than developing new cost models, data collected at the compartment level from the study sites will be used to validate existing harvest treatment cost simulations for the fuels reduction applications. Estimates of the costs of burning, with and without thinning, will be collected at each site.

A compartment is defined, for purposes of this portion of the study, as the smallest unit for which it is readily feasible to segregate gross harvesting production and operating time data. In many cases, the area served by a single landing would make an easily identified compartment, if trails into the landing are preflagged, and/or if boundaries between one landing and the next are flagged. Where feasible, information will be collected on multiple operational compartments within each unit so that more data points will be available. If this is not possible, the unit will make an acceptable compartment.

The site administrator will supply accurate topographic maps of all units, with compartment boundaries and landing locations indicated, to UC Davis. These will be used to calculate compartment areas, and to estimate average skidding, forwarding or yarding distances and ground slopes.

Compartment-level harvest productivity data will be collected for each stump-to-truck function e.g., felling, skidding or forwarding, etc. For mechanized functions, operating hours will be collected with electronic dataloggers mounted on each machine. When operations begin at a site, the site administrator will install a compact, self-contained datalogger on each piece of equipment. These dataloggers essentially monitor vibration level over time to indicate whether the machine is operating or not. The administrator will download information from each datalogger weekly. In addition, a paper record must be kept of the dates and approximate times each machine began and finished operating in each compartment. At the completion of operations, the dataloggers will be removed from the machines.

For thinning of small trees, it is likely that most operations will be mechanized. For manual operations such as chainsaw felling, the dates and approximate times each person began and finished operating in each compartment will be recorded on paper.

Similar records will be collected for slashing and prescribed burning activities, but at the unit level rather than for compartments within units. As was the case for mechanized harvesting, dataloggers will be used on equipment, and paper records for manual activities. To provide realistic estimates of prescribed burning costs, information will need to be collected from areas where an efficient operations layout is used and the treated area is large enough to be cost efficient.

Harvesting production from each compartment will be determined from scale (volume and/or weight) tickets and records for all products removed. Scale tickets must accurately indicate from which compartment the material was derived. Most truckloads should be derived from a single compartment, but residual partial loads may be combined as long as the truck driver makes a reasonable estimate (i.e. to the nearest 10%) of what portion of the load came from each compartment. Agreements to allow monitoring of operating times with dataloggers, and to provide scale records by compartment need to be built into contracts (or formally agreed upon in advance with purchasers) at the site level.

All the data will be transmitted by the site administrator to UC Davis, within a week of when they are collected. The UC Davis group will compare the compartment-level harvesting production and time data with simulated results, to validate harvesting models that have already been developed for estimating costs of harvesting small trees.

Estimation of the amount (volume or weight) and value of materials removed by diameter and species will first required a detailed pre-treatment inventory at the site (and compartment) level to describe the existing stand. The prescription for each treatment will designate trees to be killed or removed and those having potential product values. Pre-treatment plots will be remeasured to obtain a detailed post-treatment inventory. This will verify the starting conditions for post-treatment stand growth modeling. The differences between pre- and post-treatment will further characterize the removals. Between-compartment variation of factors such as average tree size and removal density will provide more information than would a single data point for each unit.

Since much of the material to be removed is likely to be of small diameter, it is recommended that sample plots (if circular) be fixed-radius rather than variable-radius. If it is feasible to delineate compartments, the boundaries should be designated prior to the pre-treatment inventory so that a number of plots can be located at random within each compartment. A minimum of three 0.05 ha plots (five would be preferable) should be located within each compartment, and a sampling intensity of 10% or higher is recommended.

Estimation of the effects of burning on tree mortality and wood quality as related to salvage value will be important in determining longer term treatment economics. Information gathered here will allow estimation of the potential to reduce costs of treatments by salvaging mortality after burning. This analysis will require periodic stand sampling over a number of years after the treatment by the vegetation team in each site.

Regional inventory data will be used to identify and develop composite stands representing widely occurring forest conditions. Regional inventory data will be searched to identify conditions of density, structure, and species composition most in need of treatment, along with estimates of their relative abundance within each region. Analyses will include areas where existing access is sufficient for the selected treatment.

Prescriptions will be developed to address high risk conditions in major forest types, and use existing forest growth models (e.g. the Forest Vegetation Simulator or FVS) to project stand conditions over time. This work will provide an understanding of the scope the of problem at the regional level and generate information on the amount and types of materials that will be generated by silvicultural cuttings over time, as well as the magnitude of potential burning programs. An expert opinion survey approach will be used to develop harvest and treatment costs applicable to the forest types and conditions needing treatment. This will involve working with logging contractors to develop cost estimates for hypothetical sales modeled after the proposed treatments, and working with various landowners/managers to develop cost estimates of associated treatments, e.g., thinning, prescribed burning. Interviews with logging contractors will be used to develop cost estimates for silvicultural cuttings in common forest types using generalized prescriptions. State and federal agencies, Indian tribes, and private companies are a source of expertise on the costs of prescribed burning and other treatments.

We will also use detailed regional forest industry databases and simulation models to determine product uses and values by species and diameter. This analysis will evaluate the capability of the existing industry to process materials removed during treatments and highlight different kinds of processing facilities that could increase the value and utilization of this material. It will also provide information useful for planning new facilities to efficiently process materials removed during future treatments.

Social Dimensions

Although there are only a few studies of human responses to landscape changes resulting from fire and alternative ecosystem management methods, there is a substantial body of literature on environmental psychology describing human response to landscapes and natural phenomena. There is literature describing emotional responses to wildfire and natural disasters. The first step should be a systematic review of the literature to develop hypotheses about probable human response to fire, fire surrogates, and the consequences for the landscape. The literature reviews will provide useful guidelines that can be applied immediately by practitioners; equally importantly, they will suggest research questions and specific study designs to address those questions.

