Study Plan

for the

Southern Cascades Site

of the

National Study of the Consequences of Fire and Fire Surrogate Treatments

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INTRODUCTION

Over the past century, selective logging, effective fire suppression, and successional changes have resulted in high fire hazard over large areas of the western United States. These changes have been especially evident in ponderosa pine and pine/fir dominated forests. Pine forests over much of their range were historically maintained in relatively open conditions by frequent, low-moderate intensity fires. Effective removal of this process from much of the landscape, coupled with selective logging, has resulted in dense stands, commonly accompanied by a change in species dominance from pine to more shade-tolerant fir. Conditions such as these are widely represented in California. Unusually large and severe fires in California forests in recent years have aroused public concern, and manifested the need for well-designed management treatments to reduce the scale or intensity of such events, particularly in areas where humans or property are at risk. To address this concern, the National Joint Fire Science Program funded a nationwide study, National Study of the Consequences of Fire and Fire Surrogate Treatments (FFS), to evaluate the effects on a suite of resources of alternative fire and fire surrogate treatments designed to reduce fire hazard. The overall study consists of 13 sites nationally, and incorporates a common experimental design, including four similar treatments and consistent response variables and sampling protocols at each site.

The Southern Cascade Range Site, located in the Goosenest Adaptive Management area of the Goosenest Ranger District, Klamath National Forest, California, was selected as one of 11 original sites in the Fire/Fire Surrogates (FFS) national network (Fig 1).

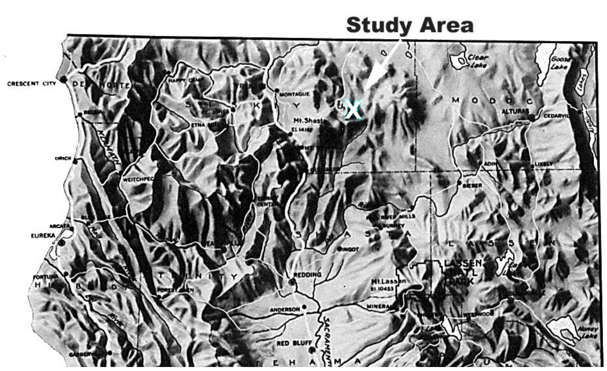

Figure 1. Vicinity Map

Current forests dominated by white fir/ponderosa pine developed after heavy cutting in the early 1900s, and are representative of thousands of acres of forests with similar disturbance histories east of the Cascade/Sierra Nevada crests. Recent large, destructive wildfires in California during the summers of 1977, 1987, 1990, 1992, 1999, and 2001 provide stark evidence of the potential of existing forest conditions for extensive and severe fires. However, before treatments to address these conditions can begin, a desired condition or range of conditions must be determined.

Detailed dendrochronological work in ponderosa and Jeffrey pine dominated forests east of the Cascade/Sierra Nevada crests (Agee 1993, 1994; Skinner and Chang

1996; Taylor 2000) profile a pine dominated forest type that was originally moderately open, uneven-aged, large-tree dominated, and shaped by frequent low-intensity fires. Collectively, these sources provide the basis for developing a desired range of conditions for pine/white fir forests. For purposes of this study, a desired future condition will be defined as a stand density/structure/species composition condition (or range of conditions) that has the potential to accelerate and sustain the large-tree associated elements of late-successional forests originally created and sustained by historical disturbance processes such as frequent fires (USDA Forest Service 1996). An additional requirement of the FFS is that "…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" (Weatherspoon and McIver 2000).

OBJECTIVES

The national FFS study plan provides broad objectives for the overall study. The Fire/Fire Surrogates studies are designed to be interdisciplinary in nature. However, for simplicity and organizational purposes, both objectives and methods will be presented in a disciplinary format. The primary objectives of this study are:

1. Determine the effects of alternative cutting, burning, and cutting/burning treatments on tree growth, tree mortality, tree regeneration, and undergrowth species composition and abundance.
2. Determine the effects of alternative treatments on the type, volume, size, and distribution of fuel loadings over time and their effects on modeled fire behavior.
3. Determine the effects of alternative treatments on soil physical, chemical, and microbial properties.
4. Determine the effects of alternative treatments on nest productivity of birds, functional response of bark gleaners, and abundance and diversity of small mammals and herpetofauna.
5. Determine the effects of alternative treatments on bark beetle populations, prevalence of above- and below-ground pathogens, and associated tree mortality.
6. Determine the treatment costs and product revenues (if applicable) associated with alternative treatment scenarios.

