Fire and Fire Surrogates National Study

Mission Creek Site
Okanogan and Wenatchee National Forests

A cooperative project between the Forest Service and University of Washington:

U.S.D.A. Forest Service,
Pacific Northwest Research Station,
Wenatchee Forestry Sciences Laboratory
and the
Okanogan and Wenatchee National Forests

University of Washington,
College of Forest Resources

Principal Investigators in Alphabetical Order:

James K. Agee, UW
Robert L. Edmonds, UW
William L. Gaines, FS
Richy J. Harrod, FS
Paul F. Hessburg, FS
John F. Lehmkuhl, FS
Darlene Zabowski, UW

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Introduction

Many U.S. forests, especially those with historically short-interval, low- to moderate-severity fire regimes, are 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. Both ecological and economic aspects must 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 also 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.

National Objectives

Objectives of the national project are as follows:

1. Quantify the initial effects (first five years) of fire and fire surrogate treatments on a number of specific core response variables within the general groupings of (a) vegetation, (b) fuel and fire behavior, (c) soils and forest floor (including relation to local hydrology), (d) wildlife, (e) entomology, (f) pathology, and (g) treatment costs and utilization economics.
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. 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 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.
4. 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.
5. 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.
6. Over the life of the study, quantify the ecological and economic consequences of fire and fire surrogate treatments in a number of forest types and conditions in the United States. Develop and validate models of ecosystem structure and function, and successively refine recommendations for ecosystem management.

National Research Approach

Experimental Design

Overview. 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 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.

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.

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.

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 vegetation, fuel and fire behavior, soils and forest floor, wildlife, entomology, pathology, and treatment costs and utilization economics. (A social science component probably will be linked to the study through no-cost cooperative arrangements and/or non-JFSP funding.) 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 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.

The Mission Creek Site

The Mission Creek site is located on the Wenatchee National Forest. During 1999, approximately 30 candidate stands were identified in the Mission Creek watershed and a few smaller watersheds immediately adjacent to the west. From these 30 stands, the 12 treatment units were chosen (Figure M-1). Constraints included no units on north aspects, or average unit slopes >40% (there are locally steeper slopes), or >10% rock or nonforest vegetation, or areas with known plant or animal species of concern (except for survey and manage species). Twelve (12) were randomly selected as study units, and assignments of control, burn only, thin/burn, and thin only, with three (3) replications per treatment, were randomly done. Most study units are remote and access is difficult. Most are not immediately adjacent to roads, and will not be, as the burn units do not require road access and the thin units will be helicopter-yarded. Boundaries are mapped with GPS. Each unit is gridded with a 40 m grid (this is the wildlife grid spacing, and we thought it best to maintain one grid matrix, rather than independently overlay a 50 m grid which is the national standard – see figure M-2). Surveys for "Survey and Manage" species under the Northwest Forest Plan are complete on all 12 plots.

1. **Timeline**. Our timeline remains: Yr 2000 is pre-treatment sampling; Yr 2001 is pre-treatment sampling, then thinning treatment; Yr 2002 is fall burning of burn-and-thin and burn-only units; and, Yrs 2003 and 2004 are post-treatment sampling. We have a cooperative agreement in effect that transfers funds from the PNW Research Station to UW, College of Forest Resources (CFR) for the CFR portion of the project.

2. **Data Archiving**. Local data archiving will be at the PNW lab in Wenatchee, 1133 N. Western Avenue, Wenatchee, Washington 98801.

3. **Costs of Treatment**. We still have no commitment of national fuels dollars for the burning treatments, as proposed to be negotiated with the Washington Office. The Pacific Northwest Region Office in Portland and the Okanogan and Wenatchee National Forests are very supportive of the project, but have not committed funds for this purpose.

4. **Plans for Data Analysis and Publication**. At this stage it is premature to speculate as to when and where publications will appear. All principal investigators on the project have productive records of publication. We anticipate that there will be at least one interdisciplinary monograph summarizing the project as a whole, several graduate theses, and a number of refereed journal publications.

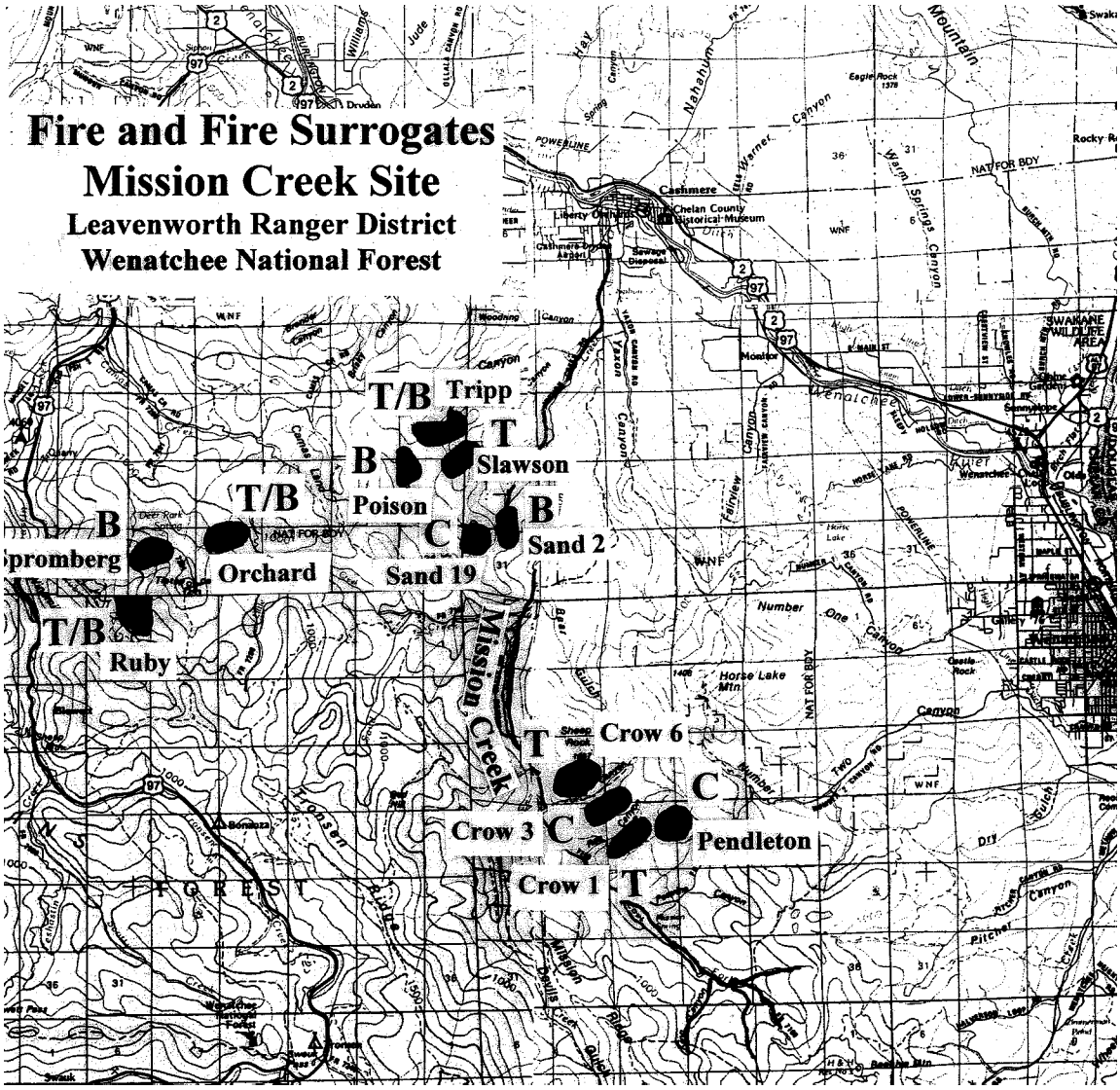

Figure M-1. Location of Mission Creek Study Site and Treatment Units. Each unit is labeled with the Unit Name and the treatment (C= control, T = thin, B = burn, T/B = thin and burn).

North ↑

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12
F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12
G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12
H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12
J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12
K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12
L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12

Figure M-2. UTM Grid Cell Numbering: (40-m interval)

First Year Deliverables

1. **Develop a detailed study plan** in coordination with Forest Service cooperators that will be submitted to the Network Manager (Dr. James McIver at the La Grande PNW FSL Lab) by September 15, 2000. This is the current document in draft form.

2. **Begin and continue pre-treatment data collection** as noted above for vegetation, fuels/fire behavior, wildlife, soils, soil biodiversity, and entomology/pathology. This work will continue through the second year and will require a second year of funding.

3. **Produce a one-page interpretive insert** that can be placed in the national FFS interpretive brochure.

Vegetation
Richy J. Harrod, Okanogan-Wenatchee NFs

Introduction

The vegetation component of the national Fire and Fire Surrogate Study 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 distribution
- Bole scarring and crown condition

Repeated photographic images from permanent photo points
Stand composition
Shifts in abundance and diversity
Stand function
Tree radial growth rates (diameter changes)
Shrub and herb layer structure
Cover and frequency by species and life form
Shrub and herb layer composition
Shifts in abundance and diversity

For the Mission Creek site, the basic vegetation questions to be addressed are:

1. What are the initial (2 yr) effects of prescribed fire and thinning on stand density, tree condition, patch/gap distribution, and snag distribution?
2. What are the initial (2 yr) effects of prescribed fire and thinning on understory composition, species richness, and species cover and frequency?

In general, it is hypothesized that the short-term response of prescribed fire and thinning will have differential effects on overstory and understory structure and composition. Table V-1 summarizes the hypothesized treatment effects for the variables measured.

Table V-1. Hypothesized short-term response to prescribed fire and thinning for each vegetation variable measured at the Mission Creek site. An increase in a certain variable are indicated by "+", a decrease by "-", and neutral or unchanged response by "o". Large increases or decreases indicated by "++" or "--."

Variable	Thin	Burn	Thin/Burn	Control
Seedling/Sapling Density	-	--	--	o
Tree Height	o	o	o	o
Tree dbh	o	o	o	o
Tree Crown Condition	o	o	o	o
Height to Live Crown	o	+	++	o
Height to Dead Crown	o	+	+	o
Canopy Cover	-	--	-	o
Bole Scarring	o	+	o	o
Tree Age	o	o	o	o
Shrub Cover*	+	+	++	o
Herb Cover*	+	o	++	o
Species Richness (0.1 ha)	+	o	++	o
Gap/Patch Size	+	++	+	o

*depending on the speed of recovery, shrub and herb response could be -, 0, or + over the short term

Vegetation Sampling Design

At the Mission Creek FFS site, we have attempted to use a sampling scheme that incorporates all the elements indicated above and is consistent with a similar, nearby study (Pendleton Study). Some of the vegetation data from the Pendleton Study could be combined with vegetation data collected in the Mission Creek FFS, thereby increasing our sample size.

The specific core vegetation variables to be measured are:

Forest Structure

- Tree (>1.37 m height) and seedling/sapling density by species
- Tree status (live or dead)
- Tree height
- Tree dbh
- Tree crown condition
- Tree height to live and dead crown
- Canopy cover
- Snag density
- Bole scarring
- Shrub and herb cover

Forest Composition

- Species richness at 0.1 ha scale

Forest Function

- Change in tree dbh

Landscape Pattern

Gap/patch distribution

Forest Vegetation. In the 10 ha study units, the largest standing trees (95th percentile in dbh, determined from plot samples) will be censused and individually identified. For each tree, species, dbh, status (live, dead), bole scarring, height, live and dead crown ratios, height to base of dead and live crown, and crown condition (Keen's (1943) for pine and Hawksworth (1977) for Douglas-fir).

Forest vegetation will be sampled in 20 x 50 m plots scattered across the units and referenced to the grid points (Fig. 1). Based on analyses of the Pendleton vegetation data, it was determined that 6 plots per unit would adequately account for species diversity and provide reasonable estimates of species cover. Plots will be located in continuous forest vegetation, which will be stratified by plant association (Lillybridge et al. 1995). Preliminary field work has shown that most units consist of two forest plant associations, so in each unit we will attempt to place three plots in each plant association. Within the entire plot, each tree >1.37 m tall will be identified and the following attributes recorded: dbh, status (live, dead), bole scarring, height, height to base of the live crown, and crown condition (Keen's (1943) for pine and Hawksworth (1977) for Douglas-fir). Canopy closure will be measured in the center of the plot using a Lemmon Spherical Densiometer, Model-C. Also, photosynthetically active radiation (PAR in µmols) will be measured every 5 m on the center line of the plot using a Licor 250i light meter. Each measurement will consist of a mean from a 10 sec. Reading.

Nested 5 x 10 m subplots placed in a continuous 10 x 50 m strip in the center of each 20 x 50 m plot will be used to collect shrub cover (Fig. 1). Cover will be ocularly estimated to the nearest percentage point. Shrubs are considered those species with a persistent woody base; a list of shrub species has been generated from the Pendleton Study.

Also nested within the 20 x 50 m plots will be 20, 1 x 1 m quadrats located in a stratified random fashion (Fig. 1). In each quadrat, all herbaceous species will be inventoried and their cover ocularly estimated to the nearest percentage point. Species not inventoried in the quadrats but occurring within the plot (20 x 50 m) will also be recorded. Cover, density, and height of tree seedlings/saplings <1.37 m tall will be recorded. Percent of plot that is bareground, litter/duff, cryptogams, rock, or tree boles also will be recorded.

Non-forest Vegetation. The Mission Creek site is dominated by ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) plant associations in a spatially complex matrix with bitterbrush (*Purshia tridentata*) communities. Bitterbrush is an important browse species for deer and these communities may have unique responses to the various treatments.

Species-area curves and cover graphs were compiled from data collected in several locations scattered throughout the study area. This preliminary analysis suggested an area of 600 m^2 in each unit would adequately account for species diversity and cover. Three 10 x 20 m plots will be randomly assigned to the pool of non-forest polygons designated on aerial photos and referenced to the grid points. Species cover will be ocularly estimated on the entire plot to the nearest percentage point.