Landscapes at each of the sites will be sampled using random walks with panoramic photographs taken at each point of course change. The photographs will be used to measure emotional responses, as stimuli for focus groups, to measure willingness to pay, and in attitude and perception studies. Small groups or individuals will actually walk the random path and respond to the same measures used with groups observing the photographs.

The random walk is laid out by selecting a point on the edge of the landscape at random. A compass heading and a number of paces (between 30 and 300) to be walked on that heading are selected at random. Initial compass headings must lead into the landscape. Therefore, the initial headings will be selected from between 10 and 170 degrees from a line parallel to the edge of the landscape to be sampled. The observation points must be within the landscape. Therefore, if the number of paces selected would take one out of the landscape at any point, the observation point should be located where the heading crosses the boarder of the landscape. Obstacles are passed using the route of least resistance counting paces as if on a straight line. When the required number of paces have been walked, the point will be marked and photographs taken. A new heading and number of paces will be selected at random and the process repeated.

Each random walk should have 20 stations where photos are taken and where the walking parties will stop. The number 20 is arbitrary, based on a personal estimate of the number of photographs needed for sorting activities and a reasonable number of stops for a visiting party of subjects to observe. The range for the number of paces, between 30 and 300, was selected to provide relatively uniform coverage of the landscape along the walk. These numbers might be revised with early experience.

The route will be marked with unobtrusive indicators that a guide can follow. An unobtrusive marker will be established at each change of heading and mapped. GPS coordinates should be taken at each location and careful records kept of the marker and its location with respect to durable landscape features so that later researchers can find the point even if many years pass. These photo-points may be used long in the future for other purposes not yet imagined.

Several random walks may be established in landscapes at different sites depending on the size of the site and the variability of the larger landscape. If the landscape is homogenous in slope, aspect, and vegetation type, fewer walks need to be established. If there is greater variability. more walks will be needed to represent the range of potential landscape experiences. In mountainous landscapes, it may be wise to lay out the random walks totally within small watersheds. The watershed limits provide natural visual limits organizing the landscape for a viewer. They also are natural landscape units for fire behavior, vegetation and other ecological responses.

Random walks should be established in landscapes that will be subjected to the various treatments before the treatments are applied. Photographs should be taken to document each major vegetation state. For example, in the mid-west, winter with snow cover and leaves fallen, spring green-up, mid summer, fall with leaves in full color, and so on. The appropriate seasons will be different from place to place. Photographs should be taken on clear days, at the same time of day. Each year the site should be photographed within plus or minus 7 days of the dates of the original photographs. A standard color spectrum should be photographed at each location each time photographs are taken. The color standards can then be used to correct for differences in film and lighting if necessary or desirable before the photographs are used in studies. Digital cameras or film may be used. If digital cameras are used, the highest resolution should be used. There will probably be significant advances in photographic technology over the period of this research. It will be necessary to preserve the images in ways that permit comparisons over time.

Photographs can be used to evaluate emotional responses, attitudes, perceptions, and willingness to pay changes associated with landscape changes resulting from fire and fire surrogate treatments. Photographs allow studies to be conducted off site with population segments far from the location as well as those near by. It will even be possible to describe how future generations respond to present landscapes and changes to those landscapes years from now. Having that baseline comparison will allow cultural changes over time to be factored in to longitudinal studies to some degree. However, the photographs record only the visual component of the experience. The emotional and cognitive response to environments is more complex than the visual response alone. Other variables that need to be recorded include sounds, temperature, relative humidity, patterns of wind and breezes, and odors.

Sound recordings should be made at the same time the photographs are taken using professional sound recording equipment with qualified operators. On-site weather data should be recorded at typical locations in the landscapes. Averages are important but variation is much more important. A steady breeze is very different from a variable breeze, for example. Odors will need to be recorded in written notes for the present.

These data can be used to simulate to some extent the experience of the landscapes as they change under the influence of fire and fire surrogates. However, it will be necessary to validate the simulations against first hand experiences. To do that, samples of relevant population segments will visit the sites and take the random walks. They will respond to questionnaire measures on site, record their observations, and participate in individual and group interviews off-site but immediately following the experience. These on-site, real time measurements will be relatively rare within the study because of the costs, logistical problems involved, and the difficulties in sampling populations and arranging for participation on site.

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APPENDIX B
Site Descriptions

Descriptions of the 11 study sites (10 main sites plus 1 satellite site) proposed for the national Fire/Fire Surrogate Network are provided below. Site selection criteria are listed in Table 1 and discussed further in the "Research Site Locations" section. All of the main sites are required to commit to the core experimental design (see "Experimental Design" section). The South Sierra-Sequoia site, which serves as a satellite to the South Sierra-Kings District site, departs from the core design only with respect to the core suite of treatments: only prescribed burning (2 seasons) and control treatments will be included. The value of this satellite site is that it adds a missing dimension to the network by including old growth forest as a distinct structural type for the burning treatments, thereby extending our conclusions to the type of fuel reduction treatments used by the National Park Service. Site descriptions reflect the physical conditions exhibited by each site, as well as the potential for a successful study to be installed and maintained for the long term. Sites are presented beginning with the Pacific Northwest, and ending with the sites in the Southeast.

MISSION CREEK

Contact: James K. Agee, University of Washington, Seattle, WA

Cooperating host agency: USDA Forest Service, Region 6

Location: North-central Washington, 6 miles west of Wenatchee, Leavenworth Ranger District, Wenatchee National Forest

Forest type: Mixed conifer: ponderosa pine, Douglas-fir, grand fir

Total area available: 2500 acres

Topographic range: Mid-elevation forests from 2000' to 4500'

Representative land base: Several hundred thousand acres on the Wenatchee Forest alone.

Fire History: The Douglas-fir series of eastern Washington historically burned with frequent, low intensity surface fires (Agee 1993). A USGS map ca. 1900 indicated no stand replacement burns in the previous 50 years in the low to mid elevation areas that contain this forest series (Agee 1994). Nearby studies (Wright 1996, Harrod et al. 1998) suggest a fire frequency of 10-20 years for this forest type previous to about 1900.