METHODS

DESIGN

A common experimental design is being utilized at all sites in the Fire/Fire Surrogates network. The core design is a randomized design, with four treatments replicated three times. The four treatments are:

1. Cut-only consists of thinning from below and selection cutting. Trees were marked for leave, with species preference of SP>IC>PP>RF>WF. Leave trees included all trees >30" dbh regardless of species, all sugar pine and incense cedar, and all ponderosa pine in dominant and codominant positions. Cutting was based on spacing. Where trees were closer than the diameter of either a 'leave' tree or, if no leave tree, the larger tree in inches as feet plus five feet, the smaller trees were removed. Small openings amounting to approximately 15% of each of the treatment plot were created and planted in areas dominated by white fir. Cutting was completed in the summers of 1998 and 1999. There will be no follow-up fuel treatments.
2. Cut-burn consists of a thinning from below and selection cutting as described under Cut-only followed by prescribed fire of surface fuels. Cutting for plots used in FFS was completed in the summers of 1998 (plot 6) and 1999 (plots 13 and 15). Understory burning was completed in the fall of 2001.
3. Burn-only consists of prescribed burning in the fall. Initial burning will occur in the fall of 2002. Attempting to achieve the FFS 80/80 objective in a single burn would risk killing most overstory trees in the treatment units because of the necessary fire intensity. Therefore, subsequent burning will occur as fuels again accumulate to levels sufficient to achieve more thinning without significant damage to overstory trees. We anticipate several burns over at least a decade will be necessary to achieve the 80/80 objective.
4. Control (no cutting or burning).

These four treatments are being evaluated because they are representative of the primary treatment options that managers are considering for hazard reduction and ecosystem restoration in many forest areas in the western U.S. For this site, the Cut-only treatment will not have follow-up fuel treatment for two reasons: 1) it is common practice in northern California to not follow thinning with further fuels treatment where prescribed fire is not used and 2) waiting for the surface fuel to decompose after cutting is expected to take a similar amount of time as the several burn treatments that are expected in the Burn-only areas to meet the 80/80 FFS objective. In this way, we will be able to assess the time required to achieve the 80/80 objective for each treatment in addition to the costs and ecological effects.

The four FFS core treatments emerge from four common hypotheses for hazard reduction/ecosystem restoration (Weatherspoon and McIver 2000):

Hypothesis 1: Forest ecosystems are best conserved by passive management, with no direct manipulation of ecological processes (i.e., fire) or forest structure (i.e., cutting), except for a continuation of fire suppression, which leads to the control “treatment.”

Hypothesis 2: Forest ecosystems are best conserved by restoring ecosystem processes (i.e., by reintroducing frequent, low-intensity fire), which leads to the burn-only treatment.

Hypothesis 3: Forest ecosystems are best conserved by restoring ecosystem structure (i.e., by using judicious silvicultural cutting methods to restore density, species composition, and spatial pattern of the tree component), which leads to the cut-only treatment.

Hypothesis 4: Restoration of sustainable forest ecosystems requires both process and structural restoration, which leads to the cut-burn treatment.

Block and Treatment Unit Layout

Treatment plots were randomly chosen from among existing treatment plots within Pine Emphasis/No Burn, Pine Emphasis/Burn, and Control treatments of the Little Horse Peak Interdisciplinary Study (LHPIS). The LHPIS treatments were replicated 5 times and consisted of treatment plots of approximately 40 ha each plus buffers. The first three plots Cut in each of the Cut and Cut-Burn treatments were chosen for the FFS study. The three Control plots were selected randomly from the five LHPIS Control plots (Fig 2). The 10 ha FFS block was then subjectively located within each LHPIS plot to avoid inclusion of artificial regeneration units and roads.