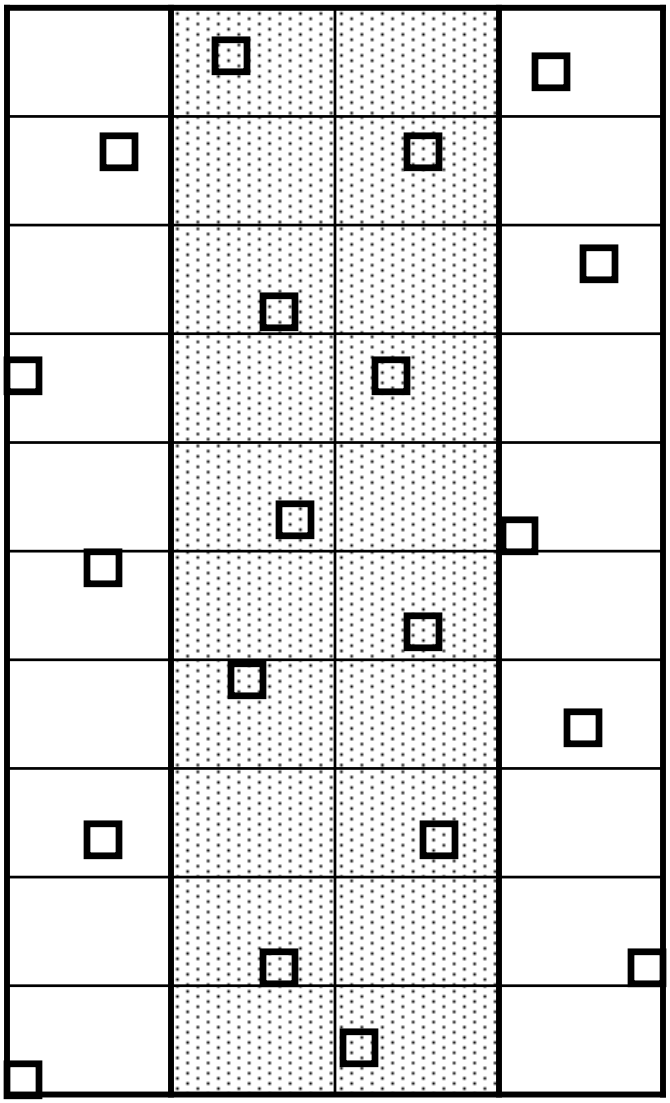

Figure V-1. Graphical representation of 20 x 50 m plots used for vegetation sampling. Tree measurements are made on the entire plot, shrub cover is sampled in a 10 x 50 m strip in the center of the plot (shaded area), and herb cover is estimated in 20, 1 x 1 m quadrats.

Permanent Photopoints. Each plot will be photographed from permanent photopoints. General guidelines for photographic monitoring can be found in Hall (1999). Two plot level photopoints will be established at the ends of each plot (20 x 50 m or 10 x 20 m). The photographer will stand at the center line and photograph the plot and the surrounding vegetation with two 35 mm cameras: one with slide film and one with print film. A meter board will be placed 10 m from the photographer on the center line of the plot; an information placard containing unit number, plot number, cardinal direction, and date will be placed at 80 cm on the meter board. The camera should be focused on the "1M" of the meter board. Photographs should be taken between 1000 and 1500. Camera and lens type, film, shutter speed, F-stop, location, and other information should be recorded on photographic forms.

Within each 20 x 50 m plot, one 1 x 1 m subplot selected from the center of the plot will be photographed. The meter board will be placed in the upper right-hand corner of the subplot and will contain and information placard containing unit number, plot number, subplot number, cardinal direction and date. A photo will be taken of the general area of subplot from 10 m away. Then, the photographer will stand 2 m away from the meter board, take one photograph of the plot with the meter board on the right-hand side of the photo, and one photograph of the subplot with the meter board on the left-hand side of the subplot. In each photo, the top of the meter board will be placed exactly in the upper corner of the photo. Camera and lens type, film, shutter speed, F-stop, location, and other information should be recorded on photographic forms.

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Fuels and Fire Behavior

James K. Agee, University of Washington

The basic question to be addressed is:

What are the initial (2 yr) effects of prescribed fire and thinning on potential wildland fire behavior, fine fuel loading, coarse fuel loading, log dimension and consumption, stem density, and above-ground fuel structure?

Hypotheses include that thinning and prescribed fire will:

- Have a differential effect on fine and coarse fuel loading and forest floor
- Have a differential effect on log biomass and distribution
- Have a differential effect on live tree fuels, as measured by height to live crown and crown bulk density
- Have a differential effect on shrub and herb biomass
- Have a differential effect on potential wildland fire behavior (rate of spread, flame length, degree of torching, and degree of independent crown fire spread potential

A matrix of potential response variable directions is shown below in Table F-1.

The protocols are summarized in four sections:

A. Fuel Inventory
B. Log Mapping via Belt Transects
C. Vegetation Structure
D. Forest Floor Biomass

All fuel sampling will be done at selected grid points within each unit. Generally, every other grid point will be sampled with minimum of 30 points per experimental unit.

A. Mission Creek Woody Fuel Inventory

At every unit, a 40 meter sample grid is present or will be established, and every other grid point will be sample for woody debris using line intersect and belt transect techniques. The belt transect protocol are described in a separate set of instructions (see next section B.). The instruction here are for the line intersect transects for woody fuel.

At each sampled grid point, two 20 meter lines will be established at random azimuths. The only constraint is that the second transect must be at least 90 degrees separated in direction from the first. Each transect will begin 5 meters away from the grid point and continue for 20 meters. Each line represents a plane (like a pane of glass) along the line.

1, 10, and 100 hr fuels (below 3 inches diameter). These numbers represent timelag classes for different fuel sizes. A 1-hr fuel is less the 1/4 inch diameter, a 10-hr fuel is

1/4-1 inch, and a 100-hr is 1-3 inches in diameter. Sampling is done by counting the number of these particles that cross the plane of the sample line, using a "go-no-go"
Table F-1. Short-term expected responses of the variables in the fuel and fire behavior section.

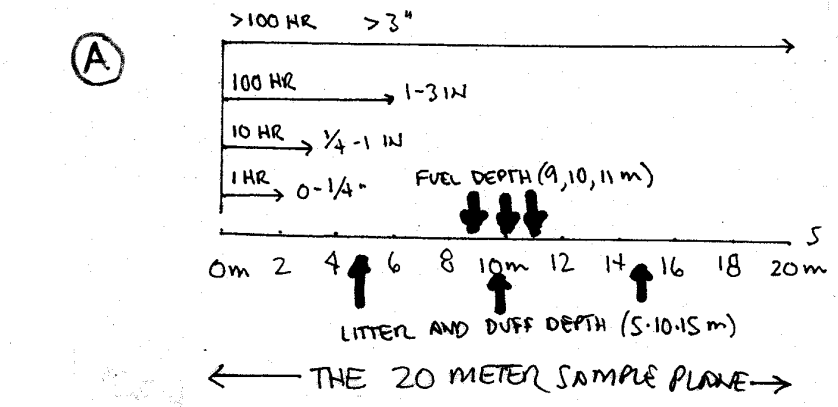
Fuel Response Variable (Short-Term)	Control	Burn Only	Thin Only	Thin and Burn
Litter and Duff Depth/Biomass	0	--	0	--
Fine and Coarse Fuel Loads	0	--	++	--
Coarse Fuel Distribution	0	>Clumpy	>Clumpy	>Clumpy
Vegetation Height to Live Crown	0	++	0	++
Vegetation Crown Bulk Density	0	0	--	--
Shrub and Herb Biomass	0	--	+	--
Potential Wildland Fire Behavior-Rate of Spread	0	-	++	-
Potential Wildland Fire Behavior-Fireline Intensity	0	--	++	--
Potential Wildland Fire Behavior-Torching Potential	0	--	0	--
Potential Wildland Fire Behavior-Independent Crown Fire Spread	0	0	--	--

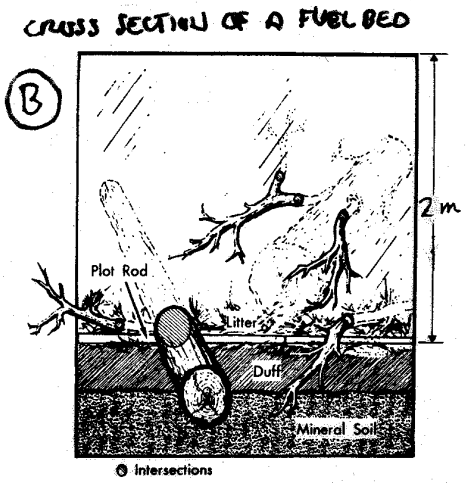
gauge. For 1-hr fuels, the length is 2 m, beginning at the start of the line. For 10 hr fuels, it is 3 m, and for 100 hr fuels, it is 5 m. The total number of particles tallied for each size class is recorded.

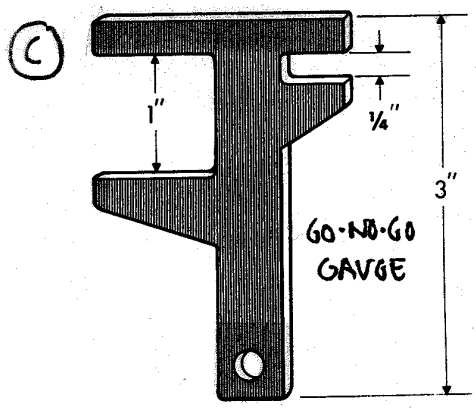
1000 hr and Larger Fuels. Larger fuels are measured over the entire transect length. For larger fuels, diameter in cm at the point it crosses the line and decay class are recorded (see coarse woody debris instructions for decay class categories). Note: pieces in litter and duff layers must be counted.

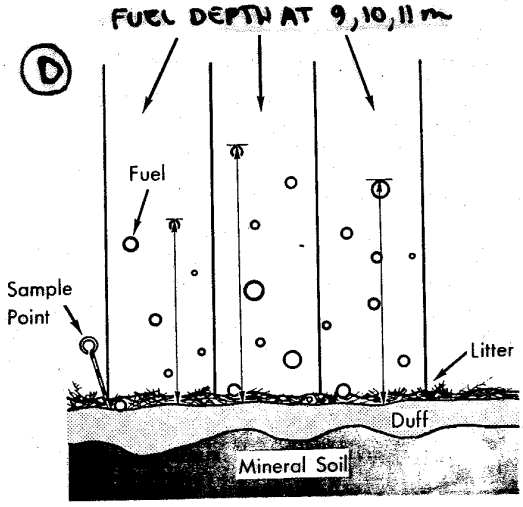
Litter and Duff Depth Measurements. Litter is recognizable leaf litter; partially decomposed and decomposed leaf litter is called duff. At three distances along the transect (5, 10, and 15 m) record the depth of litter and duff in mm.

Fuel Depth. Fuel depth is measured to the height of the tallest fuel particle in three closely spaced (9, 10, and 11 m points) points along the transect (see diagram).









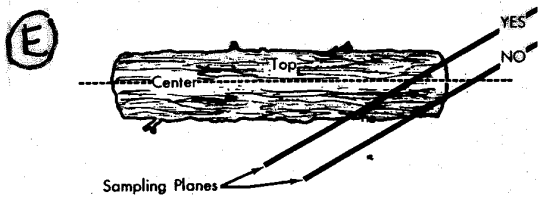


Figure 8.--An intersection at the end of a branch or log must include the central axis to be tallied.

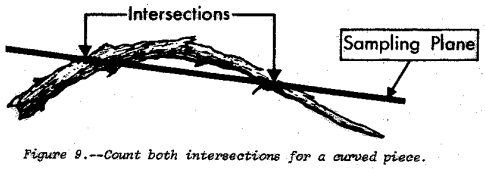


Figure 9.--Count both intersections for a curved piece.

B. Log Mapping via Belt Transects for Coarse Woody Debris

Coarse woody debris (CWD) will be measured by line and belt transects. Line transect protocol is the standard "Brown transect" for fuels and described elsewhere. The protocol below is for wildlife and entomological implications, and uses a belt transect. Every other grid point will be sampled on all experimental units. At each sampled grid point, a single belt transect (4 meters by 20 meters) will be established coincident with one of the two fuel line transects. For consistency, it will always be located coincident with the first fuel transect (the direction of which is randomly chosen). Within each belt transect only logs or parts of logs that are at least 1 m in total length and have a large end diameter 15 cm or greater (in or out of the belt transect) will be measured and counted. Logs are assumed to end when the diameter falls below 7.62 cm.

1. The species (optional, only if possible) of log is recorded.

2. Three (3) log diameters will be measured: The large end (d_1) and small end (d_2)(>7.62cm) diameters will be measured on all qualifying logs or parts of logs that fall within the boundaries of the belt transect. If a piece extends outside the belt transect, diameters are measured at the line of intercept of the belt transect boundary and CWD piece. Also the large end diameter if outside the plot (d_3) will also be recorded (if it is inside the plot it is already recorded as d_1).

3. Two (2) log lengths will be measured: Belt log length is the length of the CWD within the belt transect area. Total length is the length of the entire piece. It is used to determine the midpoint of the CWD. If the midpoint is within the belt transect, the piece is given an additional rating of 1. If the midpoint falls outside the belt transect the piece is given a rating of 0.