Contemporary fire hazard: Low severity fire regimes in the Mission Creek area have fuel buildup of both dead and life fuels that have radically altered fire behavior. The forests once had classic clustered groups of ponderosa pine at stem densities of 20-40 per acre, that are now being replaced by Douglas-fir at 125-175 stems per acre (Harrod et al. 1998).

Prior work and anticipated time line: Several management projects are currently underway, treating the matrix around any potential study site. Because environmental analysis has been accomplished, we expect to be able to begin treatments by the summer of 2000.

Level of long-term interest: The Pendleton part of the Mission Creek site has already been designated as a management demonstration area for thinning and burning treatments. In a December 17, 1998 meeting, District, Forest and local PNW research staff expressed commitment to participate in the study. One research project essential to defining silvicultural prescriptions for thinning has been completed at this site (Harrod et al. 1998).

Partnerships: Wenatchee National Forest, PNW Station, and University of Washington; possibly other academic institutions, as well as BLM and the Park Service may become involved.

Site/Plot selection constraints: No constraints on random assignment of treatments.

Treatments: All four core treatments will be installed.

5th treatment: In addition to the core treatments, we may have a fifth treatment consisting of either a second yarding technique for thinning, or an alternate season of burning.

Thinning and burning prescriptions: Thinning will include either feller-buncher or cable, and for season of burn either spring or fall burning. Prescriptions for the treatments have not yet been defined, but would be in the nature of low thins (thinning from below) and low intensity fires (flame lengths < 3 ft).

HUNGRY BOB

Contacts: James McIver, Andy Youngblood, PNW Research Station, La Grande, OR

Cooperating host agencies: USDA Forest Service, Region 6

Location: Blue Mountains of northeast Oregon, 25 miles north of Enterprise, Wallowa Valley District, Wallowa-Whitman National Forest

Forest type: Dry mixed conifer forest: Douglas-fir, ponderosa pine/snowberry plant association (Franklin and Dyrness 1988); on mostly shallow, rocky, and loamy mollisols.

Total area available: 2500 acres

Topographic range: Experimental plots are all located on the upper slopes or tops of ridges, where the dry forests typically occur. A few plots are located on lower slopes, but none extend into riparian areas.

Representative land base: The Hungry Bob project area represents a forest type and condition found throughout about 800,000 acres in the Blue Mountains and several million acres in the Columbia River Basin.

Fire history: Frequent, low intensity fire (<25 yr return interval), typically July -- October (Hall 1980). Due to fire suppression, most areas have not experienced fire for 80 years or more (Agee 1996).

Contemporary fire hazard: Fire severity and size have increased significantly in the Blue Mountains in the past 20 years. Wildfires have burned nearly 500,000 acres in the Malheur, Umatilla and Wallowa-Whitman National Forests in the past 10 years alone. Recent fires include the 1996 Summit (40,000 acres) and Tower Fires (35,000 acres).

Prior work and anticipated time line: Hungry Bob is the first proposed FFS site that is underway. This project has identical treatments and core variables as being considered for the other sites in the FFS network. Site, plot and subplot selection and layout occurred in 1997. Pre-treatment data were collected during 1998, followed by the thinning treatments. Prescribed fire treatments will be implemented in fall 1999. The first year of post-treatment data will be collected in 2000. A USDA Competitive Grant will provide much of the funding for the project through the first post-treatment year.

Level of long-term interest: Both managers and scientists involved in Hungry Bob have expressed willingness and commitment to the project for at least 10 years.

Partnerships: Wallowa Valley Ranger District (Wallowa-Whitman National Forest), Joseph Timber Co., Zacharias Logging Co., Oregon State University, PNW Research Station

Site/Plot selection constraints: Hungry Bob was selected from 8 potential available sites in the Blue Mountains. Site selection was restricted primarily by the scope and scale of fuel reduction treatment planned by the potential Ranger Districts. No plot selection constraints occurred.

Treatments: All core treatments have been or will be installed.

5th Treatment: Spring burning treatment.

Thinning and burning prescriptions: Thinning was undertaken by single grip harvester, coupled with forwarders for log retrieval. Prescription was to lower overall basal area from overstocked to 75% stocked, and to lower fuels to less than 10 tons per acre. Fire prescription is to reduce fuels to less than 10 tons per acre, and to achieve mortality of many stems less than 3" diameter. Multiple fire entries to achieve ultimate stand objectives are likely.

LUBRECHT FOREST

Contact: Carl Fiedler, Univ. Montana; Michael Harrington, Rocky Mt. Research Station, Misssoula, MT

Cooperating host agencies: University of Montana, USFS Rocky Mountain Research Station, Montana Dept. Natural Resources and Conservation

Location: Lubrecht Forest, 30 miles east of Missoula

Forest type: Dry mixed conifer: ponderosa pine/Douglas-fir

Total area available: 360 acres (120 acres/replicate x 3 replicates); additional area available, if needed.

Topographic range: Slopes range from about 10-35%, but are generally similar within a given replicate. Aspects range from southeast to southwest, but are reasonably similar within a replicate.

Representative land base: Study sites represent an extensive area of similar pine/fir forests in west-central Montana in particular, and the Northern Rockies in general.

Fire history: These stands historically experienced underburning at 5- to 30-year intervals, typical of pine/fir forests throughout western Montana and the Northern Rockies (Arno, 1980: Arno et al. 1997)

Contemporary fire hazard: The fire hazard in existing stands is high. The typical condition is densified, second-growth pine/fir forests, with thickets or a layer of Douglas-fir in the understory. Recent fires in the vicinity include the 1991 Clearwater fire, and the 1988 Milltown fire that threatened homes in the Riverside area. Recent regional fires in Northern Rocky Mountain ponderosa pine forests include the 150,000-acre Hawk Creek fire in central Montana, and the Lowman Complex on the Boise National Forest in Idaho, covering hundreds of thousands of acres.