The LHPIS plots used in the FFS study are:

Control Plots	4, 10, 18
Thin Only	5, 9, 12
Thin & Burn	6, 13, 15

The Fire Only plots added for FFS are designated: F1, F2, F3

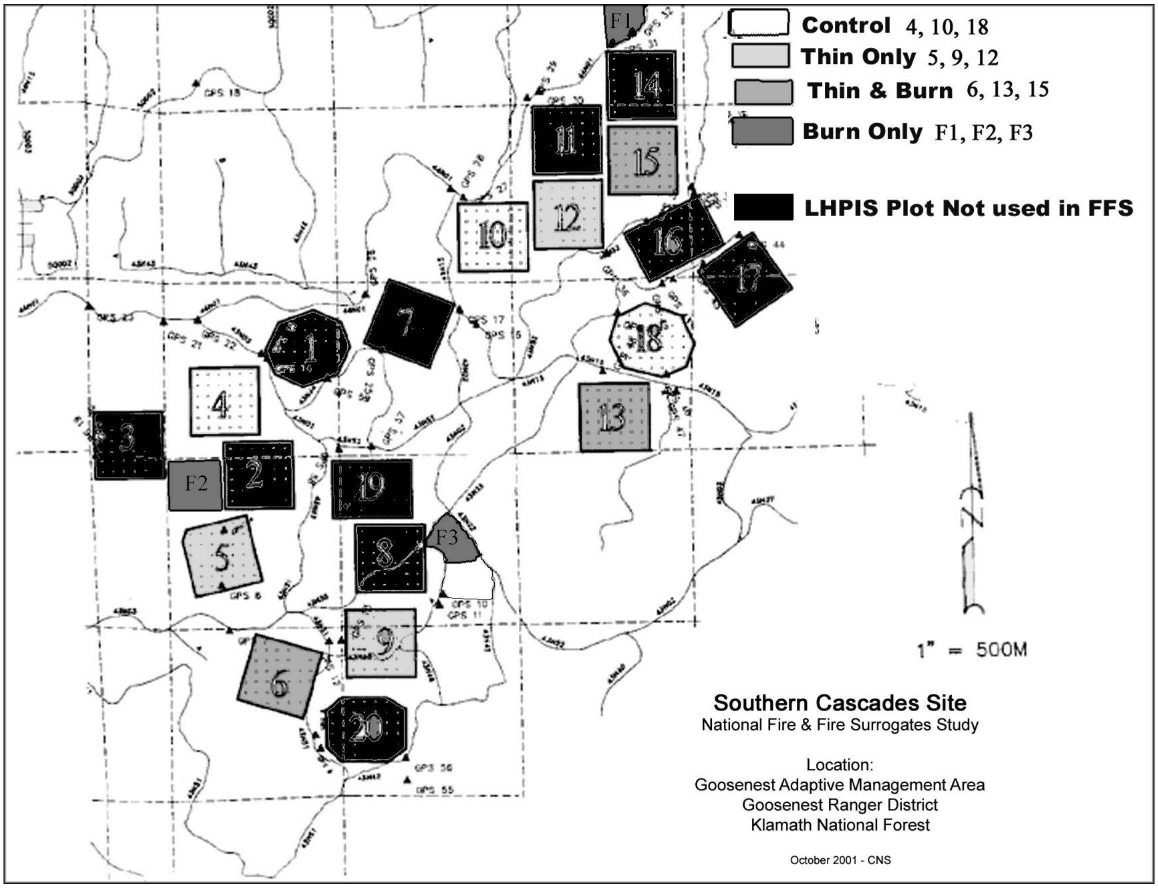

Figure 2: Map of Treatment Plots. Plots not used in FFS study are plots used in LHPIS.

The LHPIS study does not have a Burn Only treatment. A recon of the LHPIS study area provided locations of possible Burn Only treatment plots located near the LHPIS Big-Tree Emphasis plots. Three of these potential Burn Only plots were selected based on similarity of tree stands to the LHPIS Big-tree treatment plots (trees/ha, diameter distribution, species composition). The LHPIS Big-tree treatment plots were originally randomly selected.

Permanent Plot Establishment

PSW personnel will install the grid of 36 permanent grid points from which all sampling is based (including vegetation structure and composition, insects, soils, wildlife, and diseases). Each of the four 10-ha core treatment areas will have 36 (typically 6 x 6) permanent grid point centers located on a 50-meter grid. Point centers will be identified with an 18-inch length of 0.5-inch rebar driven into the ground to within 1 cm of the ground surface and capped with a stamped brass cap. A 42-inch U channel will be placed on the north side of the grid marker and painted green and yellow.