4. Decay class of each log will be recorded. The following 5 decay classes will be used to rate the CWD (same as for line intersect fuel transects:

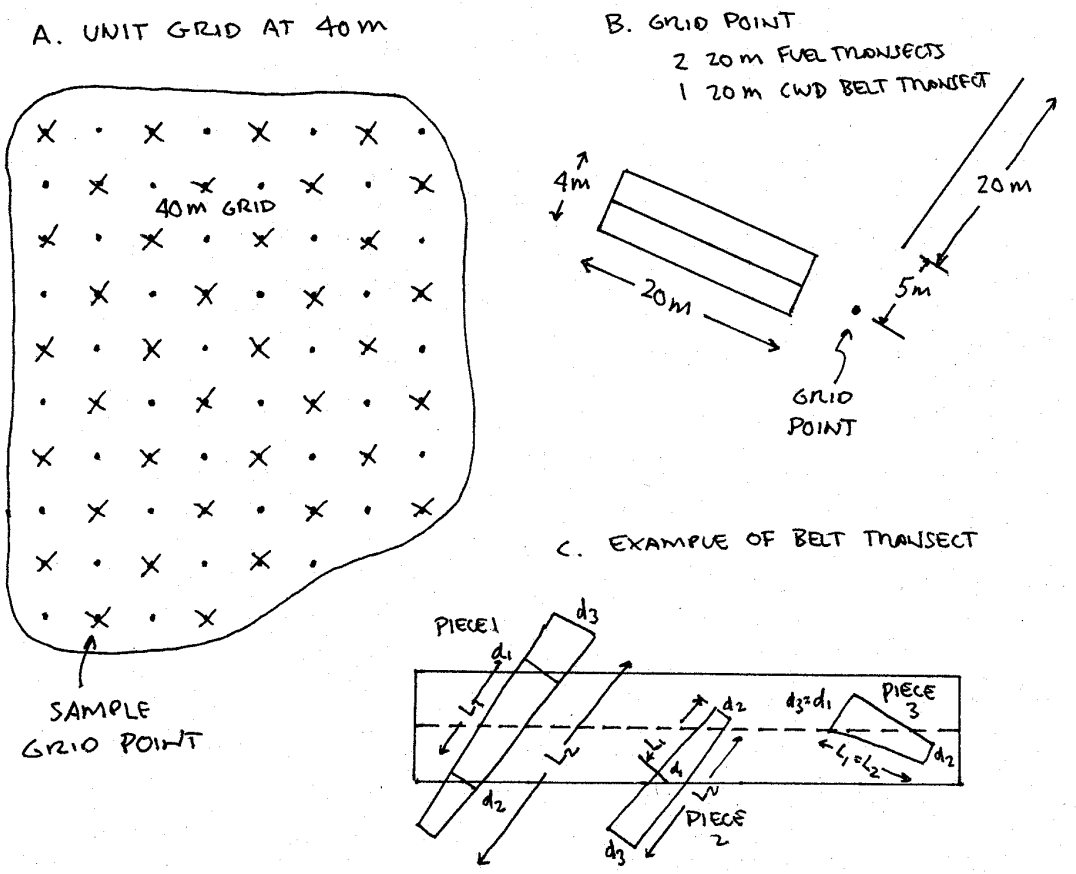
Decay Class 1 **Bark is intact; twigs are present; wood texture is sound; log is still round; original wood color.**

Decay Class 2 **Bark is intact or beginning to flake off; twigs are absent; wood texture is sound or becoming soft; log is still round; original wood color.**

Decay Class 3 **Bark is falling off; twigs are absent; wood texture is hard; log is still round; original color of wood is faded. Can penetrate sapwood with a penknife.**

Decay Class 4 **Bark is absent; twigs are absent; texture of wood is soft, blocky pieces; shape of log is oval; wood has faded to light yellow or gray. Can kick piece apart (but don't do this!).**

Decay Class 5 **Bark is absent; twigs are absent; wood texture is soft and powdery; shape of log is oval; wood has faded to light yellow or gray.**



C. Vegetation Structure for Fire Behavior Analysis

Vegetation data will be recorded at each grid point selected for fuel sampling. This is not repetitive of the vegetation sampling conducted by the Harrod team.

1. **Basic Data**
Treatment Unit and Grid Point; UTM (can be filled in at site or later)
Aspect, Elevation, and Slope.

2. **Canopy Closure**. Measure at grid point with a spherical densiometer. The densiometer has instructions for use inside the cover. Record percent canopy closure on the form.

3. **Fuel Model**. The closest-fit Northern Forest fire Lab (NFFL) model needs to be recorded. Stand at the grid point and ocularly survey an area roughly 20 m each side (an ocular 400 m^2 plot). Refer to the fuel model guide (Anderson 1982). NFFL models 2, 5, 8, 9, and 10 are the most likely to fit pre-fire conditions.
NFFL 2 is the closest fit where grass is the most common fuel.

NFFL 5 is the closest fit where a low shrub understory affects fire behavior.
NFFL 8 is the closest model where short-needled conifer is the dominant forest floor and understory vegetation and CWD is sparse.
NFFL 9 is the closest fit where pine needles are the dominant fuel.
NFFL 10 is the closest fit where understory and CWD are common fuels.
Other models may occasionally fit, and the fuel key should be reviewed.

4. **Shrub and Herb Type, Density, and Depth**. Where shrub and herb fuels are absent to very sparse, they can be ignored and zeros or dashes can be placed in these columns. Where these fuels do occur, they will be measured by type, density, and depth. Use the same ocular 400 m^2 plot that was used for fuel model. Regression equations are available to convert these data to biomass.

Herbs. Herbaceous fuels are classed in this area into one of two **types**: a fine fuel like cheatgrass (Grass Type 1) and a heavier fuel like pinegrass/sedge (Grass Type 2). One of three **density** classes should be assigned from the photo key, and **depth** of the grass (its height) should also be recorded.

Shrubs. Shrub fuels in this area are recorded into three types based on stem diameter and leaf thickness: Shrub Type 1 has thin stems and thin leaves, Shrub Type 2 has thick stems but thin leaves, and Shrub Type 3 has thick stems and thick leaves. Only one type can be selected, so choose the dominant cover type. Examples:

Shrub Type 1	**Shrub Type 2**	**Shrub Type 3**
Huckleberry	Ocean spray	Manzanita
Serviceberry	Bitterbrush	Rhododendron
Honeysuckle	Snowberry	Snowbrush Ceanothus
Hazelnut	Willow	Oregon grape

Three **density** classes are: 1 = 10-40% cover, 2 = 40-70% cover, 3 = 70-100% cover. If less than 10 percent cover, shrubs will not be a significant fuel. Also record the **depth** of the shrub layer where it occurs.

4**. Tree List.** This tree list is for fuels work only, so it is less detailed than for the vegetation plots that are 20 X 50 m. The vegetation plots for fuel will be variable-sized so that a representative sample of trees can be obtained at each sample point. The objective is to sample a minimum of 10 trees per sample point. This is usually obtained with a 10 X 10 m plot (100 m^2) in this type of vegetation, but it may have to altered smaller or larger on occasion.

First, select a plot size. Then within the plot create a tree list. Each tree will be listed by species, diameter at breast height, and three heights: height to dead crown, height to live crown, and total height. Diameter needs to be measured with a tape. Trees less than breast height are recorded with a dbh of 0. Measure height to dead and live crown on each tree to nearest 0.1 m, using a tape if needed. Total tree height can be measured on one or more trees and other nearby trees can be scaled to that height ocularly.

If there are a large number of saplings (perhaps less than 10 cm dbh), use a different plot size for them and record all those trees on the optional tree list with all of the same information recorded for larger trees.

D. Forest Floor Biomass

The fuel protocol samples only forest floor depth, so that procedures must be used to convert this information to mass. Although a number of regression equations relating forest floor depth to mass are available, we will develop site-specific relationships for litter, duff, and total depth/mass. Because our site will be helicopter-yarded, we are not planning a priori to establish different regressions for thinned vs. burned/control plots. However, before we adopt this protocol we will develop separate regressions for thinned area (already yarded by helicopter) and compare the slopes of the regressions. If slopes are not significantly different, we use use the combined data in a single regression predicting mass from depth. If the slopes are different, we will use two regression equations for prediction.

The sampling frame will be a 1 ft square frame. Sample area will be within Mission Creek watershed but not on a treatment unit. A total of 50 sample locations will be established in pine-dominated litter and 50 in fir-dominated litter, as well as another 50 samples in already helicopter-yarded units (pine-dominated). Additional samples will be taken if outlier samples (extremely shallow or deep) that are expected to occur in the treatment units are not found.

Within the frame, all litter will be removed and placed in a paper bag. Then duff will be removed and placed in a separate bag. Measurements of litter and duff depth will be made at each of the four corners of the frame to the nearest 0.1 cm. Samples will be air-dried and later returned to the laboratory and oven-dried at 70^{o}C for 48 hours. Selected samples will be ashed to determine mineral content and adjust samples for soil contamination.

E. Prescribed Fire Monitoring

Weather variables and fuel moisture will be monitored before and during burning: temperature, relative humidity, windspeed, lightning activity level, K-D and K-B drought indices, 10hr fuel moisture and foliar moisture from each treatment unit, and 100-hr and 1000 hr fuel moisture from the Leavenworth NFDRS station. A Scout datalogger fitted with four thermocouples will measure temperatures simultaneously during the fire below the soil surface (5 cm), at the soil surface, the litter surface, and at the cambium of a nearby tree. Where possible, this will be duplicated during the fire on each plot. Before the fires, stakes at known distances will be set so that rate of spread can be monitored. These will be tied to the grid system for reference. As many readings of flame length as possible will be recorded. Photographs will be taken on each plot. We anticipate the need for rapid deployment and movement of monitoring due to the need to burn all "burn" and 'thin-burn" plots in a short period of time.

Wildlife - Small Mammals

John F. Lehmkuhl, Wenatchee Forestry Sciences Lab

Introduction

Small mammal studies will attempt to quantify treatment effects on terrestrial and arboreal small mammal abundance and habitat relationships from pre-treatment in Year 1 and post-treatment sampling in Year 4. Two years of pre- and post-treatment mammal sampling were deemed desirable, but not financially feasible. Treatments will begin during the later half of the 2nd year with thinning, and continue through the 3rd year with burning.

Insectivores, mice, voles, chipmunks and squirrels are the primary focus of the small mammal study. One method used for the mammal work (pitfall traps) also will capture reptiles, primarily 3 species of lizards. However, other studies have shown that these species are either not well sampled by the method or scarce in the forest types where we are working. Hence, reptiles will be a minor focus of the study.
This document serves several functions. It describes the overall sampling design, and how and why it varies from the proposed national protocol. Detailed protocols are given for each of the 3 trapping methods to instruct field crews. Sampling schedules and a data form are given in appendices. Safety considerations are discussed. Field keys to local mammals are included. Hypothesized treatment effects on species abundances are listed in Table W-1.

Table W-1. Estimated treatment effects on small mammals rated on a 5-point scale: - - very negative, - slightly negative, 0 neutral, + slightly positive, ++ very positive. Confidence in the hypothesized effect is based on the numbers and distribution of species among sample stands from studies cited above: "A" = good confidence (well-distributed and relatively abundant [>10 individuals] within stands); "B" = fair confidence (fair numbers of animals within stands [5-10 individuals], and well-distributed among stands); "C" = poor confidence (few [<5 individuals in stands] and not in all stands).

Species		Treatment				
Common Name	Scientific Name	Thin	Burn	Thin + Burn	Control	Confidence
Gapper red-back vole	*Clethrionomys gapperi*	+	-	-	0	C
long-tailed vole	*Microtus longicaudus*	+	-	-	0	C
montane vole	*Microtus montanus*	+	-	-	0	C
					0	
deer mouse	*Peromyscus maniculatus*	+	-	-	0	A
Great Basin pocket mouse	*Perognathus parvus*				0	C
					0	
masked shrew	*Sorex cinereus*	+	-	-	0	C
dusky shrew	*Sorex monticolus*	+	-	-	0	C
Trowbridge shrew	*Sorex trowbridgii*	-	--	--	0	C
vagrant shrew	*Sorex vagrans*	+	-	-	0	C
northern pocket gopher	*Thomomys talpoides*	0	-	-	0	C
yellow pine chipmunk	*Tamias amoenus*	++	-	-	0	A
Townsend's chipmunk	*Tamias townsendii*	-	-	--	0	B
flying squirrel	*Glacomys sabrinus*	--	-	--	0	A

Sampling Design

Overview. At the Mission Creek FFS site, we have attempted to combine sampling designs for small mammals of varied size, natural history, and behavior while sampling a large treatment unit and replicating designs of other regional studies. Some sampling schemes vary from the proposed national protocol in order to more effectively sample mammals and gain greater statistical power to test treatment effects.

A 6 x 6 grid with 40m spacing will used to sample for both small terrestrial mammals and herps with pitfall traps per the national protocol. However, we will kill trap for 28 days vs. live-trap for 10 days as proposed in the national protocol. Instead of using Sherman traps on the 6 x 6 grid to sample small mammals not well sampled by pitfalls, we will snap trap on a larger 11 x 6 grid with 20m spacing inset into the 6 x 6 40m grid. Arboreal mammals will be sampled with Tomahawk traps per the national protocol, but with 2 traps per station. See rationale for changes in following sections.

Grid spacing. The FFS national protocol calls for trapping on a 5 x 5 grid with 50 m spacing with pitfall, Sherman, and Tomahawk live traps. The basic grid dimension for the Mission Creek site of the FFS study will be modified to 6 x 6 with 40 m spacing and a 40 m buffer zone from the grid and the stand boundary. The 6 x 6 grid was a compromise that attempts to increase sampling effort within the same area as the 5 x 5 grid, and to more similarly replicate sampling designs used in several other completed or ongoing regional studies of terrestrial small mammals.

The 6 x 6 40 m grid configuration for the Mission Creek site is a tradeoff of two basic trapping designs for estimating terrestrial and arboreal small mammal abundances. In several large regional studies of terrestrial small mammals and amphibians, Aubry et al. (1991), West (1997), and Hallett and O'Connell (1997) located pitfall kill traps on 6 x 6 grids with 10-15 m spacing and trapped for 28 days. Although 10 x 10 or larger grids typically are employed for small mammal trapping, the 6 x 6 configuration and trapping period provided sufficient captures to estimate relative abundance indices for hypothesis testing. For arboreal rodents a larger 10 x 10, or 8 x 8, grid and wider 40 m spacing standard has been developed (Carey et al. 1991) and used (Carey 1995) in western Washington and Oregon, and used locally by Lehmkuhl (pers. comm., Wenatchee Forestry Sciences Lab).

A problem arises when both groups of species need to be sampled simultaneously and effectively in large experimental units. Small grids and narrow spacing don't sample well the entire area or large species, such as arboreal rodents. Large grids with wider spacing sample large species well and small species across the whole treatment unit, but smaller species are sampled at grid spacings too large to estimate abundance well. For large studies that attempt to sample both groups simultaneously in many replicates, some compromise in grid size or spacing must be made. Moreover, another important consideration for experimental studies such as FFS, is the need to sample most of the treatment unit in order to adequately sample the variation in treatment effects over a relatively large 10-15 ha experimental unit (e.g., forest stand). Small 6 x 6 grids with 15 m spacing do not sample a large enough area to adequately meet that need.

Lehmkuhl et al. (1999) developed a solution to the issue of sampling intensity and distribution for such studies. Since grid configuration for arboreal rodents was the critical factor, they used an 8 x 8 grid with 40 m spacing to pitfall trap for terrestrial small mammals and Tomahawk trap for arboreal rodents. (Even the 8 x 8 grid was a compromise from Carey et al.'s [1991] recommendation of a 10 x 10 grid; experimental units were not big enough to contain the larger grid.)The design was minimally adequate

for estimating abundance of arboreal rodents; the number of pitfall traps and spacing was adequate for estimating and index of relative abundance for small mammals and amphibians, although not for estimating absolute abundance or density; and, the size and spacing distributed the sampling effort throughout most of the experimental unit.