Prior work and anticipated time line: Field locations have been selected for each of the three replicates; anticipated startup summer 2000.

Level of long-term interest: The Univ. of Montana School of Forestry, Montana Dept. of Natural Resources, and Rocky Mt. Research Station have all expressed long term commitment in the project.

Partnerships: University of Montana School of Forestry, the USFS Rocky Mountain Research Station, the Montana Department of Natural Resources and Conservation - Forestry Division, Clearwater State Forest, USFS Region 1, Missoula Ranger District, BLM District Office, State of Montana Dept. Natural Resources, and Plum Creek Timber Company.

Site/Plot selection constraints: No constraints on random assignment of treatments.

Treatments: All four core treatments will be installed.

5th treatment: None planned.

Thinning and burning prescriptions: Thin to approximately 50 ft^2/acre of basal area (the exact level will be determined collaboratively among the partners; the appropriate burning prescription and season of burn will be determined collaboratively among the partners.

KLAMATH PROVINCE

Contacts: Gary Fiddler, Carl Skinner, and Phil Weatherspoon, Pacific Southwest Research Station, Redding, CA.

Cooperating host agencies: USDA Forest Service (Region 5), USDI Bureau of Land Management, and possibly private land owners.

Location: No specific site location has been selected. Possible sites could be located on four National Forests in California (Klamath, Shasta-Trinity, Six Rivers, and Mendocino), USDI lands west of Redding, CA (both BLM and NPS [Whiskeytown Nat. Rec. Area]), and/or on lands owned by Sierra Pacific Industries.

Forest types: Douglas-fir--tanoak--pacific madrone (SAF 234), Sierra Nevada mixed conifer (SAF 243), pacific ponderosa pine--Douglas-fir (SAF 244), and pacific ponderosa pine (SAF 245).

Total area available: Since no specific site selection has been made this can only be addressed in a general nature. The forest types above represent vast areas (hundreds of thousands of acres) in the Klamath Province. Site selection will not be restricted due to lack of area.

Topographic range: All aspects are included. Ground based harvesting systems can be utilized on some of the area; major portions of the area will require the use of cable harvesting systems.

Representative land base: The forest cover types listed cover between 1,500,000 and 4,000,000 acres in the Klamath Province.

Fire History: Frequent fires of low-moderate intensity were characteristic of presettlement fire regimes in the forest types listed above (Agee 1991, Wills & Stuart 1994, Taylor and Skinner 1998). Median fire return intervals for 1-2 ha sites range generally from 10-20 yrs. Due to fire suppression, many of these areas have not experienced fire for 50 - 80 years.

Contemporary fire hazard: The efficiency of fire suppression has contributed to increased fuel build-up in these mountains similar to the build-up in other parts of the western United States. Millions of acres once characterized by low-moderate intensity fires now often burn with high intensity due to fuel build-up over the course of the 20th Century (especially since 1950). As a result, the Klamath Mountains have experienced several major fire years in the last couple of decades. Each of these years has seen the burning of 10,000s of acres of forest lands (~300,000 in 1987 alone), many acres at high intensity.

Prior work and anticipated time line: Almost all potential sites have had some form of harvesting in the past. Known candidates for study sites on National forest lands have varying degrees of environmental documentation; in some cases, no more documentation will be required prior to treatment implementation. In others, more NEPA work will be required in order to allow treatment installation. All other factors being equal, a potential site having all the NEPA documentation completed will be favored for selection. This consideration will greatly dictate implementation. If no NEPA work must be done, implementation can begin in the spring of 2000.

Level of long-term interest: Forest Service District, Forest, and Regional Office staff indicate interest and commitment to the project. This interest is manifesting itself in the form of candidate sites being offered by District staff even prior to the scheduling of user meetings. Long-term interest among PSW scientists is keen.

Partnerships: All candidate sites being offered by National Forest staff come with full support of that organization. The scientific support of PSW will be added to owner support regardless of the site selected. This scientific support often brings support from cooperators from the state universities. Some interest in a possible satellite site located on National Park Service lands has been expressed. If chosen, this would include NPS partnerships.

Site/Plot selection constraints: Slopes are moderate to very steep. Major river drainages divide the Province. Management options (and thus site selection options) are often restricted in these drainages due to environmental constraints. Several T&E species are found in the Province. Management options are severely restricted by the presence of these species. Full replications might not be placed side by side due to the broken nature of the terrain. Plot shapes may not be squares due to dissected topography.

Treatments: All core treatments will be installed.

5th treatment: The need or desire for a 5th treatment will be determined after site selection.

Thinning and burning prescriptions: Thinning will probably be a combination of hand falling and mechanical cutting, depending on size of cut trees and steepness of the site. Yarding will be by ground based equipment on the more gentle slopes, and some form of "flying" on the steeper slopes. Initial prescribed fires will be of moderate intensity. Additional information will be generated from the site meetings.

KINGS DISTRICT ADMINISTRATIVE STUDY AREA

Contacts: Scott Stephens, California Polytechnic State University , San Luis Obispo, CA; Mark Smith and Alan Quan, Sierra National Forest, Clovis, CA

Cooperating host agency: USDA Forest Service, Region 5

Location: Bear Meadow management unit within the Kings District Administrative Study Area, Sierra National Forest.

Forest type: Sierra Nevada mixed conifer forest: ponderosa pine, sugar pine, white fir, incense cedar, and California black oak

Total area available: 1400 acres

Topographic range: West and southwest aspects, 10-30% slopes. Entire area can be tractor logged.

Representative land base:. The mixed conifer forests in the Bear Meadow unit are typical of this area of the Sierra Nevada. Fire suppression policy has been implemented for the last 100-120 years (Phillips 1999). In the Sierra Nevada there are 3,345,000 acres of Mixed Conifer Forests (SNEP 1996).