Plot and Subplot Layout

Ten 20x50 m Whittaker plots were established at grid points 02, 04, 09, 11, 13, 16, 20, 23, 25, and 27 within each treatment unit (Fig.3), The long side of the plots began at the measurement grid point and followed a southerly direction so that it ended at another grid point.

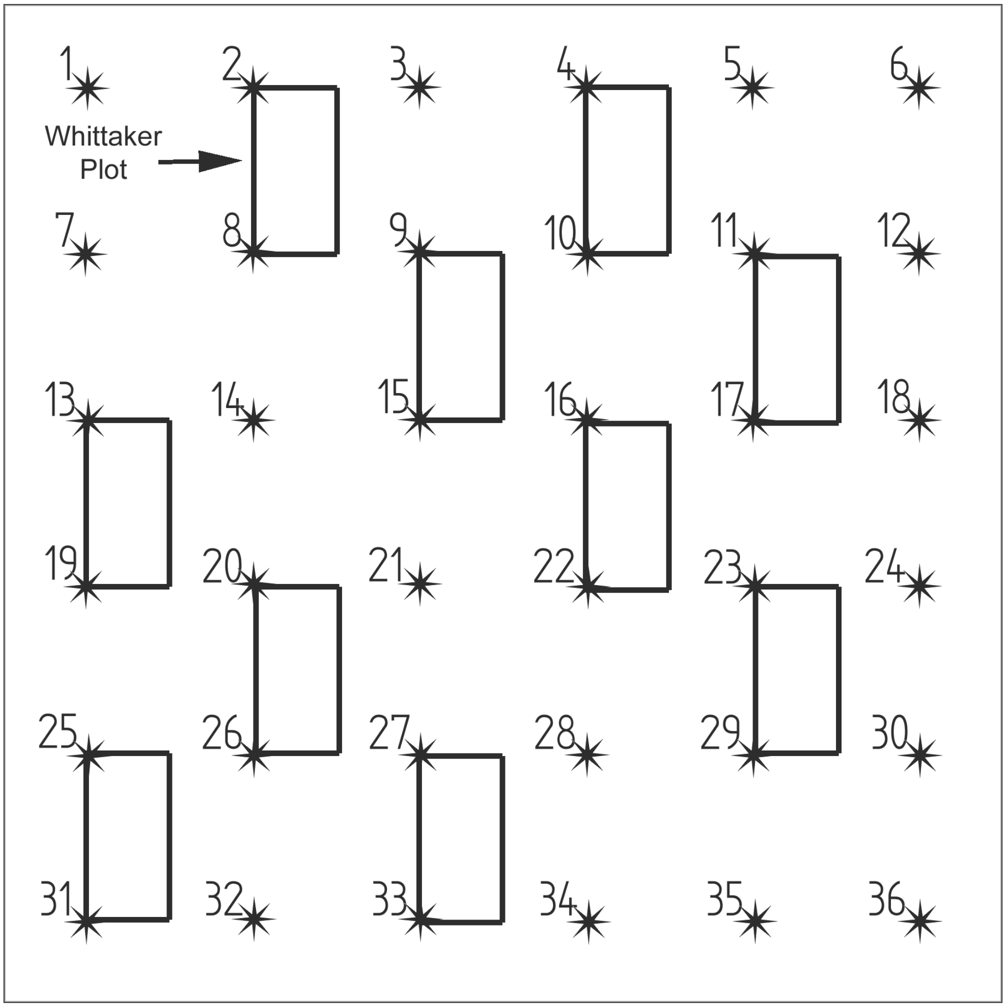

Figure 3: Treatment Plot Layout

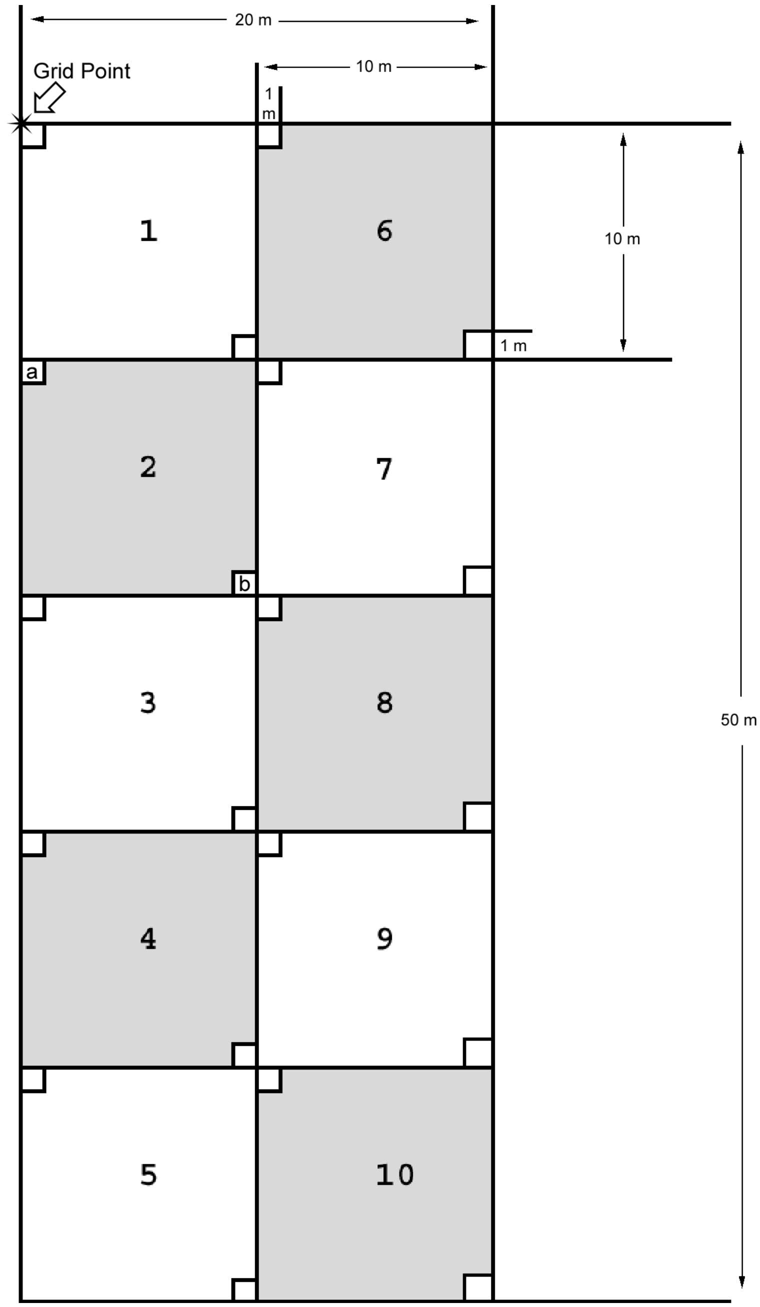

Figure 4: Whittaker plot layout.

Each Whittaker plot will be subdivided into ten, 10 x 10 m subplots (Fig. 4). Two, 1 x 1 m square quadrats will then be installed in opposite corners of each 10 x 10 m subplot for the purpose of sampling seedlings and undergrowth vegetation < 1 m in height. At the time of measurement, cloth tapes will be stretched along the two 50-m outer sides of the sample plot and another parallel and half way between the first two. Other tapes are placed perpendicular to those on the long sides and at 10-m intervals.

Exceptions to the FFS National Protocols

The FFS national protocols state that it is desirable to have at least one season of data collection before treatments begin to serve as a baseline. However, since the Southern Cascades Site will be located within the Little Horse Peak Interdisciplinary Study it will not be possible to gather pre-treatment data according to FFS protocols. The LHPIS mechanical treatments have already been completed. We will be able to gather data for post-mechanical treatments before application of prescribed fire and pre-treatment data for the Burn Only plots. It should be noted that this should not significantly reduce the value of the study, since the study is designed to compare effects among treatments and not as a before/after study. However, we will not be able to assess the degree of pre-treatment similarity/dissimilarity of the study plots for those variables (e.g., soils) that have no pre-treatment data.

The LHPIS does have pre-treatment data for some variables: vegetation, fuels, wildlife, and insects. However, these data were collected following different protocols and referenced to a 100 meter grid rather than the 50 meter grid of the FFS study. This affords us the opportunity to compare for similar variables the results from the different sampling protocols.