West (pers. comm., University of Washington) and Gaines (pers. comm., Okanogan-Wenatchee National Forests) used similar configurations of pitfall traps on 6 x 6 40m grids to trap for small mammals in the Teanaway River and Pendleton Creek drainages. Grids smaller than used by Lehmkuhl et al. were necessary because forest stands in those areas typically are smaller than in western Washington forests where Lehmkuhl et al. worked. FFS stands are in the same ecological landtype as those studied by West and Gaines, so the same constraints apply.

Trap Types & Trapping Duration. The pitfall traps will be run as kill traps for 10 days. The stands will not be sampled again until after treatments, which will occur from 1-2 years after sampling, so that removal of animals is unlikely to affect the test of experimental effects.

The change is justified by a local pilot study that indicated the need for a longer sampling period, which would not be feasible with live trapping. Gaines (pers. comm., Okanogan-Wenatchee National Forests) ran pitfall kill traps on a 6 x 6 grid with 40 m spacing for 28 days in 12 Ponderosa pine stands in Pendleton Canyon, adjacent to the FFS study area, and found cumulative captures increased up to 25 days and species richness peaked at 15 days. Moreover, captures were at best sufficient (mean 12 individuals) and well distributed in all treatment stands after 25 days, and for only one species (*P. maniculatus*). The time series of *P. maniculatus* captures suggested that local animals were collected first, followed by a lull in captures, then several other pulses of captures. Catching similar numbers of animals with catch-and-release pitfall trapping over a shorter 10-day period as nationally proposed would require about twice, or more, the trap-days, which is not financially possible with the given budget.

Gaines' pilot study also points to the need for other trapping methods that target species not well captured by pitfalls. We will use Museum Special snap traps to better capture cricetine (deer mice, etc.) and microtine (voles) rodents, as well as supplement captures of insectivores. The national protocol suggested Sherman live traps run for 10 days on a 6 x 6 grid to meet that need, but West (pers. comm, University of Washington) advised that snap traps are about 3 times more effective in capturing these species, especially microtines, than Sherman traps. The Pendleton Canyon pilot study showed that very few microtines were captured with pitfalls traps; hence, the need to more effectively capture those species. It is possible that few microtines occur in our stand types, but it is necessary to employ the most effective means to determine that fact.

Moreover, we will snap trap on a larger 11 x 6 grid (20m spacing on the 11 dimension, and 40m spacing in the 6 dimension) to boost captures relative to the sparser 6 x 6 40m grid, and to sample more effectively the small-scale patchiness created across treatment units by fire and thinning treatments. (An 11 x 11 grid with 20 m spacing was attempted

but the increased effort was not logistically feasible given concurrent pitfall and Tomahawk trapping efforts). We will trap for 8 days concurrent with the Tomahawk trapping for sciurids (4 days on, 2 days off [weekend], 4 days on per Carey et al.'s [1991] Tomahawk standard). Fewer days might be trapped if capture rates drop during the initial 4 days. Snap traps also are effective at capturing insectivores, so we anticipate that snap trapping combined with pitfall trapping will yield higher captures for more species than pitfall or Sherman traps, hence more power to test treatment effects on a larger number of species. The Pendleton Canyon pilot study with pitfall trapping alone yielded sufficient captures only for deer mice.

There are important safety reasons for kill trapping with pitfalls and snap traps. Hanta virus is endemic in this area in deer mice, and human deaths from hanta virus have occurred in both eastern and western Washington, hence it is a serious concern. Pitfall kill-trapping with water will effectively reduce the potential for aerosol transmission of the virus with that technique. Snap trapping will reduce the potential of hanta virus exposure by minimizing the handling time and potential for aerosol virus transmission that might occur with the handling of live active animals in Sherman traps.

Moreover, kill trapping will result in exact identification for species that are difficult to identify in the field (insectivores, voles), and determination of reproductive condition (e.g., number and size of embryos, and number of placental scars and corpora lutea), which is important for determining the effects of treatments on fitness of individuals. Cost savings in equipment and crew time are other secondary advantages of kill trapping. The bottom line is that our proposed methods will yield more reliable data with greater safety for personnel than with methods proposed nationally for the FFS study.

The Tomahawk trapping protocol will be altered slightly to conform to methods used in concurrent studies by Lehmkuhl (Wenatchee Forestry Sciences Lab). Two traps per station will be used on an 6 x6 grid, rather than 1 trap per station as proposed nationally. We attempted to use an 8 x 8 grid, but over half the stands were too small for that size grid. Also, we will trap 8 days, rather than 10 days as described in the national protocol.

Pitfall Traps

Layout. Pitfall traps will be located in the study stands on the basic 6 x 6 grid point with 40 m spacing. There will be one trap per grid point.

Trap design. A pitfall trap will consist of two large (#2) coffee cans taped together with duct tape - the top can has both top and bottom removed and the bottom one with just the top removed. The trap is buried to the lip of the can and a plastic margarine container with the bottom cut out is fitted into the top of the trap to prevent animals from crawling or jumping out. Each trap will be filled with about 10 cm (4") of water to operate them as kill traps. There will be no cover sheltering the opening. Traps will be closed with original plastic tops and weighted to preclude accidental captures. In addition, a wire mesh panel or sticks will be inserted before closing to provide an escape ramp in case the traps is opened by wind or bears.

Trap placement. Pitfall traps are placed alongside logs, or other natural runways of small mammals, or at the base of a tree as close to the grid point as possible but not more than 5 m away. Pitfalls out in the open ground away from down wood or vegetation will not be effective.

Duration. 10 continuous days

Trapping procedure. Crew collecting animals will have read the safety information concerning field work and medical issues. Water in pitfall trapping will minimize the risk of aerosol transmission of disease agents, such as hanta virus, but caution should be used in breathing near trap opening and collected animals, and in not contaminating field equipment with hands that have been in pitfall traps. Water in traps will be contaminated with bacteria as well. Wear a double of gloves – a latex glove covered by a heavier rubber glove similar to dishwashing gloves. Carry plenty of extra gloves and a plastic bag to dispose of soiled and torn gloves. Carry waterless antibacterial hand cleaner in the field.

Collect animals from each trap by lifting out of the trap by hand. Skulls of shrews are very delicate, so handle with care. Recorded each individual by species on the field data sheet, and bag individually in a plastic "sandwich" bag with a "Rite 'n Rain" paper label that identifies the date, stand, grid point where captured, and species field identification. Put the individually bagged animals from a grid point in single larger plastic bag, then seal.

Back at the truck, place all the bagged specimens in a cooler with Blue Ice (cooler to be used exclusively for specimens – no food or drinks!) for transport back to the Forestry Sciences Lab. At the Lab, place specimens in the freezer (in the basement wood shop) for later species identification, weighing, sexing, and determination of reproductive condition. If time allows, species identification, weighing, sexing, and necessary measurement for identification will be done in the Lab the same day as trapping.

Lab examination of specimens (opening bags, handling animals) is to be done only in a Lab hood with the exhaust fan operating. Hands are to be double gloved, and all surfaces disinfected with Lysol or bleach per defined protocols. During Lab work, the Lab door is to be closed and locked to discourage visitors.

What very few amphibians that are captured (very likely none) will still be alive. Record and bag the live animal as with dead mammals. Before bagging the animal add moss or other soft material (litter, humus, batting, etc.) to the bag, wet with water, add the animal, blow air into the bag, then seal. Bring the animal to the Lab ad store in the refrigerator (not freezer) until the end of the sampling period when animals will be returned to their capture site.

Post-trapping Handling of Traps and Collected Animals. Traps will be removed from the stands, cleaned and disinfected, and stored after trapping is completed. Follow the

guidelines in the attached document on hanta virus safety protocol for details on cleaning and disinfecting traps.

Soiled traps, trap covers, and batting should be double bagged for transportation in the back of a pickup to avoid contamination of vehicle cabins. Dead animals will be double bagged and put in the cooler for transport to the Lab. If possible, also put the cooler outside the passenger cabin of vehicles.

Snap Traps

Layout. 11 x 6 grid with 40 m spacing along the 11 trap dimension and 40 m spacing along the 6-trap dimension (see the previous discussion of the different spacing). One trap per grid point.

Trap placement. Runways and other likely locations for trapping within 5m of grid points.

Duration. Concurrent with Tomahawk trapping – 8 days total with 4 days on, 2 days (weekend) off, 2 days on. If capture rates are high or drop by the end of the first week, then the trapping period may be curtailed.

Bait. Bait will be a mixture of whole oats, peanut butter, and molasses (same as for Tomahawk trapping).

Trapping procedure.
Pre-trapping Procedure:

- Make sure you have a complete set of your personal trapping equipment. Check off each item on the equipment check list.
- Make especially sure you have a compass, stand maps, water, lunch, and insect repellent. Bring your rain gear, even if you think you will not use it and just end up leaving it in the truck.
- Check that each vehicle has a first-aid kit (including bee sting kit) and Forest Service radio.
- Be sure of the safety procedures regarding travel in the woods and diseases potentially picked up from handling small mammals: reread the safety section of this protocol to refresh your memory when starting a trapping session.

Trapping Schedule:

We will trap a stand for 8 days. We will monitor trapping success daily to determine when removal may be complete and determine if trapping might be stopped before 8 days. Traps will be opened on Monday, baited, and tested to ensure proper working order, closed on Friday, then reopened the following Monday.

Checking Traps:

- Traps are checked every 24 hours.
- Crew will be rotated among the stands and blocks to reduce bias associated with individuals. People set traps at different sensitivities and locations, so we want to distribute this variation evenly among all the stands.
- Follow disease safety precautions in handling traps. Don't stick your nose near traps, or blow onto them or on animals. Keep the wind at a right angle to you and the animal if possible.
- There are a lot of traps to check, so work the trap grid quickly, but don't sacrifice careful and thorough examination of traps and animals, or safety moving through the woods.

Removing and Handling Animals:

- Remove animal from trap carefully and bag in and individual zip-loc bags. Write the date, stand, and grid point on the outside of the bag with a Sharpie. Make the bags are securely closed.
- Record in your field book sprung or stuck traps. That information will be used later to adjust trapping effort.
- Make notes in your field notebook on the condition of the animal or trap (killed by weasel, trap damaged, trap, trap sprung by bear, etc.), or changes in the condition of the trap site (e.g. recent windthrow or other disturbance, human intrusion, etc.).
- Rebait, set, and position traps. Replace damaged traps with fresh ones.
- Reflag trap positions if hard to find.
- Back at the truck, have data recorders wash their hands before taking notes. Record captures on a single data sheet, noting stand name, station, and tentative species identification or whether it was a stuck or spring trap. Bag all animals from a grid for that day in a single larger bag – make sure the person holding the large bag has clean hands so as not to contaminate the outside bag. Put dead animals in a cooler with Blue Ice, then deposit the same day in the Lab's freezer for later examination.

Post-Trapping Handling Of Traps and Collected Animals. Traps will be removed from the stands, cleaned and disinfected, and stored after trapping is completed. Follow the guidelines in the attached document on hanta virus safety protocol for details on cleaning and disinfecting traps.

Soiled traps should be double bagged for transportation in the back of a pickup to avoid contamination of vehicle passenger cabins. *Do not put soiled traps in the back of a SUV – if necessary, cache material until a pickup is available at a later date.* Dead animals will be double bagged and put in the cooler for transport to the Lab. If possible, also put the cooler outside the passenger cabin of vehicles.

Be sure to wash your hands with the soap provided, and bag and isolate potentially contaminated equipment or clothes.

Tomahawk Live-Trapping for Sciurids

Layout. We will be using 2 Tomahawk 201 traps on each grid point of the 6 x 6 layout. One trap will be on the ground near the grid point at the base of a tree, and another trap attached at breast height to a the largest tree within 5 m of the grid point.

Trap design. Each trap will have a outer cover consisting of a 1/2 gallon milk carton that is slipped over the closed end of the trap to provide shelter. Inside the trap will be smaller carton that is cut to form a nest box with the addition of nonabsorbent polyethylene batting. The nest cup is placed behind the treadle at the closed end of the trap in such a way that it does not interfere with the action the treadle.

Trap placement. Place ground traps on or near a fallen tree or at the base of a standing tree, with the trap horizontal or with the entrance slightly lower than the back for drainage of rain water. Ensure that the trap is firmly placed and does not wobble or move with slight hand pressure. Cover the trap with rocks, moss, or woody debris to increase rigidity and further insulate the trap.

Hang the second trap 1.5 m (5') off the ground in a tree within 5 m of the sampling point. Choose the largest tree available, because it is easier to mount a trap on a large rather than small tree. Drive 2 nails 5 cm (3 in) apart into the tree and hang the trap on the nails flush with the bole of the tree. Tie a piece of nylon string to one of the top nails, pull the string across the outside of the trap , and tie it to a 3rd nail driven about 0.5 m (18 in) below the center of the trap.

The trap should be horizontal or on a slight incline with the front angled down to keep rain from flowing into the back of the trap. The edge of the entrance of the trap should be flush (or nearly so) with the tree, but there should be enough space to insert the cloth funnel of a handling cone between the trap and the tree when placing the cloth over the entrance to the trap.

The side of the trap with the trigger mechanism should be away from the tree for easy adjustment and manipulation. The trap should be immobile. As with the trap on the ground, place moss or woody debris on the top, and ensure the treadle and door operate properly. Place a handful of bait in the rear of the trap.

Trap adjustment. Adjust the trigger mechanism with pliers to ensure the trap will spring with a slight pressure. Set the trap treadle at an angle of 10-20 degrees from the bottom of the trap. Make sure the door closes completely and locks into place.

Bait. Bait will be a mixture of oats, peanut butter, and molasses. The purpose of the bait is not only to attract the animals, but to provide food during their confinement and reduce the risk of death from hypothermia. Place a small handful (about 1 tablespoon) of bait in the back of the trap in the nest cup. Be sure that the angle of the trap is not so severe that the nest cup or bait slide forward and interfere with the treadle.

Trapping procedure.
Pre-trapping Procedure:

- Make sure you have a complete set of your personal trapping equipment. Check off each item on the equipment check list.
- Calibrate your scale.
- Make especially sure you have a compass, stand maps, water, lunch, and insect repellent.
- Bring your rain gear, even if you think you will not use it and just end up leaving it in the truck.
- Check that each vehicle has a first-aid kit (including bee sting kit) and Forest Service radio.
- Be sure of the safety procedures regarding travel in the woods and diseases potentially picked up from handling small mammals: reread the safety section of this protocol to refresh your memory when starting a trapping session.