Fire history: Mean fire return intervals from 1771 to 1873 within the mixed conifer forests of the Kings District Administrative Study Area ranged from 3.2 to 5.4 years (Phillips 1999). Maximum fire return intervals varied from 6 to 12 years, minimum fire return intervals varied from 1 to 2 years (Phillips 1999). Mean fire return intervals in the Kings District Administrative Study Area are shorter than those reported in other mixed conifer forests in the central Sierra Nevada (Kilgore and Taylor 1979; Caprio and Swetnam 1995).

Contemporary fire hazard: The potential of large, high severity wildfires in this area is high. The Bear Meadow unit has been repeatedly harvested, significant components of large overstory trees remain, understory dominated by small shade tolerant trees. High surface fuel loads and high horizontal and vertical fuel continuity has produced a forest that is vulnerable to catastrophic fire (Stephens 1998). Archived fire records for the Administrative Study Area revealed a high rate of lightning caused fires, with one lightning fire within the Administrative Study Area requiring suppression every 1.36 years from 1911 to 1965 (Phillips 1999). From 1910 to 1997 approximately 40 percent of the forests within 6 miles of the Administrative Study Area have burned due to wildfires.

Prior work and anticipated time line: The Kings River Administrative Study Area has a diverse research program which includes erosion and stream sedimentation, aquatic ecology, soil productivity, hypogeous fungi, demographic studies of California spotted owls, and small mammal and songbird population dynamics (Verner 1999). An Environmental Assessment on the Bear Meadow management unit was written and released to the public on 10/98 that included a 3 page summary summarizing the goals of the Fire-Fire Surrogate Study. This information was included in the EA with full knowledge that this particular site may not be selected for the network. If selected, the treatments would be installed beginning in the summer of 2000 and all treatments would be completed by the fall of 2001.

Level of long-term interest: The Kings River Administrative Study Area is included in the existing Sierra National Forest Land Management Plan and the area will be used for research and demonstration for at least the next 200 years. The full support of the Sierra National Forest and the Kings District Administrative Study Staff has been given.

Partnerships: USFS PSW Fresno, Cal Poly San Luis Obispo, UC Davis, UC Berkeley, and Humboldt State University. If this site was selected the monitoring protocols could be performed by some of these groups, other groups would also be used. There is the potential for the Sierra National Forest site to be connected to a satellite site located in Sequoia-Kings Canyon National Parks (see SEQUOIA-KINGS CANYON SATELLITE site description). The park site would be installed in an old growth mixed conifer forest. This type of forest structure is fundamentally different because no logging has occurred in the parks.

Site/Plot selection constraints: None

Treatments: All core treatments will be installed.

5th treatment: Harvest using group selection and thinning from below followed by moderate intensity prescribed fire. After initial structural restoration is completed application of prescribed fire to simulate the pre-historic fire regime, no additional mechanical treatments allowed.

Thinning and burning prescriptions: Area will be thinned by hand felling and yarded with tractors. Initial prescribed fires will be of moderate intensity. Additional information will come from the forthcoming site meeting.

SEQUOIA-KINGS CANYON SATELLITE

Contacts: Jon E. Keeley and Nathan L. Stephenson, USGS Biological Resources Division, Sequoia-Kings Canyon, CA; Anthony Caprio, USPS Natural Resources Division, Sequoia-Kings Canyon.

Cooperating host agencies: US Park Service, US Geological Survey

Location: East Fork and Marble Forks of the Kaweah Drainage, Sequoia National Park.

Forest cover: Mixed coniferous forest: *Pinus ponderosa, P. lambertiana, Abies concolor, Calocedrus decurrens*

Total area available: NA

Topograhic range: 15-25' inclination, aspects not yet determined.

Representative land base: These studies would have applicability to other U.S. National Park Service lands in the Western U.S.

Fire history: Bulk of the forest within 5 - 25 years return interval. Previous research on fire history for these forests is extensive.

Contemporary fire hazard: "Old growth" forest with substantial fuel loads above historical range of variation.

Previous work and anticipated time line: Initial treatments could begin in Fall 1999 and Spring 2000. A significant fraction of proposed sites are within the Prescribed Fire Operations Five Year Work Plan for Sequoia National Park. Hence, fire management personnel are confident they can work within the proposed time frame and restrictions imposed by random site selection criteria.

Level of long-term interest: Sequoia National Park representatives from the Division of Fire

Management and the Division of Science and Natural Resources Management are enthusiastic about cooperating with this project. The park has a long history of involvement in fire research.

Partnerships: Sequoia National Park already cooperates with researchers from various universities from throughout the country. Future collaborations are expected to increase with the focus of the new University of California campus at Merced, with its proposed focus on problems of the Sierra Nevada.

Site/Plot selection constraints: No thinning treatments would be applied; burning treatments would be randomly assigned to experimental units.

Treatments: Only prescribed fire treatments would be applied. This site however, would serve as a satellite to the KINGS DISTRICT ADMINISTRATIVE STUDY AREA site, and would add a missing dimension to the Joint Fire Science study plan by including old growth forest and manipulating fuels by altering season of burning. Treatments would be: Control, Autumn burning, Spring burning

Burning prescriptions: NA

FLAGSTAFF AND WILLIAMS ARIZONA

Contact: Carl Edminster, Rocky Mt. Research Station, Flagstaff, AZ

Cooperating host agency: USDA Forest Service, Region 3

Location: Experimental blocks will be located in the wildland-urban interface area west Flagstaff on the Peaks Ranger District, Coconino National Forest, and on the Williams Ranger District, Kaibab National Forest. The two areas are separated by about 30 miles, but will be considered as one site for purposes of the Fire and Fire Surrogates study.

Forest type: Ponderosa pine, with bunch grass understory and occasional Gambel oak

Total area available: Specific areas are the A-1 Mountain west ecosystem management unit (about 5,000 acres) around Flagstaff and the Frenchy ecosystem management unit (18,000 acres) east of Williams.