<u>VEGETATION</u>

Sampling for the vegetation component of the overall F/FS study was focused on the 20 x 50 m Whittaker plots assigned to 10 of the 36 grid points located within each 10-ha treatment plot (Fig. 4). Trees >10 cm diameter breast height (DBH - 1.4 m) will be recorded on the entire 20 x 50 m Whittaker plot in the Cut and Cut/Burn plots and recorded on half of the 10 x10m subplots nested within the Whittaker plots in the Control and Burn Only plots; saplings (trees with DBH >0.1 cm but $\leq$10 cm) and shrubs will be sampled on half of the 10 x 10 m subplots nested within the Whittaker plots; and seedlings (<1.4 m tall), forbs, and grasses/sedges will be sampled on 1 x 1 m quadrats nested within each of the 10 x 10 m subplots.

Trees

All trees >10 cm DBH on the entire 20 x 50 m Whittaker plot in the Thin Only and Thin & Burn treatments will be measured and recorded. However, in the Fire Only and Control treatments the plots are too dense to sample at that level so all trees >10 cm DBH in 5 of the 10 x 10 subplots (02, 04, 06, 08, 10), will be measured (shaded areas in Fig 4). An aluminum nail was used to place a numbered aluminum tag on each measured/recorded tree, approximately 1.4 m above the ground. Each tree will be recorded by tree number, species, DBH, height, height to live crown, height to dead crown, crown condition, % live crown, crown position and tree damage. For trees that meet the Cut criteris, increment cores will be extracted at 20 cm. above the ground in the Control and Fire Only treatments to establish product age. In the Thinning Only and

Thinning with Fire treatments the rings on three stumps of trees harvested in this project will be counted to establish product age.

Crown Cover

At each Whittaker plot, 10 points, one in 'a' microplot of each 10m x 10m subplot will be recorded for crown cover as 0 or 1 using a moose horn scope.

Saplings

Saplings, defined as trees >1.4 m tall and <10 cm DBH, will be sampled on five selected 10 x 10 m subplots (02, 04, 06, 08, 10) on each Whittaker plot (shaded areas in Fig 4). Saplings rooted within the 10 x 10 m subplot will be recorded by species, status (live or dead) and diameter class code, where:

1 = 0.1 to 3.0 cm DBH
2 = 3.1 to 6.0 cm DBH
3 = 6.1 to 10.0 cm DBH

Shrubs

Shrubs will be defined as any non-tree vegetation possessing a woody stem and over 0.5 m tall. Shrub species will be identified and ocularly estimated for cover on five selected 10 x 10 m subplots (i.e., 02, 04, 06, 08, 10) on each Whittaker plot (shaded areas in Fig 4). Percent cover will be estimated for every shrub species and recorded.

Seedlings

Seedlings, defined as all trees <1.4 m in height, will be tallied by species and origin class (germinant or established plant) on all 20 1 x 1 m quadrats within each Whittaker plot. Density and cover class will be also recorded, where cover class code:

0 = 0%	1 = <1%	2 = 1-10%	3 = 11-25%
4 = 26-50%	5 = 51-75%	6 = 76-100%	

For seedlings rooted outside the 1 x 1 m quadrats, those portions of crowns extending within the vertical projection of the quadrat were included in percent coverage estimates. Conversely, for seedlings rooted within the quadrat, those portions of crowns extending outside the quadrat boundaries will not be included in percent coverage estimates.

Grasses/Sedges/Forbs

Grasses, sedges, forbs and shrubs <0.5 m tall will be identified by species on all of the 20 1 x 1 m quadrats within each Whittaker plot. Percent cover will be occularly estimated for each species, and recorded by a coverage code:

0 = 0%	1 = <1%	2 = 1-10%	3 = 11-25%
4 = 26-50%	5 = 51-75%	6 = 76-100%	

Percent cover will be estimated for each species as if no other species is present; hence if coverages of all species are summed, they could exceed 100%. Plant origin will be recorded: germinant, established plant, or sprout. After the 20 1 x 1 m quadrats are examined, the entire 20 x 50 m Whittaker plot will be examined in an attempt to find species not found on any of the 1 x 1 m quadrats. Any additional species will be recorded.

WOODY FUELS, FOREST FLOOR, AND FIRE BEHAVIOR

Protocols for this portion of the sampling will directly follow those presented in the FFS proposal (Weatherspoon and McIver 2000). As discussed in the proposal, the vegetation sampling crew will provide additional overstory and understory fuels information. See the Fuel and Fire Behavior section of Appendix A-2, Protocols in the national FFS study plan (McIver 2001).