Trapping Schedule:

- We will trap a stand for 10 days.
- Traps will be opened on Monday, baited, and tested to ensure proper working order.

Checking Traps:

- Traps are checked every 24 hours.
- Crew will be rotated among the stands and blocks to reduce bias associated with individuals. People set traps at different sensitivities and handle animals differently, so we want to distribute this variation evenly among all the stands.
- Each trap should be checked even if the door is open to ensure that the mechanism is in proper working order and bait is present. Sometimes the treadle gets jammed by the nest cup or batting and needs to be freed, or the bait is stolen by small mammals that do not trip the door closed. Reach in the trap and trip the door by pressing down on the treadle, check for bait, then reset the mechanism. Test the treadle action once to make sure it works, then reset.
- Replace damaged nest cups or lost batting.
- Replace batting that is heavily soiled by feces or urine; put soiled batting in plastic bag and dispose or carefully.
- Plan to replace traps that have captured skunks.
- There are a lot of traps to check, so work the trap grid quickly, but don't sacrifice careful and thorough examination of traps and animals, or safety moving through the woods.

Removing and Handling Animals:

- You should be familiar with identifying the species, sex, and age of the animals that will be found in the traps. There will be relatively few species caught in the large

Tomahawk traps, so this should not be a big problem. There will be training with study skins, keys, and in the field with live animals prior to the regular trapping session. We likely will have people working in pairs in the field, so you can exchange information and learn from each other. The first days of trapping are hectic with learning how to handle and identify animals.

- Data will be collected on every animal that is caught in the traps. Study the data sheets so you are familiar with what needs to be recorded. Fill out the header information on each data sheet no matter if it is a continuation of a first page with the same information. The subsequent columns have spaces for trap station, trap placement, species, capture code, tag number, age, sex, sexual condition, weight, number of fecal pellets collected and the fecal pellet tracking number (entered later at office from log book), and comments on animal condition, etc. Record this information in a methodical and thorough manner with legible printing in pencil. Make sure you are using Rite 'N Rain paper if the weather is damp.

- Remove animals by placing the cloth of the trapping cone over the entrance of the trap. Make sure the fit is tight and the cloth is secure, or else the animal will escape and data will be lost. Hold the cage of the cone out in front of the trap and tap the end of the cage where the animal is hiding. When the animals moves into the cone, twist the cloth to trap the animal, then begin processing.

Data Collection Procedures

Ear tags - Check the ear tag numbers, if an old capture, immediately after removing the animal from the trap. This will allow for recording of some data if the animal manages to escape before the full examination is done. Animals are ear tagged on both ears following the procedures in the attached appendix: read these instructions carefully before tagging. Place the tag on the rear margin of the ear with the numbers facing forward. Be sure that the tags in each ear are identically numbered. If you capture an animal with 1 tag (the other begin ripped out, etc.), then replace the absent tag with a new tag with a different number and record carefully on the data sheet. Tags come in numbered pairs, so put the second tag not used on the animal in your pocket and later throw out so that it is not used later on another animal, thus confusing the identity of individuals.

Species, sex, age, etc. - Examine the animals to determine species, age, sex, reproductive condition, and weight. Some species will be easy to identify, but others may take careful examination and reference to keys. If you catch something unusual that you cannot identify, make notes as to its pelage color, appearance, weight, body length, tail length, etc. for later identification. If possible, put it alive in a bag for others to see.

The data coding sheet will have codes for the age classes of the different species. Recording reproductive condition will be most important in the spring when animals are reproductively active. Refer to the attached appendices on assessing reproductive conditions in males and females.

Weigh animals while they are in the capture cones, then weigh the cone after the animal is released to subtract cone weight, and record the net weight of the animal. The cone should be weighed nearly every time you weigh an animal if the cone weight might change as you trap with the addition of dirt, rainwater, and dew; if the weather and conditions are such that cone weight is not changing, then a periodic re-weighting of the cones is only necessary. Accurate weights are important for later refining age classes and animal condition.

Sick or dead animals - Hypothermic or injured animals may be encountered in traps, and it is your responsibility to care for these animals and ensure their recovery and release. Carry a dropper bottle of sugar water, heating pads, and a sick-animal bag. Quickly record information on the animal then administer the juice or sugar water and keep it warm in the bag. You may need to continue checking traps while the animal warms up. If the animal recovers, return it to the grid point where it was captured. Despite attempts to keep animals warm and dry in traps and to administer first aid, we can expect some mortality, but usually only a few percent of the captures.

Dead animals are processed like live animals. Record the probable cause of death. After recording data on the dead animal, bag, label with a "dead tag", and collect for later lab work. Record the dead-animal number from the dead animal log at the crew quarters on the tag and field data sheet. Place dead animals in the freezer after returning to the quarters.

Notes - Make notes in the comment field or footnoted at the bottom of the sheet on the condition of the animal or trap (killed by weasel, trap damaged, trap door stuck open overnight, trap sprung by bear, etc.), or changes in the condition of the trap site (e.g. recent windthrow or other disturbance, human intrusion, etc.).

Post-Trapping Handling Of Traps and Collected Animals. Traps will be removed from the stands, cleaned and disinfected, and stored after trapping is completed. Follow the guidelines in the attached document on hanta virus safety protocol for details on cleaning and disinfecting traps.

Soiled traps, trap covers, and batting should be double bagged for transportation in the back of a pickup to avoid contamination of vehicle cabins. *Do not put soiled trapping material in the back of a SUV – if necessary, cache material until a pickup is available at a later date.* Dead animals will be double bagged and put in the cooler for transport to the Lab. If possible, also put the cooler outside the passenger cabin of vehicles.

ARBOREAL AND TERRESTRIAL MAMMALS POTENTIALLY TRAPPED IN TOMAHAWK TRAPS

We can anticipate capturing several species of arboreal, semi-arboreal, or terrestrial rodent species. The following table lists species that are most likely to be caught (**bold**), as well as some species that might be caught:

Common Name	Scientific Name	Code (for field data forms)
Pika	*Ochotona princeps*	OCPR
Snowshoe Hare	***Lepus americana***	**LEAM**
Mountain \Cottontail	*Sylvilagus nutallii*	SYNU
Northern Flying Squirrel	***Glaucomys sabrinus***	**GLSA**
Douglas Squirrel	***Tamiasciurus douglasii***	**TADO**
Western Gray Squirrel	*Sciurus griseus*	SCGR
Chipmunk-like (generic)	*Tamias or Spermophilus*	TASP
Townsend's Chipmunk	***Tamias townsendii***	**TATO**
Yellow-Pine Chipmunk	***Tamias amoenus***	**TAAM**
Least Chipmunk	*Tamias minimus*	TAMI
Cascade Golden-Mantled Ground Squirrel	***Spermophilus saturatus***	**SPSA**
Bushy-Tailed Wood Rat	***Neotoma cinerea***	**NECI**
Weasel (generic)	*Mustela species*	MUSP
Ermine	*Mustela erminea*	MUER
Long-tailed weasel	*Mustela frenata*	MUFR
Striped Skunk	*Mephitus mephitus*	MEME
Western Spotted skunk	*Spilogale gracilis*	SPGR

Wildlife - Birds

William L. Gaines, Okanogan and Wenatchee National Forests

The wildlife avian component of the study will attempt to estimate treatment effects on avian species occurrence, relative abundance, and behavior. Avian studies include point counts, functional response of bark gleaners and woodpeckers, and nest productivity for pre-treatment Years 1 and 2 and for post-treatment Years 4 and 5. Treatments will begin during the later half of the 2nd year with thinning, and continue through the 3rd year with burning.

This document serves several functions. First, it provides a list of hypotheses that describes how the response variables (bird abundance, nest productivity and foraging habitat) may be affected by each of the three treatments. Second, it describes the overall sampling design, and how and why it varies from the proposed national protocol. Finally, detailed protocols are given for each of the avian field studies to instruct field crews. Data forms and a bird species list from the Pendleton pilot study are provided.

Research Question and Predicted Responses

The basic research question to be addressed in this study is: What are the initial (2 year) effects of prescribed fire and thinning on avian abundance, nest productivity and foraging behavior?

The predicted responses of the most common avian species to the treatments are shown in the following tables. Predicted responses were developed from the literature and bird species identified in the Pendleton pilot study. The predicted responses of the avian species to each of the treatments are shown in Table W-2.

Table W-2. Estimated treatment effects on bird species rated on a 5-point scale: - - very negative, - slightly negative, 0 neutral, + slightly positive, ++ very positive. Numbers in parentheses refer to literature citations at the end of the table.

Response variable: Bird abundance.

Bird Species	Thin Only	Burn Only	Thin and Burn
American Robin	+ (1)	+ (6)	+ (1,6)
Brown Creeper	- (2)	- (3)	- (2,3)
Cassin's Finch	+ (1)	+ (9)	+ (9)
Chipping Sparrow	+ (1)	+ (3,6)	+ (1,3,6)
Dark-eyed Junco	- (1)	+ (6)	0
Hairy Woodpecker	- (1)	+ (3,4)	+ (3,4)
Hammonds Flycatcher	- (8)	- (8)	- (8)
Mountain Chickadee	- (1)	+ (5)	- (1)
Pine Siskin	- (2)	0	0
Red Crossbill	+ (9)	+ (9)	+ (9)

Red-breasted Nuthatch	- (2)	- (6)	- (2,6)
Solitary Vireo	0	+ (6)	+ (6)
Townsend's Solitaire	- (2)	0	0
Townsend's Warbler	- (9)	- (9)	- (9)
Western Tanager	- (1)	+ (6)	0
Yellow-rumped Warbler	0 (1)	+ (6)	+ (6)

+ = increased abundance, 0 = no change in abundance, - = decreased abundance

Response Variable: Nest Productivity

Bird Species	Thin Only	Burn Only	Thin and Burn
Ground nesters	- (1)	- (1)	- (1)
Cavity nesters	- (1)	- (1)	- (1)
Depression nesters	0	0	0
Foliage nesters	+ (1)	+ (1)	+ (1)

+ = increased productivity, 0 = no change in productivity, - = decreased productivity

Response Variable: Foraging Habitat

Bird Species	Thin Only	Burn Only	Thin and Burn
Red-breasted Nuthatch	- (2)	- (6)	- (2,6)
Mountain Chickadee	-	-	-
Hairy Woodpecker	- (1)	+ (3,4)	+ (3,4)

+ = increased foraging habitat, 0 = no change in foraging habitat, - = decreased foraging habitat

1: Szaro and Balda 1979; 2: Finch et al. 1997; 3: Lowe et al. 1978; 4: Blake 1982; 5: Horton and Mannan 1988; 6: Bock and Bock 1983; 7: Martin 1993; 8: Sedgwick 1994; 9: Sallabanks 1994

Protocols for Avian Species Abundance

Point counts are a relatively standardized method for estimating the relative abundance and diversity of avian species (Buckland 1987, Ralph et al. 1993, Reynolds et al. 1980). The point count method allows for the study of yearly changes of bird populations, differences in species composition between habitats, and abundance patterns of species. The point count method is probably the most efficient and data rich method of counting birds, and is the preferred method in forested habitats or difficult terrain (Ralph et al. 1993).

From mid-April to mid- May field crews will flag routes to the study stands and flag routes to be used to traverse all the points in the stand. At least two weeks will be devoted to the development of birding identification skills (sight and sound) specific to the study area. In mid-May the point counts will be initiated (based upon avian studies

conducted in similar habitats such as the Pendleton Study and Riparian Bird Study.

Field Methods. Point counts will be conducted at 4-6 points/stand for a total of six visits to each of the 12 study stands. Point will be located at least 160 meters apart (80 meter radius). This is a deviation from the national protocol which called for 100 meter radii because of the size and shape of the study stands, and the overriding goal of at least 4 point count stations/stand.

Each point count will begin within ½ hour of the official sunrise. Once at the point, the observer will wait 2-4 minutes then count birds for 10 minutes. The observer will be quiet and move as little as possible once at the point. Detections of birds will be recorded at 10 meter increments out to 80 meters. Birds detected flying directly overhead would be recorded as "10" because first detection was directly overhead. All measurements will be as horizontal distance.

A complete count of all stands should be completed before the second visit is done to any stand. A random number will be used to determine the sequence of sampling. Standard four-letter codes for each bird species will be recorded (Pyle 1997). All points used for counts should be geo-referenced using the GPS unit purchased for the study.

Protocols for Functional Response of Woodpeckers and Other Bark-Gleaning Birds

Wildlife species can respond to changes in their habitats through numerical responses, such as changes in bird densities, or functional responses, such as changes in foraging behavior. This portion of the avian studies will assess the foraging behavior and foraging habitats of woodpeckers and other bark gleaning species (chickadees, nuthatches, creepers). Most research and management approaches for cavity-nesting birds have focused primarily upon the relationships between cavity-nesting birds and snags used for nesting (Mannan et al. 1980, Neitro et al. 1985). In these approaches it is assumed that maintaining adequate snag habitat for nesting would also provide adequate foraging habitat for woodpeckers. Mannan et al. (1980) showed that woodpeckers sometimes do forage on the same habitats used for nesting, however, there is no information to determine if management focused solely on nesting habitat is adequate to provide foraging habitat to support woodpecker populations (Weikel and Hayes 1999). Therefore, the main objectives of this portion of the Fire/Fire Surrogate Study (FFS) are: 1). Quantify the foraging activities of woodpeckers and bark-gleaners, and 2). Quantify the selection of foraging habitat by woodpeckers and bark-gleaners.

Methods. In general, we will use focal animal sampling techniques (Martin and Bateson 1986) to quantify the foraging activities of woodpeckers and other bark-gleaning species. A list of the species, and their relative abundance, that were located in the nearby Pendleton Study area is shown in the following table. This list should provide a good idea of the species that will be encountered in the FFS study stands.

Sampling Period. Observations of the focal bird species (see following table) activities and habitat selection will be made during a two hour sampling period made upon

completion of the point counts. These observations will be completed prior to 1400 hours. Each stand will be sampled for a total of 12 hours, and 144 hours of observation would be completed this year across all study stands.

Transects. Observations of bird foraging activities and habitat use will be made along transects that traverse the grid points within each stand. The transects will be started at the corner of the stand and a different starting point and route should be used for each sampling period.