Topographic range: NA

Representative land base: Approximately 5 million acres in the Southwest

Fire history: Low intensity ground fires occurred historically every 2 to 10 years before the 1880's (Swetnam 1990, Dieterich 1980). In a study near Flagstaff, fire intervals averaged from 1.25 to 4.9 years for the period from 1540 to 1865 (Dieterich 1980). The Coconino National Forest experiences over 300 lightning caused fires per year with a density of over 160 fires per million acres (Barrows 1978).

Contemporary fire hazard: Around the Flagstaff wildland-urban interface, the 1977 Radio fire burned over 7,000 acres on Mount Elden just northeast of the city. In 1996, the Hochderffer and Horseshoe fires combined to burn over 25,000 acres north of the city. All of these fires were high intensity crown fires outside the range of natural variability for the ponderosa pine type. Conditions have become worse in recent years with increases in stand density and more residential development in forested areas. Within wildland-urban interface areas in the Southwest, there are nearly 1 million acres with over 300,000 homes at high risk of catastrophic wildfire (Patton-Mallory 1997).

Prior work and anticipated time line: Environmental analysis of the A-1 Mountain area has been completed. Research plot installation could begin as soon as funding is available and treatments could be implemented in the 2000 operating season. The Frenchy environmental analysis process will be completed during summer 1999. Research plot installation could begin as soon as funding is available and treatments could be implemented during the 2000 operating season.

Level of long-term interest: Both management and research partners are committed to long-term success of the projects. The proposed Fire and Fire Surrogates study installations will expand ongoing work in alternative management strategies for fire risk reduction and forest health restoration. The National Forests have pledged support in implementing the treatments under the Fire and Fire Surrogates program as part of their management implementation in the two management units.

Partnerships: Principally Coconino and Kaibab National Forests, the Rocky Mts. Research Station, and the Grand Canyon Forests Partnership. The latter partnership is guiding the fire risk reduction and forest health restoration effort in the Flagstaff area. The Partnership is community based and has a formal cooperative agreement with the Forest Service, Rocky Mountain Research Station, and the Forest Products Laboratory. The Partnership includes environmental organizations, federal and state agencies, county and city governments, and Northern Arizona University.

Site/Plot selection constraints: There are no known restrictions on random assignment of treatments.

Treatments: All four core treatments will be installed. In both areas, 2 replicates of the Fire and Fire Surrogates treatment design are proposed, for a total of 4 replicates. The Rocky Mountain Research Station will provide funding for the fourth replicate if not available through the Fire and Fire Surrogates program.

5th treatment: A possible fifth treatment is the use of a tree shredder/mulcher to dispose of large numbers of cut non-merchantable trees and heavy slash accumulations.

Thinning and burning prescriptions: Silvicultural treatments for both areas are an uneven-aged or uneven-sized residual stand structure using group selection. The goal of the silvicultural treatment will be to enhance structural and spatial diversity in the residual stands with fuels reduction and restoration of forest health.

JEMEZ MOUNTAINS NEW MEXICO

Contact: Carl Edminster, Rocky Mt. Research Station, Flagstaff

Cooperating host agency: USDA Forest Service, Region 3

Location: Two study areas will represent the Jemez Mountains site, located about 30 km apart, west and northwest of Los Alamos; Espanola and Jemez Ranger Districts, Santa Fe National Forest

Forest type: Ponderosa pine and mixed conifer: ponderosa pine, southwestern white pine, Douglas-fir, white fir, Gambel oak, aspen

Total area available: Several thousand

Topographic range: NA

Representative land base: 5 million acres in the southwest

Fire History: Natural low intensity ground fires generally occurred historically every 2 to 10 years before the 1880's (Swetnam 1990). Local studies in the Jemez Mountains show a mean fire interval in the range of 5 to 25 years (Swetnam and Baisan 1996, Touchan et al. 1996) with the longer intervals in ponderosa pine/mixed conifer vegetation type.

Contemporary fire hazard: Stands are becoming much denser relative to historical conditions. There have also been higher levels of insect and disease infestations and higher risk of large scale outbreaks. Three major catastrophic wildfires have burned in the Jemez Mountains study area in recent years. The 1977 La Mesa Fire burned over 15,400 acres in Bandelier National Monument, on the Santa Fe National Forest and Los Alamos National Laboratory. The 1996 Dome Fire burned 16,000 acres in the Monument and on the National Forest. The 1998 Oso Fire burned 5,000 acres on the National Forest north of Los Alamos. All of these fires had large areas of high intensity crown fires outside the range of natural variability for the ponderosa pine type.

Prior work and anticipated time line: In the Jemez Mountains area, an Interagency Wildfire Management Team is a guiding force in the fire risk reduction effort. The team includes representatives from the Santa Fe National Forest, Bandelier National Monument, Los Alamos National Laboratory, the town and county of Los Alamos. The research program is a collaborative effort to examine the results of alternative management strategies developed by the partnerships in an adaptive management framework. Due to prior commitment by management to fuel reduction, implementation of the Jemez Mountain FFS site could occur as early as the summer of 2000.

Level of long-term interest: Both management and research partners are committed to long-term success of the projects. The Santa Fe National Forest has pledged support in implementing the treatments under the Fire and Fire Surrogates program as part of their management implementation in the two management areas.

Partnerships: Sante Fe National Forest, Rocky Mountain Research Station

Site/Plot selection constraints: Sites on both Districts have received prior partial harvests more than 40 years ago. Within the Valle area, plot locations will be restricted to areas large enough to meet study specifications. Subject to that restriction, there are no known restrictions on random assignment of treatments. On Virgin Mesa, current plans call for prescribed fire in a portion of the mesa and thinning followed by prescribed burning in other areas. The Jemez District will accommodate the establishment of the study plots without restriction on random assignment of treatments, subject to needs to protect portions of the mesa and adjacent lands from wildfire.

Treatments: All four core treatments will be installed, 3 replicates at the Jemez Mts. study area, 1 replicate at Valle, and 2 replicates at Virgin Mesa. One of the Virgin Mesa replicates will be established in an area with both 19th and 20th century cohort trees, and the other in an area with only 20th century cohort trees.