Coarse Woody Debris Sampling

Coarse woody debris (CWD) will be sampled at odd-numbered grid points in every treatment unit, for a sample of 18 points per unit. A single transect 20-m long will be run along the same azimuth as the first fuel transect, starting at the grid point. This transect will be used as the centerline for a 4 x 20 m strip plot. Within the strip plot, only logs with a total length greater than one m and an actual large end diameter greater than 15.0 cm will be measured. For each qualifying log, several measurements will be taken. First the large-end diameter will be obtained. This will be the largest diameter of the portion of the log located within the strip plot. If the largest end of the log is out of the plot, the diameter of the log at the edge of the strip plot will be recorded as the large-end diameter. A similar protocol will be used for the small-end diameter. However, small-end diameter will be only measured down to 7.6 cm – anything smaller will be ignored. If an otherwise qualifying log lay with just the tip in the plot and the tip is less than 7.6 cm, the log will not be counted. The length of the log within the strip plot will then be measured, excluding the tip smaller than 7.6 cm. An indicator code will be then assigned to the log:

0 = Midpoint of the log out of the plot

1 = Midpoint of log in the plot

A decomposition class will also be assessed for the log:

1 = Wood texture is intact; log may be elevated on the support points; twigs are present; bark is intact; original wood color; log is round.
2 = Wood texture is sound or becoming soft; log may be elevated on support points, but sagging slightly; twigs are absent; bark is intact; original wood color; log is still round.
3 = Wood texture is hard; log is sagging near ground; twigs are absent; bark has begun to fall off; original color of wood is faded; log is still round.
4 = Texture of wood is soft; all of log is on the ground; blocky pieces; twigs are absent; bark is absent; wood has faded to light yellow or gray; shape of log is round to oval.
5 = Wood texture is soft and powdery; log fully on/in the ground; twigs are absent; bark is absent; wood has faded to light yellow or gray; shape of log is oval.

Finally, the tree species associated with the log will be determined and recorded.

<u>SOILS</u>

Forest Floor

At the network scale, it was agreed that the spatial pattern of the soil and forest floor sampling would 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 and N content of forest floor, we will take six samples per plot, with two coming from the subplot and four from the corners of the larger 0.1 ha plot. Sampling will take place in July of each year.

As our sites typically lack a continuous, well-defined, easily differentiated humus layer common in many conifer forests, we will sample the unconsolidated litter and fragmented layers as a single unit. A steel 15 cm X 15 cm X 10 cm forest floor sampler will be used to obtain these samples and they will be returned to the laboratory in paper bags. Forest floor samples will be dried at 70C to constant weight and then weighed to determine total forest floor mass.

After drying and weighing, the six samples of the forest floor will be composited into two composite samples, one consisting of the four corner samples and the other of the two samples from the subplot. Subsamples of these composite forest floor samples will be analyzed for C content by Walkley-Black oxidation/titration (Nelson and Sommers 1982). Subsamples will also be digested in H_2SO_4:H_2O_2 and analyzed for total:N by colorimetry on a BioTek Microplate Reader. Should the use of an automated C:N analyzer become available to us, we will switch our analysis to this instrument. The methods used in a C:N analyzer protocol are preferable to the methods we propose, as automated analysis is, in the long run, cheaper, produces less toxic waste and is safer for lab personnel. However, cost constraints have eliminated the purchase of an automated C:N analyzer as an option.

Mineral soil will also be sampled for C, N, and macronutrient content using the sample protocol and timing indicated above for the forest floor. Total C and N in mineral soil will be analyzed as above as well. Mineral soil samples will be extracted for Ca, Mg, and K with 1M NH_4OAC (Thomas 1982), for Al and P with 0.5M K_2SO_4, (Olsen and Sommers 1982). Cation analysis will be done by atomic absorption spectroscopy, and P analyses by stannous chloride/molybdate colorimetric method. Soil pH will be determined in a 1/5 w/v slurry. Previous studies in this site have demonstrated that sampling the uppermost 20cm of the A_1 horizon is sufficient to characterize the chemical and physical characteristics of the soils) (Riemenschneider 1964).

Analysis of nutrient availability (i.e. N mineralization and nitrification) will be done during mid-June to mid-July of each year using aerobic, *in situ* incubations for measurement of N mineralization and nitrification. This sampling timing corresponds to the early season peak in plant growth and microbial activity. Analysis of N mineralization and nitrification by this method involves the following field steps:

(1) placing 3 PVC pipes in the ground at the dedicated subplot,
(2) extracting one sample immediately and returning it to the lab,
(3) covering one of the pipes while leaving the other uncovered,
(4) after 20-30 days, the two samples, which have remained *in situ* in the PVC pipes, are recovered and extracted and returned to the lab for inorganic N the same way.