Statistical Independence. Concerns about statistical independence have been identified as a problem in studies of wildlife behavior and other ecological investigations (Hurlbert 1980). Therefore, the following steps will be taken to ensure statistically independent observational and habitat data are collected:

1. We will sample an individual from the above species once while foraging, then move on to another species.
2. Do not collect data on the first species until at least two other species have been detected **OR** observations of the same species are separated by at least 3 grid points (120 meters).
3. Do not collect data on the same individual more than once. If uncertain whether the individual is the same or not, error on the conservative side and don't sample.

Foraging Activities. The emphasis is on collecting data from bark-gleaners only when they are foraging in trees. Observations will be made while walking along the transect until one of the target species is heard or seen. Once a visual detection is made:

1. Wait for the bird to engage in some form of foraging behavior.
2. Once foraging, record the variables (see attached data sheets) as if taking a "snapshot" at the time the foraging activity is initially detected.
3. Record the type of foraging activity.
4. Do not collect data on the first species until at least two other species have been detected **OR** observations of the same species are separated by at least 3 grid points (120 meters).
5. Do not collect data on the same individual more than once.
6. When more than one bird is detected at the same time, choose the woodpecker species.

Habitat Selection. The objective of this portion of the research is to quantify information on the type of habitat birds are observed foraging on (used habitats) and compare that to information from a nearby similar tree (available habitats).

1. At the time of detection of a bird that is foraging record the habitat variables (see data sheet).
2. Use a random number to select a compass bearing (N,S,E,W) and one to determine a distance in 10 meter increments up to a maximum of 50 meters.

3. At the randomly chosen point select the nearest tree of the same type that the bird was foraging in (live conifer, snag, or live deciduous) and record the same habitat variables.

Bark Gleaner Bird Species List from the Pendleton Study. In parentheses are the number of detections for each species/ total number of detection for all birds.

Woodpeckers

Black-backed woodpecker (1/2611)
Hairy woodpecker (40/2611)
Northern flicker (23/2611)
White-headed woodpecker (2/2611)
Williamson sapsucker (incidental)
Downy woodpecker (incidental)
Red-naped sapsucker (incidental)

Chickadees, Creepers, Nuthatches

Black-capped chickadee (2/2611)
Brown creeper (50/2611)
Mountain chickadee (149/2611)
Pygmy nuthatch (2/2611)
Red-breasted nuthatch (288/2611)
White-breasted nuthatch (33/2611)

Bark Gleaner Observation Form

Site _____Unit _____ Time Start _____ Time End _____
(1 hr session)

Date Observer

Bird Species Code		Random Tree		Random Tree		**Random Tree**		**Random Tree**
Foraging Behavior								
Sex								
Tree Species								
Tree dbh								
Tree height								
Horizontal Strata								
Vertical Strata								
Fire Effects								
% bark (nearest 10%)								
Bark condition								
Beetle exit holes near breast ht								
Hard or Soft Snag								

Notes:

Bird Species Code		Random Tree		Random Tree		**Random Tree**		**Random Tree**
Foraging Behavior								
Sex								
Tree Species								
Tree dbh								
Tree height								
Horizontal Strata								
Vertical Strata								
Fire Effects								
% bark (nearest 10%)								
Bark condition								
Beetle exit holes near breast ht								
Hard or Soft Snag								

BARK GLEANERS AND BARK PROBERS DATA

Behavior and Habitat Variables

Behavior: (while foraging) **GL** glean from bark surface**; PR** probe in crevice; **H** Hammer**; PK** peck (softer than hammer)**; CH** chisel (sideways hammering)**; FL** flake (breaking off small pieces of bark**; PY** pry**; PU** pull
Tree Species: Use a four-letter code (make sure to standardize and report codes)
Tree dbh: in cm
Tree height: : in meters, use clinometer
Vertical Strata: LB, UB, LC, UC, or TS (below)
Horizontal Strata: BO, SD, LD, SL, ML, LL, BT, or CN (below)
Fire Effects: 1 none**, 2** trunk only**, 3** lower leaves only, **4** half of tree's leaves, **5** nearly all or all leaves
%Bark: to nearest 10%
Bark Condition: 1 tight, **2** loose
Beetle exit holes (at breast ht): 0 none**, 1** few (< 10 evident), **2** many (> 10 evident)
Hard Snag (decay class 1-2**), Soft Snag (**decay class 3-5**)**

Foraging Habitat Codes

Code	Location	Definition
(Vertical strata)		
LB	Lower bole	Lower half of the portion of the trunk lacking live foliage, or lower half of a snag
UB	Upper bole	Upper half of the portion of the trunk lacking live foliage, or upper half of a snag
LC	Lower crown	Lower half of crown of live tree
UC	Upper crown	Upper half of crown of live tree
TS	Top of snag	Top 0.25 m of a snag
(Horizontal strata)		
BO	Bole	Main trunk of a tree or a snag
SD	Short-dead branch	Dead branch < 1 m long
LD	Long-dead branch	Dead branch > 1 m long
SL	Small-live branch	Living branch < 4 cm in diameter at location used by bird
ML	Medium-live branch	Living branch 4-8 cm in diameter at location used by bird
LL	Large-live branch	Living branch > 8 cm in diameter at location used by bird
BT	Branch tip	Tips of living branches
CN	Cone	Cone of a coniferous tree

Protocols for Avian Nest Productivity

Standardized methods have been developed to assess avian productivity (Martin and Geupel 1993, Ralph et al. 1993). Nest searches provide the most direct measurement of nest success in specific habitats. They also allow identification of important habitat features associated with successful nests and insight into important habitat requirements and species coexistence. In the Mission Creek area nest searching and monitoring should begin in early May and continue until mid July.

Nest Searches. Nest searches will be conducted in two replicates of each treatment (including controls) and nests will be monitored until the fate (fledging young or failure) has been determined. The eight stands for nest monitoring were randomly selected and include the following:

Control/Treatment	Stand Name
Control No. 1	Crow No. 3
Control No. 2	Sand No. 19
Thin No. 1	Crow No. 1
Thin No. 2	Crow No. 6
Burn No. 1	Poison No. 6
Burn No. 3	Spromberg No. 4
Thin/Burn No. 1	Tripp No. 9
Thin/Burn No. 2	Camas No. 11

As a general rule, it is recommended that one person be assigned to nest search on 2-3 study stands. The searchers should work alternating days on these stands for the entire nest season. Some nest searching can be combined with point counts and foraging observations. Ideally, nests will be located during nest construction to provide the best estimates of nest success (Ralph et al. 1993). Often the most effective way of finding nests is to locate and follow females, although males may provide some cues (Ralph et al. 1993). Nest searchers will be trained in the cues to look for to aid in finding nesting birds.

Stands will be thoroughly searched for nests following routes that traverse through all parts of the stands. Once a nest is found, flagging will be used (10-15 meters away) to indicate the species and nest number. A detailed drawing (using the attached form) will be made so that the nest can be relocated for subsequent monitoring.

Nest Monitoring. The goals of the nest monitoring are to determine the number of days that a nest was active, and whether or not a nest is successful. Nests will be checked from a distance, whenever possible, and all efforts will be made to minimize disturbance. When transitions are expected (onset of incubation, hatching, fledging) nests should be checked every 2 days. Otherwise, on average nests will be checked every 3-4 days, keeping careful track of the stage of each nest. Species-specific literature on clutch sizes, incubation, and nestling periods will be used to estimate when incubation, hatching or fledging is likely to occur so that more frequent visits can be made during these times.

Dead-end paths will be avoided when checking nests by entering along one path and exiting along another so that predators have difficulty determining the exact nest location. Active nests will not be visited if predators are nearby. If no activity is observed at the nest spend as much time as feasible, up to 30 minutes, will be spent to assume that the parents aren't just away from the nest. The total time spent trying to determine if a nest is active will be recorded. Nest monitoring will follow nest progress through termination. Nests that appear inactive will be confirmed by inspection. The nest check forms will be used to record observations as accurately and thoroughly as possible.

FFS National Study: Nest Discovery and Monitoring

Location: _____

Nest ID #: _____ Species: _____ Unit #: _____

Observer: _____ Date of Discovery: _____ Time: _____

Location of Flagging from Gridpoint : ___ ___ : _____° @ ____ m in _____

Location of Nest from Flagging: ___° @ _____ m in _____ Search method: _____
(PB, F, SS, NBC, L, PY, YB)

Text:
(include how nest was found with notes on bird behavior)

Drawing:

Mo	Day	Time	Min @ nest	Obs	Stage	Nest cont. seen?	# Eggs	# Yng	Min age yng	Max age yng	# CB eggs	# CB yng	Comments

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Soils

Darlene Zabowski, University of Washington

The effects of wildfire on soils are many and have been well documented. Throughout the US, natural wildfires have been suppressed resulting in a buildup of fuels and standing forests. A common example from the eastern slopes of the Cascade Mountains, are forests that have few open park-like stands with few large ponderosa pine trees, and many 'dog-hair' stands of many small trees. This study will address the effects on soil of prescribed fires (F) to mimic low intensity natural fires, and the effects of thinning as a fire surrogate (FS). This study plan describes protocols for the soil assessment at one of the sites involved in this study, the Mission Creek site located within the Wenatchee National Forest. Four treatment types will studied: control, thinning, thinning with burning, and burning. Soils will be assessed before treatments (2000), after thinning (anticipated to occur in 2001) and after burning (anticipated to occur in 2002). Each treatment area is $\geq$ 10 ha, and there are 3 replicates of each treatment area.

Overall, the soils study will address the question: What is the effect of fire and fire surrogate treatments on soil properties? Specific soil properties such as nutrient content and pH will be considered, along with physical properties such as surface sheet and rill erosion and hydrophobicity. One hypotheses to be tested:

H_o: There is no effect of F or FS treatments on soil C, N, pH or exchangeable nutrients.

Because of the rugged, mountainous terrain of the study area, spatial variability is likely to be high. Although most of the study area has a sandstone parent material, other parent materials such as volcanic ash and inclusions of conglomerates and other rock types will increase soil variability. Likewise, steep slopes will increase variability through a variety of slope positions and aspects, as will changes in amount and type of vegetative cover. Thus another question to be addressed is the amount of spatial variability within the treatment area. It may be that spatial variability is great enough that any effects of fire or fire surrogates are less than variability. Thus, another hypothesis to be tested is:

H_o: There is no detectable effect of F or FS treatments on soils due to the high natural variability of the study area.

This hypothesis may be true for many soil properties. However, reductions in soil C from fire may be greater than natural variability. Table 1 shows some response variables that will be examined for treatment effects along with potential increases, decrease or no effect results.

Table S-1. Possible treatment effects by response variables for the Mission Creek Study Site. A '+' indicates an anticipated increase, a '-' indicates a decrease, and a 'o' no expected change.

	Possible Treatment Effects		
Response Variable	Thinning	Burning	Thinning + Burning
O horizon depth	o	-	-
C in A horizon	o	-	-
C in B horizon	o	o	o
N in A horizon	o	-	-
N in B horizon	o	o	o
CEC	o	o	o
% Base Saturation	o	+	+
pH in A horizon	o	o	o
pH in B horizon	o	o	o
% surface erosion	o	+	+
% bare soil surface	o	+	+
hydrophobicity	o	+	+
Soil temperature	+	+	+
Soil moisture content	+	+	+

The protocols for the soils study at Mission Creek are broken into three parts: Soil and site characterization, Field sampling and Laboratory analyses. See the national study plan for additional details about overall soil protocols.

Soil and Site Characterization

At each site, 3-4 pits will be dug to characterize soils. One pit will be located at a ridge top, another in a valley bottom, a third on a side slope and a fourth on a bare soil area (if present). Typical sites that are representative of these areas in terms of vegetation and microsite will be chosen for each pit. At each pit a soil profile description will be completed using the form shown as Attachment 1. Special attention will be given to horizon types, horizon depths and range in thickness of horizons to address variability. Color, texture, structure and other standard soil properties will also be recorded for future comparison. Specific site characteristics at the pit area such as slope, aspect, slope position, % vegetation cover and type of vegetation will be noted at each pit location. In addition to soil and site descriptions, samples will be collected from all major genetic horizons for chemical analysis and bulk density. All samples collected during the pretreatment year will be analyzed for C, N, and pH. In addition, CEC and % BS will be determined on a subset of samples, as will extractable P. Samples collected at each soil pit will be labeled as per 'grid' samples with the exception that 'pit' and location type (e.g., ridge, valley, etc.) will be included in the label. A total of approximately 200 soil samples will be collected from soil pits.

Each pit area will be photographed to show the site and the soil profile.

All field data sheets and field books will be photocopied with one copy to be kept in a master file, and the original to remain with the field collection. Information from the field sheets will be entered periodically into a spreadsheet for later statistical analysis.

Following completion of data collection, the within treatment area and among treatment area variability will be assessed. In addition, basic soil profile information will be entered into the GIS database for the Mission Creek Site.

In conjunction with the soil biodiversity team, a survey of some microclimatic data will be collected. At one slope pit location in each treatment area, soil moisture and temperature blocks (fiberglass blocks) will be inserted in the O, A, B and C horizons. The blocks will not be read during the first month after installation to allow for equilibration with the soil after the disturbance of installation. After this, readings will be taken in the morning every 4-6 weeks during the spring, summer and fall. A winter reading will be done if possible, depending on the snowpack.

Field Sampling

Soil sampling for the study site will be done using the grid established within each treatment area. The grid has been placed on a 40m spacing. Soil sampling will be done at every other node as shown in Figure 1. This should result in between 18 - 24 sample points per treatment area. Samples will not be collected right at a node due to installation disturbance. In year 0 (the pretreatment year), soil sampling will be done at 7 m due E of a sampling node. In year 1, sampling will be done at 7 m SE of the node and 7m NE in years 3 or 4 (see Figure 1).

Prior to soil sampling, a 4-m^2 area (see Figure 1) will be ocularly assessed for % bare soil, coarse woody debris, grass, shrub and herbaceous cover using a 1-m grid. This same area will be used for an ocular assessment of % sheet and rill erosion. The 16 m^2 area around the soil sampling location will be ocularly assessed for % tree canopy. The ten nearest trees will be used to assess relative amount of lichens present and average diameter of trees at grid point.

In addition, % slope, aspect, slope position and any other unique features about the location will be noted. A photo of each grid-pit site will be taken with a board showing the node ID. Photos will be taken using the grid point as the photo point.