Thinning and burning prescriptions: Proposed silvicultural treatments for both areas are a multi-aged or multi-sized residual stand structure using group selection. The goal of the silvicultural treatment will be to enhance structural and spatial diversity in the residual stands with fuels reduction and improved forest health.

***Note:** A potential satellite site is in Bandelier National Monument, however, resources are not currently available for establishment of control and prescribed fire treatment plots to the Fire and Fire Surrogates study specifications.

OHIO HILL COUNTRY

Contacts: Daniel A. Yaussy, Todd Hutchinson [a], Elaine Kennedy Sutherland [b]
[a]Northeastern Research Station, Delaware, OH, and [b] Rocky Mountain Research Station, Missoula, MT;

Cooperating Agencies: US Forest Service--Wayne National Forest; Ohio Division of Forestry, Mead Paper Corporation, The Nature Conservancy

Location: The site is located in southern Ohio on lands managed by the Wayne National Forest, the Ohio Division of Forestry, Mead Paper Corporation, and The Nature Conservancy

Forest type: Oak-Hickory: white oak, chestnut oak, black oak, scarlet oak, hickories, maples, tulips, black gum

Total area available: Ohio contains 3 million ha of timberland of which, approximately, 20% is owned by industry and public agencies. More than 50% of the forested land is classified as sawtimber. Considering areas set aside for other uses and purposes, there is, conservatively, 200,000 ha of forested land available for experimentation.

Topographic range: Highly dissected topography, 10-40% slopes, elevation ranges 200 to 300m

Representative land base: Land base represents forests in the Ohio River Valley including

Kentucky, s. Illinois, s. Indiana, Missouri, and s. Ohio

Fire history: Diaries and descriptions depict frequent under burning by Native Americans during the dormant seasons (Barker 1958, Loskiel 1794, Michaux 1904). Fire histories in similar oak-hickory forests in Missouri (Guyette and Cutter 1997) indicate presettlement fire intervals of 12.4-17.7 years. Postsettlement frequencies were high and less variable spatially, averaging 3.7 years. In Ohio, fire histories developed in second-growth forests 100-150 years old show fire frequencies of 3-5 years, occurring during the dormant season (dominantly in the spring) and very early (April) growing season (Sutherland 1997 and Sutherland, unpublished data).

Contemporary fire hazard: Typical fires occur during the dormant (leaf-off) season, usually in the spring but with a significant fire season during the autumn. Most fires are surface fires, carried primarily by hardwood litter which is highly flammable when dry. Ignition is almost entirely from humans, and lightning fires are extremely rare (Haines et al 1975, Yaussy and Sutherland 1993). Fire suppression effects are evident in the oak-hickory (Region 9 and Kentucky) wildfire records, indicating a reduction in number and size of fires through the early 1980's. Since then, however, fire size has been increasing while fire numbers have held steady. Variation in fire size is also increasing with dramatically higher fire sizes during drought periods (Yaussy and Sutherland, unpublished data). Forest structure has become more closed over the past 60-70 years, with a continuous canopy and litter layer covering the ground. Urban-wildland interfaces issues are a serious consideration in these areas of relatively dense human populations.

Previous work and anticipated time line: A study was initiated in 1994 to investigate the use of prescribed fire in the ecological restoration of oak-hickory forest ecosystems in southern Ohio. Treatments include annual burning for four years, burning at four year intervals, and an unburned control, each of which is replicated four times. Variables similar to the core variables have been monitored annually since 1994. For the proposed study, site selection would occur summer 1999, and plot layout spring 2000. Pre-treatment data collection would occur summer 2000, with thinning and herbicide treatments applied autumn 2000, and prescribed fire spring 2001. Post treatment data collection would occur 2001-2004.

Level of long-term interest: Both the science community and managers have already demonstrated commitment to a four year ongoing project, and have expressed interest in committing resources for the future as well.

Partnerships: The Ohio team, consisting of land managers and scientists, has a well-established working relationship. The site has an existing program for fuel treatments. Laboratory and computational facilities and personnel at the Delaware laboratory and The Ohio State University provide low-cost and established resource for chemical analyses and spatially-related database development.

Site/Plot selection constraints: No management constraints on site or plot selection.

Treatments: All core treatments would be installed

5th treatment: herbicide only, or herbicide X fire

Thinning and burning prescriptions: Thinning is designed to remove poor-quality oaks and low-value species retaining 50% of the canopy, 40% of the basal area (Brose and Van Lear 1998). Herbicide treatments will remove all stems between 5 to 20 cm which are not oak or hickory, reducing the basal area to approximately 70% of the basal area and 100% of the canopy. Fires will be conducted in the early spring during the fire season, primarily March 15-April 15.

SOUTHEASTERN PIEDMONT

Contact: Thomas A. Waldrop, Research Forester, Southern Research Station, Clemson, SC 29631-1003 (864) 656-5054 or **twldrp@clemson.edu**

Cooperating host agency: Clemson University, Department of Forest Resources

Location: On Clemson University grounds, adjacent to the campus

Forest unit: Clemson Experimental Forest

Forest type: Piedmont pine and pine-hardwood type (*Pinus taeda, P. echinata, Quercus alba, Q. coccinea, Q. falcata, Q. stellata*)

Total area available: approximately 17,000 acres

Topographic range: 650 to 750 ft. above mean sea level, including all aspects. Slopes are moderate to steep. Dissected topography will limit the possibility of installing treatments in square blocks.

Representative land base: The Clemson Experimental Forest is representative of the 29 million acres of commercial forest land in the southeastern Piedmont. Of that land base, 72 percent is owned by nonindustrial private landowners who typically do not manage their land and few use any type of fuel-reduction treatment.