Net N mineralization is calculated as the difference in total inorganic N (NH_4+NO_3) between the initial samples and those incubated *in situ* for 20-30 days. Proportional nitrification is calculated as the net difference in NO_3 concentration between the initial and incubated samples divided by the total NH_4 available for nitrification (i.e. initial NH_4 + net N mineralization) (Raison et al. 1987).

Each summer we will establish a transect along the long axis of each 0.1 ha vegetation plot. Along this transect we will select 20 random points at distances of 1-3 m. At each point penetrometer readings of soil strength of 15cm will be taken and the condition of a 1m2 circular plot surrounding that point assessed using the categories listed in Table 1.

Table 1. Surface disturbance classes used to assess physical soil disturbance at Southern Cascades

Class	Category	Description
0	Undisturbed	Soils undisturbed and considered to be in a natural state. Vegetation present with well-established root systems. No evidence of past equipment operation.
1	Slight	Site in virtually undisturbed. Vegetation present or redeveloping with well-established root systems. Organic layers intact. Surface soil intact and uncompacted. Impressions of wheel tracks may be present.
3	Moderate	Vegetation present or redeveloping. Old organic layers partially intact or missing; new litter layer developing. Surface soil intact but puddled and/or compacted. Wheel tracks or cleat marks evident.
4	High	Vegetation shows signs of stress. Organic layer removed. Surface soils partially or totally removed, or may be mixed with subsoil. Some evidence of blading, gouging, or turning.
5	Severe	Vegetation restricted or severely stunted. Organic layer removed. New litter layer redeveloping or absent. Surface soil absent. Subsoil exposed, compacted, or removed. Evidence of excessive blading and gouging. Hydrology affected.

Using these methods, soil exposure at the plot level will be considered the proportion of transect points classified 3 or higher divided by the total number of points per plot. Similarly, the proportion of the soil that will be considered uncharacteristically compacted is the number of transect points with penetrometer readings greater than 150% of the median for that plot determined in the pretreatment sampling divided by the total number of penetrometer readings per plot. Total soil disturbance (%area disturbed) is the number of exposed plus compacted points minus points in which both disturbances have occurred, divided by the total number of assessed points per unit.

The primary method used for biodiversity analyses will be a suite of soil enzyme activity determinations, paralleling similar studies done as part of our larger prescribed burning-ecosystem management research program for the last six years. Each August/September two samples per Whittaker plot, taken from opposite corners will be analyzed for the activity of acid phosphatase, phenol oxidase, and chitinase using p-nitrophenyl-linked substrates and spectrophotometric methods (Decker et al. 1999, Boerner et al. 2000). Previous studies in the region have demonstrated that late season sampling for enzyme activity reduces within-plot variability and maximizes the probability that among-plot treatment effects can be resolved.

PATHOLOGY

Protocols for pathology sampling will follow those presented in the national proposal (Weatherspoon and McIver 2000) except that there will be no pre-treatment sampling. All sampling will follow completion of treatments. This is because the FFS Southern Cascades site is being conducted within an existing study where thinning treatments have been completed. See the Pathology section of Appendix A-2, Protocols of the national FFS study plan (McIver 2001).

ENTOMOLOGY

Protocols for entomology sampling will follow those presented in the national proposal (Weatherspoon and McIver 2000) except that pre-treatment data collection for Cut-only and Cut-burn treatments was done on a 100m grid rather than the FFS 50m grid. This is because the FFS Southern Cascades site is being conducted within an existing study where a 100m grid was used. See the Entomology section of Appendix A-2, Protocols of the national FFS study plan (McIver 2001).

WILDLIFE

Protocols for wildlifer sampling will follow those presented in the national proposal (Weatherspoon and McIver 2000) except that pre-treatment data collection for Cut-only and Cut-burn treatments was done on a 100m grid rather than the FFS 50m grid. This is because the FFS Southern Cascades site is being conducted within an existing study where a 100m grid was used. See the Wildlife section of Appendix A-2, Protocols of the national FFS study plan (McIver 2001).

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