Hydrophobicity will be measured in the field by timing the penetration of a 0.5 ml drop of water into the surface of each horizon using a fresh flat surface.

Soil samples will be collected from the O, A and B horizons, collecting all horizons present to a minimum depth of ~30 cm. Samples should be representative of the entire horizon thickness. Depth of O and A horizons will be recorded at each site as well as the

depth of sampling in the B horizon. Samples will be collected for chemical analysis from all horizons, and bulk density samples will be taken from the A horizon and B horizon (if present). Bulk density samples will be collected using a soil corer. The Fire and Fuels Team will provide bulk density assessment of O horizons. A total of approximately 750-800 samples will be collected from the grid points of the treatment areas.

All samples will be labeled with the following:

F&FS (to indicate study)
Treatment Area
Grid Pt. ID (At profile sites, 'Pit' and site type)
Horizon
Type of sample (chem or BD). If BD, include number of rings
Date
Initials of collector

A data collection sheet for each grid sample point is shown in Attachment 2.

Mineralization will be assessed at each treatment area using an *in situ* aerobic incubation. At four randomly selected grid points within each treatment area, a fresh O and A horizon sample will be collected (using soil from three spots 10m apart) in one bag. Samples will be collected in spring. After mixing, half of the sample will be returned to the lab for immediate KCl extraction for ammonium and nitrate, and half will be placed in a polyethylene bag and returned either to the O or A horizon. Field bags will be retrieved after 28 days and extracted for ammonium and nitrate to determine net mineralization.

Laboratory Analyses

All soil samples collected during year 1 will be analyzed for C, N, and pH to assess variability. In future years, some compositing may be done prior to analysis depending on the results of the first year variability assessment. A subset of samples will be analyzed for CEC, exchangeable cations and Al, and for extractable P.

All samples will be kept refrigerated prior to drying, and air-dried prior to analysis. Some samples will be tested for moisture content--if moisture content is 2% or less, then additional moisture correction measurements will not be done. If greater, then moisture corrections will be made.

Bulk density samples will be oven dried (105^{o}C), cooled and weighed, and bulk density calculated.

A CHN analyzer will be used on ground, air-dried soil to determine total C and N. If any carbonates are present, carbonate C will be determined separately. A combination pH electrode will be used on a 1:5 soil paste to determine soil pH. Cation exchange capacity will be determined using 1 M NH_4Cl and standard methods, with exchangeable cations

determined using an ICP. Exchangeable P will be measured using 0.01 M $CaCl_2$. Mineralizable N samples will be extracted using 2 M KCl followed by ammonium and nitrate analysis with an autoanalyzer. Details on the methods and references for laboratory methods are given in the National Study Plan.

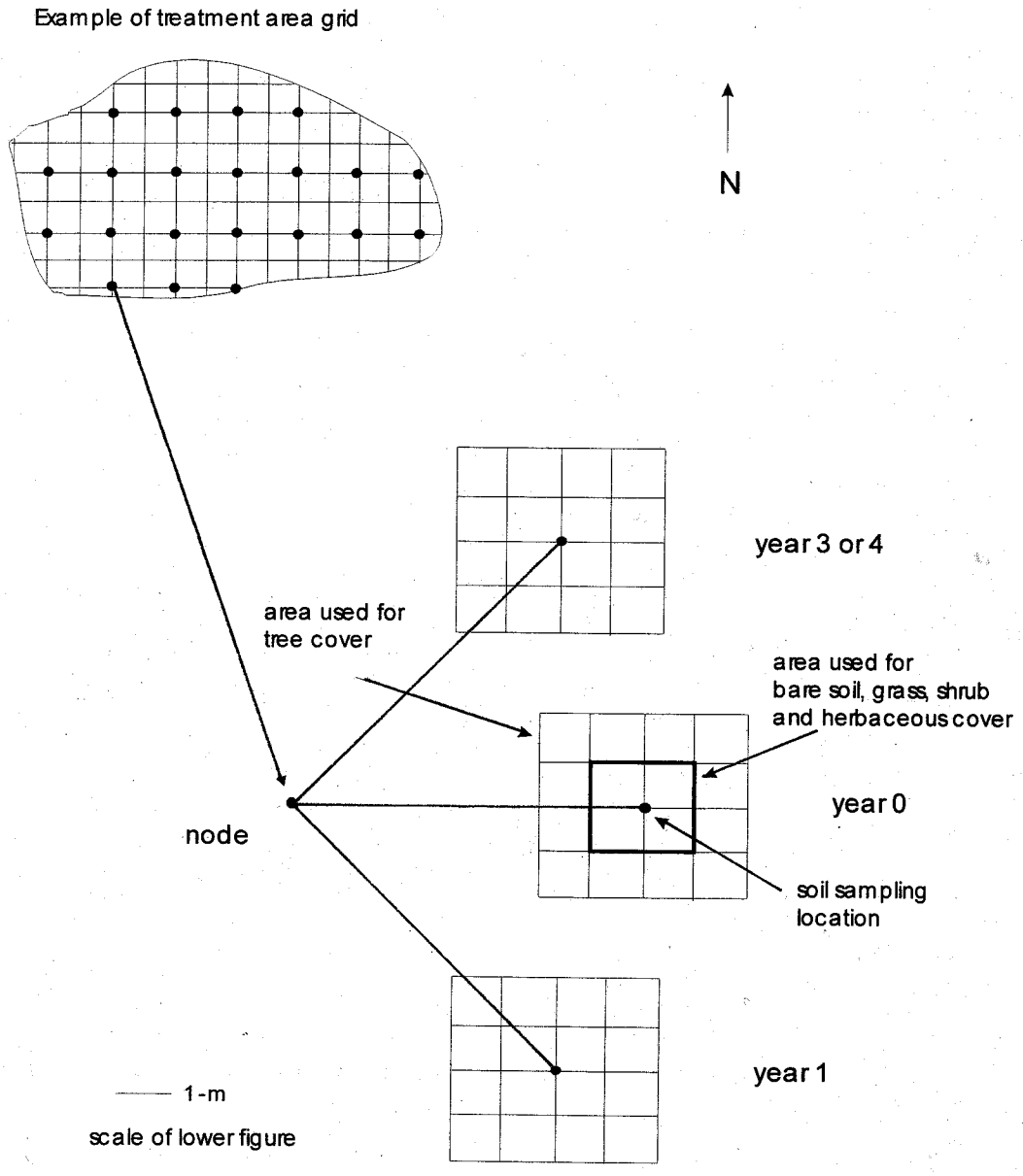

Figure 1. Layout of soil sampling points in treatment area grid and sampling for a grid node.

Attachment 2. Soil Data Form

Date: **Percentage Categories: 1**: < 15% **2**: 16-35% **3**: 36-60% **4**: 61-85% **5**: 86%-closed

TRT. AREA	**GRID ID**	**slope:**		**% vegetation**		**% canopy**	**% erosion**		**Soil horizons**	**depth (cm)**	**hyd. (sec)**	**chem. smpl.**	**BD smpl.**
				cwd		%	sheet:		O				////////
		%		bare		type:	rill:						
	Photo:	aspect		grass			other:						
		slp. pos.		herb									
				shrubs		x Diam:	**Notes:**						
				lichens									
				cwd		%	sheet:		O				////////
		%		bare		type:	rill:						
	Photo:	aspect		grass			other:						
		slp. pos.		herb									
				shrubs		x Diam:	**Notes:**						
				lichens									
				cwd		%	sheet:		O				////////
		%		bare		type:	rill:						
	Photo:	aspect		grass			other:						
		slp. pos.		herb									
				shrubs		x Diam:	**Notes:**						
				lichens									
				cwd		%	sheet:		O				////////
		%		bare		type:	rill:						
	Photo:	aspect		grass			other:						
		slp. pos.		herb									
				shrubs		x Diam:	**Notes:**						
				lichens									
				cwd		%	sheet:		O				////////
		%		bare		type:	rill:						
	Photo:	aspect		grass			other:						
		slp. pos.		herb									
				shrubs		x Diam:	**Notes:**						
				lichens									

USDA - Forest Service

SOIL DESCRIPTION
(Reference FSH 2509.18)

1. Map Unit Symbol | 2. Family or Series | 3. Date | 4. By | 5. Photo. No. | 6. Stop No. | 7. USGS Quad | 8. Location: Sec. ____ T. ____ R. ____

9. Area | 10. Forest | 11. Ranger District | 12. State | 13. County

14. Parent Material | 15. Bedrock Name | 16. Elevation | 17. Erosion: a. Kind ____ b. Class ____

18. Landform | 19. Slope: a. % ____ b. Shape ____ c. Length ____ d. Aspect ____ | 20. Drainage Class | 21. Surface Stone and Rock a. GR ____ b. CB ____ c. ST ____ d. BY ____

22. Potential Natural Vegetation | 23. Annual Precipitation | 24. Measured Soil Temperature | 25. Water Table *(Depth)*

HORIZON DESIGNATION *(a)*	DEPTH *(b)*	COLOR *(c)* Moist *(1)*	COLOR Dry *(2)*	COLOR Mottling *(3)*	TEXTURE *(d)* %C	STRUCTURE *(e)*	CONSISTENCE *(f)* Dry *(1)*	CONSISTENCE Moist *(2)*	CONSISTENCE Wet *(3)*	SPECIAL FEATURES *(g)* Cutans *(1)*	SPECIAL FEATURES % of Rock Fragments *(2)*	SPECIAL FEATURES Roots *(3)*	SPECIAL FEATURES Pores *(4)*	EFFER. CLASS *(h)*	FIELD pH *(i)*	BOUNDARY *(j)*
											GR - CB - ST -					
											GR - CB - ST -					
											GR - CB - ST -					
											GR - CB - ST -					
											GR - CB - ST -					
											GR - CB - ST -					
											GR - CB - ST -					
											GR - CB - ST -					
											GR - CB - ST -					

26. Particle Size Control Section | a. Depth: | b. Average Clay %: | c. Average Rock Fragment Content: | 27. Depth to Lithic or Paralithic Contact:

28. Diagnostic Horizons | a. Surface: | b. Subsurface: | 29. Moist Control Section Depth:

Previous edition is obsolete. FS-2500-1 (2/86)

EXISTING VEGETATION

30. *(Species)* TREES *(% Crown Cover)*	31. *(Species)* SHRUBS *(% Crown Cover)*	32. *(Species)* FORBS *(% Crown Cover)*	33. *(Species)* GRASSES *(% Crown Cover)*

34. Additional Notes *(Use and Management)*:

Standard FS Form FS-2500-1 (2/86)

Soil Biodiversity

Robert L. Edmonds and James L. Marra
University of Washington

Prescribed fire is used by forest managers to reduce fuels to avoid catastrophic wildfire and maintain forest health. Use of prescribed fire, however, may not be the only way to achieve these goals. Thinning can also be used, perhaps in combination with prescribed fire. This study will address the effects on soil biodiversity of prescribed fires to mimic low intensity natural fires and the effects of thinning as a fire surrogate at the Mission Creek site of the National Fire and Fire Surrogates (FFS) Study. The National FFS Study Plan provides detailed information about the overall study design, rationale and locations of all sites. The study design involves four treatments:control, thinning, thinning with burning, and burning replicated three times (12 plots). Burn treatments will be autumn fires of low intensity, and the thin treatments will be conducted by helicopter to about 15 m^2 ha^{-1}. The 10 ha plots are in the Camas Creek drainage, Leavenworth Ranger District, Wenatchee National Forest, and a 40 m grid system will be established. This study plan describes protocols for the soil biodiversity component of the study in the dry ponderosa pine forests on the east slopes of the Cascade Range in Washington.

The above-ground portion of forest ecosystems is strongly influenced by prescribed resulting in understory mortality and consumption of the forest floor. Fire effects, however, go beyond the above-ground influence; soil organisms are also affected. After fire soil fungi are depressed while bacteria are stimulated (Ahlgren and Ahlgren, 1965; Pietikainen and Fritz 1995). Ectomycorrhizas are also influenced since they tend to proliferate in the forest floor layers and would be expected to be reduced after prescribed fire. This is sometimes difficult to demonstrate statistically because of high variability (Buchholz and Gallagher 1982). Stendell et al. (1999) noted a reduction in total ectomycorrhizal biomass in the litter/organic layer one year after prescribed fire in a Sierra Nevada ponderosa pine forest, but mycorrhizal biomass in the two mineral soil layers was not significantly reduced. They also noted that mycorrhizal fungi were differentially affected. Soil invertebrates are also strongly influenced by fire and mites may be good indicators of changes in soil biodiversity. In addition, soil enzymes are good indicators of soil functional diversity and have been used to examine the influence of forest fires on soil organisms (Saa et al. 1993).

Thinning is expected to have quite a different effect on soil biodiversity than prescribed fire. Thus we will test the following **hypotheses** (Table SB-1)**:**

1. Prescribed fire alone will reduce ectomycorrhizal diversity, soil enzyme activities and mite diversity because of reduction of organic matter in the forest floor and changed, pH, temperature and moisture conditions. The impact will be less in the mineral soil.
2. Thinning alone will increase ectomycorrhizal diversity, soil enzyme activities and mite diversity because of the initial increased forest floor organic matter. However, litter inputs over time will be decreased because of thinning.

3. Thinning plus fire will have an intermediate influence on ectomycorrhizal biodiversity, soil enzyme activities and mite diversity.

Table SB-1. Hypothesized responses of soil biodiversity to FFS treatments rated on a 5-point scale: - - very negative, - slightly negative, 0 neutral, + slightly positive, ++ very positive.

Variable	Thinning	Burning	Burning + Thinning
Ectomycorrhizal diversity	+	-	0/-
Soil enzyme activity	+	-	0/-
Mite diversity	+	-	0/-

The protocols for the soil biodiversity study are broken into three parts – soil enzymes, ectomycorrhiza, and mite sampling. Sampling will be coordinated with the soils (Zabowski), fuels and fire behavior (Agee), and pathology and entomology (Hessberg) studies. We will coordinate our sampling in particular with the soil pits that will be dug at each site representing different topographic positions and vegetation types in each plot. The soil pits will be located at a ridge top, valley bottom, side slope (open and dense vegetation) and bare soil area (if present). Soil pits will be referenced with respect to the 40 m grid system. Fuels and fire behavior in the vicinity will be determined. In conjunction wit the soil characterization team some microclimatic data will be collected. At the pit locations in each treatment areas soil moisture and temperature blocks will be inserted in the O, A, B and C horizons. Readings will be taken every 4-6 to 6 weeks during the spring summer and fall. A winter reading will be done depending on the snowpack. If possible continuously recording Hobotemp data loggers will be installed in the A horizon in the closed vegetation side slope position in each plot.