Fire history: Southeastern Piedmont ecosystems have historically been disturbance dominated. Native Americans were nomadic hunters and gatherers who used fire as a weapon, to control dense undergrowth, to clear land for cultivation and to ensure favorable habitat for game species. Whites introduced large scale cultivation, and fire suppression had become commonplace by the early 1900's.

Contemporary fire hazard: Fire suppression policies remained intact until the 1950's but prescribed burning was not widely accepted until the 1960's. Consequently, fuels have built since the reforestation period of 1910 through 1940 and have reached dangerous levels. Each year, the State of South Carolina alone suppresses almost 4,500 wildfires. During 1985, ten wildfires averaging over 2,000 acres each were suppressed by the state. Because of the high degree of urban/wildland interface in the region, fires of this size usually destroy homes, businesses, or other private property.

Prior work and anticipated time line: The Clemson Forest is managed by the University for timber production, protection, and multiple uses. Currently there are few constraints to establishing a full installation of FFS treatments. We anticipate being able to begin work in the summer of 2000.

Level of long-term interest: Clemson University has a long history of commitment to research on the Clemson Experimental Forest. Several University faculty members have agreed to participate by sponsoring students to conduct most of the research. Furthermore, the Southern Research Station has a long standing and fruitful relationship with Clemson University.

Partnerships: Clemson University (Departments of Forest Resources, Parks, Recreation and Tourism Management, and Biological Sciences; Strom Thurmond Institute); South Carolina Department of Natural Resources, Game Management Program, Heritage Trust Program, and South Carolina Forestry Commission; Southern Research Station

Site/Plot selection constraints: None

Treatments: All four core treatments will be installed

5th treatment: None planned

Thinning and burning prescriptions: Thinning is designed to remove vertical fuels by eliminating the understory and midstory and reducing stand basal area to a level that protect from crown fires but allow economically-feasible stand management. Burning will be frequent (2- to 3-year rotation) to eliminate sprouting and support a savannah-type community (Waldrop and others 1992).

FLORIDA COASTAL PLAIN

Contact: Robert Dye, Park Manager; Dale D.Wade, Research Forester, Southern Research Station, Athens, GA; Thomas A. Waldrop, Research Forester, Southern Research Station, Clemson, SC

Cooperating host agency: Department of Environmental Protection, Division of Recreation and Parks, Myakka River State Park, Sarasota, Florida

Location: Southwest Florida, 50 miles south of Tampa, Myakka River State Park

Forest type: Both longleaf pine (Pinus palustris) and south Florida slash pine (Pinus elliotti var.densa) are represented with the latter predominating. Advanced successional flatwoods are characterized by ascendent saw palmetto (Serenoa repens) with a canopy of live oak (Quercus virginiana) and sabal palm (Sabal palmetto) with scattered pines.

Total area available: 37,500 acres

Topographic range: All sites represented are at or below 45 feet above mean sea level.

Topography is flat; slope and aspect do not affect site conditions.

Representative land base: Flatwoods occur throughout the southeastern coastal plain and cover approximately 50 percent of the land area of Florida (Abrahamson and Hartnett 1990). The systems under management by Myakka River State Park are representative of all stages of succession possible within flatwoods. Southern Rough or the Palmetto/Gallberry Fuel Model as flatwoods and Florida dry prairie are often called by prescribed burners, is notorious for its destructive, frequently unmanageable, fires when normal fire return intervals are exceeded.

Fire history: The park was once dominated by Florida dry prairie and open, savanna-like pine flatwoods. Flatwoods and prairie systems require frequent fire return intervals (annually to 7 years) to maintain the vegetative aspect and composition which characterizes them; low, herbaceous dominated ground cover with as many as 80 different species per square meter in frequently burned areas having no history of fire interruption.

Contemporary fire hazard: Aggressive fire exclusion and suppression starting in 1934 precipitated advanced succession with heavy fuel build-ups in the highly pyrogenic ground-cover, compositional skewing to woody species (especially saw palmetto), and the advent of far greater densities of pine in those areas of the park successfully "protected". Highly destructive wildfires evolved as early as 1943 and despite the initiation of a prescribed fire program in the early 1970's, which became very active in the 1980's, woody dominance continues to support atypically intense, often severe fires which preclude pine reestablishment and a return to an herbaceous dominated ground-cover. The conditions on this site also exemplify conditions now found throughout Florida; conditions which invited and supported nearly 2300 wildfires in 1998 . These fires burned nearly 500,000 acres, destroyed 126 homes, accounted for 124 injuries and a total damage estimate of 500 million dollars.

Prior work and anticipated time line: A variety of mechanical treatments to reduce fuel loads and reverse successional responses have been used since 1985 at this site. Furthermore, to the maximum extent possible, a 2-3 year fire return has been initiated via prescribed burning. Appropriate management requires the mechanical treatment of more than 10,000 acres of atypical, high-risk fuels in the park however proposals to do so remain unfunded. Implementation of the surrogate study could begin as soon as funding can be gained.

Level of long-term interest: Park management has made a commitment to fuel reduction and restoration of all pyric communities within the park and has tried to be a paradigm for other land managers with similar needs. Research is recognized as critical to the success of ecosystems restoration and long-term relationships have been cultivated with researchers from universities, county, state, and federal agencies and other organizations. Studies on mechanical and burn treatments have existed for nearly 15 years and one on longleaf pine demographics for almost a decade. Interest in the Fire/Fire Surrogate Study is strong.

Partnerships: Southern Research Station, Clemson University, USDA Natural Resources and Conservation Service, Sarasota County Natural Resources Department, Florida Game and Fresh-water Fish Commission, Florida Division of Forestry, Southwest Florida Water Management District

Site/Plot selection constraints: None

Treatments: All core treatments will be installed.

5th treatments: Herbicide application

Thinning and Burning Prescriptions: Thinning is designed to remove vertical fuels by eliminating the understory and midstory and reducing stand basal area to a level that protect from crown fires but allow economically-feasible stand management. Burning will be frequent (1- to 2-year rotation) to eliminate sprouting and support a savannah-type community.

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