Soil enzymes

Soil samples will be collected using a 4 cm diam soil corer at 4 locations at each of 4 soil pits (located at a ridge top, valley bottom, side slope (open and dense vegetation) in each plot from the O and A horizons (or the upper 10 cm). Locations will be 5 m from the soil pits and points will be referenced to the 40 m grid system (Figure 1). Samples from each of the 4 locations will be composited. Samples will be taken in spring, since this is expected to be the time of greatest microbial activity, before and after treatments are established. Four enzymes will be chosen involved in the release of N and P and degradation of labile and recalcitrant C forms: acid phosphatase, B-glucosidase, chitobiase, and phenol oxidase. The rationale for using enzyme assays for functional biodiversity monitoring is attached along with detailed methods. Eight samples (1x4x2) will taken at each of the 12 study plots each year; the total number of annual samples will be 96 (8x12).

Ectomycorrhizas

Ectomycorrhizal fruiting bodies will be collected in fall and spring from the areas surrounding the soil pits and returned for identification and molecular analysis at the University of Washington Botany Mycology lab. Their positions will marked relative to the grid. In addition the plots will be walked and the location of fruiting bodies will be marked relative to the 40 m grid locations. Unknown species will be collected for identification and molecular analysis.

In spring soil cores will be collected from each of the sampling sites used for the soil enzyme sampling. Cores will be 4 cm in diameter and 20 cm deep. Resulting holes will be filled with soil to minimize disturbance. Cores will be returned to the lab and stored at 4 C. Techniques for sorting and processing the roots are described in Stendell et al. (1999). Cores will be divided into the litter and organic soil layer and the mineral soil. Roots will be classified by morphotype. DNA will be extracted from root tips with different morphotypes and from sporocarps and matched. PCR and ITS-RLFP will be used.

Mites

The soil samples collected for the enzyme analysis will be used to extract mites. A modified high gradient Berlese extraction will be used (Moldenke 1994). Mites will be identified to genus and morphological types (Moldenke and Fichter 1988).

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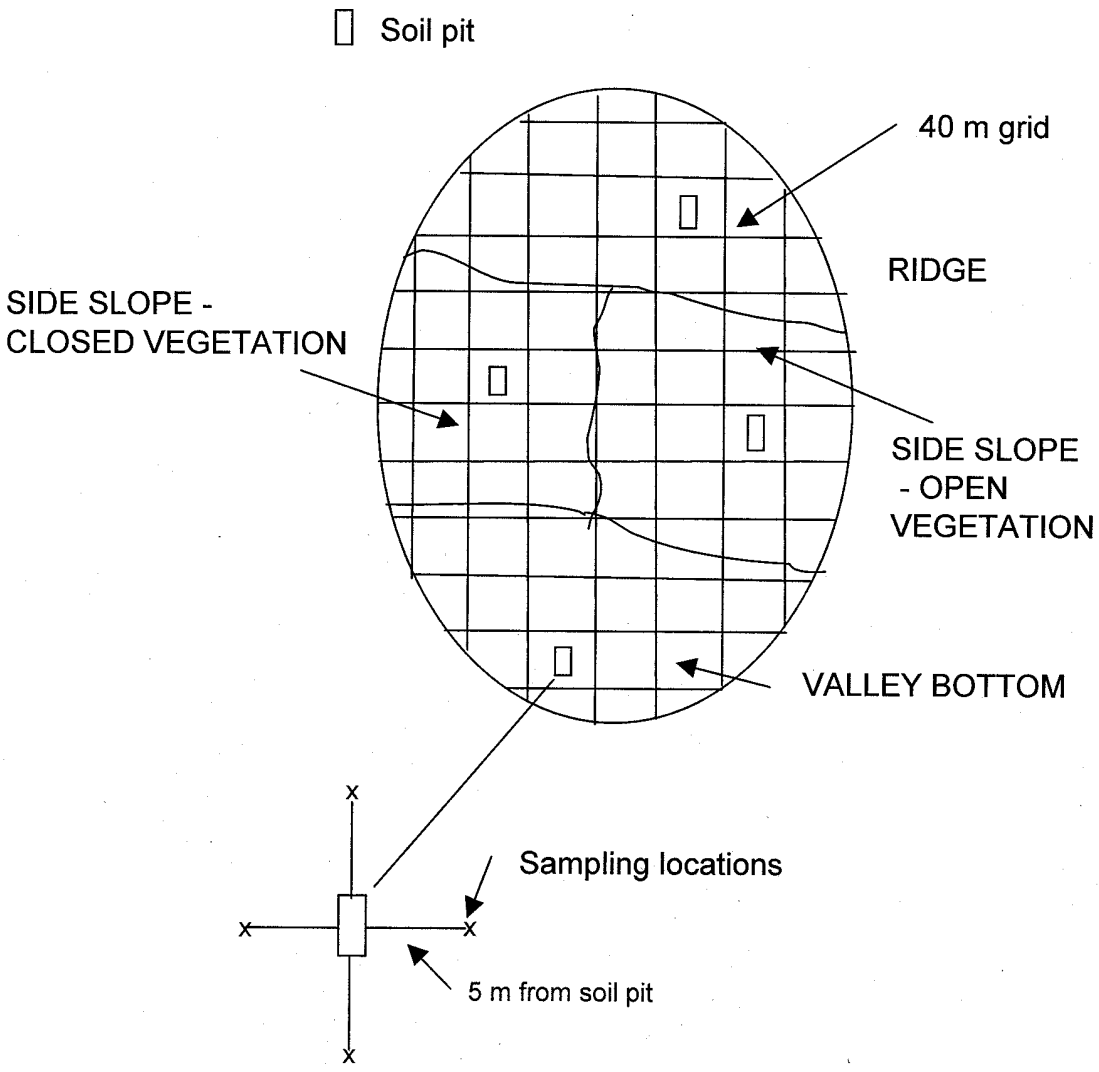
Pietikainen, J. and H. Fritze. 1995. Clearcutting and prescribed burning in coniferous forest: comparison of the effects on soil fungal and total microbial biomass, respiration activity and nitrification. Soil Biology and Biochemistry 27:101-109.

Saa, A., M. C. Trasar-Cepeda, F. Gil-Sotres and T. Carballas. 1993. Changes in soil phosphorus and acid phosphatase activity immediately following forest fires. Soil Biology and Biochemistry 25:1223-1230.

Stendell, E. R., T. R. Horton and T. D. Bruns. 1999. Effects of prescribed fire on the structure of the ectomycorrhizal fungus community in a Sierra Nevada ponderosa pine forest. Mycol. Res. 103 (10): 1353-1359.


Soil pit
40 m grid
RIDGE
SIDE SLOPE -
CLOSED VEGETATION
SIDE SLOPE
- OPEN
VEGETATION
VALLEY BOTTOM
Sampling locations
5 m from soil pit

Entomology/Pathology

Paul Hessburg and Robert Edmonds
USDA Forest Service and University of Washington

Study design

The study will take place in the Mission Creek watershed. There will be a total of 12 treatment units. Each unit will range in size from 10-20 ha. Among the 12 treatments, 3 will be controls, 3 thin-only, 3 burn-only, and 3 thin-and-burn. Units will be placed on all other aspects but north, on slopes < 40%, with no more than 10% rock cover, and areas with survey and manage or rare plant species will be avoided. Units will be placed in a narrow range of dry forest environments indicated by dry Douglas-fir potential vegetation types including the PSME-SPBE, PSME-PUTR, PSME-CARU and PSME-SYAL plant associations. Thinned units will be helicopter-yarded. Pretreatment measurements will occur during the FY00 field season (May-September); thinned units will be harvested in 2001, burned units will be ignited in 2002. Post-treatment resurvey will occur during the 2003 and 2004 field seasons.

Each treatment unit will contain an 8x8, 40-m permanently referenced grid (Appendix B). All plot measurements will be referenced to the grid. Grid points will be geo-referenced by GPS. Measurement variables will be expressed at the unit level with appropriate variance terms. A more detailed study description is given in the National FFS proposal (http://ffs.psw.fs.fed.us/proposal.html) and in the Vegetation Protocols by Harrod.

In general terms, this study is simply about applying prescribed burning, thinning, and combined treatments to replicated stands and evaluating differential effects of treatments on various dimensions of each stand. We will statistically evaluate significance of treatment effects on response variables individually and in multi-way combinations. Response variables will capture the change in status of various stand characteristics as a function of treatment. Response variables will apply to the existing fuelbed, duff and litter depth, snag and down wood abundance and characteristics, tree, shrub, and herb communities, tree demography, soil properties, soil flora, passerine bird abundance, small mammal abundance, incidence and severity of native forest pathogens and insects, and a host of other related characteristics. In this study plan, we provide protocols for establishing insect and disease conditions prior to treatment, and for re-evaluating those

conditions after treatment. We provide hypotheses concerning treatment effects on insect and disease response variables in Table E-1.

Table E-1. Hypotheses concerning the effects of prescribed burning (B) and thinning (T) treatments on pathology and entomology response variables:

Response variables (stand-level)	**Treatment**			
	Thin	Burn	Thin/Burn	Control
Armillaria root disease infection (*A. ostoyae*)	-	0	-	0
Armillaria root disease mortality (*A. ostoyae*)	0	+	0	0
Annosum root disease infection (P-group)	+ +	0	+ +	0
Annosum root disease mortality (P-group)	0	0	0	0
Dwarf mistletoe incidence	- -	-	- -	0
Dwarf mistletoe severity	- -	- -	- -	0
Bark beetle mortality	- -	+ +	- -	+
Woodpecker foraging	- -	+ +	- -	+

Note: anticipated changes are **for the time frame of the study only (FY00-04)**. (++) = significant increase; (+) = nonsig. increase; 0 = no change; (-) = nonsig. decrease; (- -) = significant decrease.

Response variables (stand-level)	**Treatment**			
	Thin	Burn	Thin/Burn	Control
Armillaria root disease infection (*A. ostoyae*)	-	+	+	+
Armillaria root disease mortality (*A. ostoyae*)	-	+	+	+
Annosum root disease infection (P-group)	+ +	0	+ +	+
Annosum root disease mortality (P-group)	+ +	0	+ +	+
Dwarf mistletoe incidence	- -	+	- -	+ +
Dwarf mistletoe severity	- -	+	- -	+ +
Bark beetle mortality	- -	+	- -	+ +
Woodpecker foraging	- -	+	- -	+ +

Note: anticipated changes are **for the 30 year period following the study**. (++) = significant increase; (+) = nonsig. increase; 0 = no change; (-) = nonsig. decrease; (- -) = significant decrease.

2. Geo-referencing the treatment units

2.1. Orthogonally rectifying the aerial photos. In the entomology and pathology portions of the study we will be collecting exclusively spatially referenced data rather than plot-based data. This will be done to enable future change and spatial analyses.

Indeed, bark beetle mortality centers are spatially autocorrelated, and it seems foolish to assume that treatment effects on bark beetle populations and associated mortality will occur within treated stands only. To connect treated stands and treatment effects with the larger surrounding landscape, we will geo-reference all data and if needed populate spatially referenced data back to an established plot grid in the GIS.

In addition, we are conducting 100% surveys and developing spatially referenced data sets to increase the power of multi-way analysis of variance or other tests of independence. If treatment units and individual trees are geo-referenced prior to treatment, then treatment effects can be geo-referenced. With geo-referenced data it will be possible to consider in multi-way analysis of variance or discriminant function analysis a great variety of interactions that may be associated with treatments while increasing degrees of freedom over conventional plot based analysis. For example, if we are interested in evaluating interactions between litter and duff depth, fuel consumption, and bark beetle mortality by treatment we can interpolate a continuous map of these feature using other correlated continuous maps or statistically by kriging, combine the continuous maps into a single coverage, rasterize the coverage to 30-m and run multi-way analysis with several hundred rather than several dozen degrees of freedom.

By the time we begin to implement the pathology and entomology field protocols, treatment unit boundaries and the 40-m permanent plot grid will be GPS-ed. Unit boundaries will constitute a separate map coverage in a geographical information system (GIS). We will procure 38" x 38" enlargements of CY92, 1:12,000 resource aerial photos from the Salt Lake City, Aerial Photo Field Office that provide full coverage of each treatment unit within the effective area of a photo. The resultant photo scale will be 1:3,000 (38"x38" format). We will also procure 17.5 µm and 50 µm resolution digital images of each photo. We will orthogonally rectify the digital images using the OrthoRec® ArcView extension, effectively making them 1:12,000 scale orthophotos.

To rectify the digital photographic image, we will select a minimum of 6-8 control points for each photo displaying treatment units within the effective area of the photo. Control points will be also important for aligning the pre- and post-treatment insect and disease mortality maps to the orthogonally rectified aerial photos. Control points will be landmarks such as road junctions, stream confluences, rock outcrops, and the like, which are fixed in space over long time frames. The same control points will be identified on the 1:24,000 digital orthophotos and the 1:12,000 digital aerial photos along with their

XYZ coordinates from a 10-m or 30-m DEM (digital elevation model). Coordinates will be used to correct for airplane attitude deviations from horizontal, and thereby rectify the control points, unit boundaries, and individual trees to the terrain via the DEM.

Once the digital aerial photo files are orthogonally rectified, the picture image of each treatment unit will be a geo-referenced coverage. We will combine this photo coverage, a coverage of the GPS-ed treatment unit boundaries, and a coverage of the GPS-ed 40-m permanent plot grid, with a 10-m or 30-m digital elevation model (DEM) in a GIS. This will enable us to reproduce geo-rectified, printed paper copies of the photos that are magnified to readily show individual dominant, codominant, and intermediate trees. We will plot the printed copies within the limits of magnification so as not to distort depth of field or depth of focus.

In addition, we will extend the 40-m plot grid to the treatment boundaries using a 40-m UTM grid referenced to the original established grid. This will enable other FFS scientists (*e.g.,* Agee/Fuels, Zabowski/Soils) who may need to sample outside the original established 8 x 8 plot grid, to continue their samples at the original grid interval without having to survey and tape to each of the new grid points, and to readily establish and permanently reference the additional grid points in the field.

2.2. Mapping insect and disease mortality centers. Once the digital aerial photos are rectified, we will combine the 40-m UTM grid and the rectified photo coverage (such that a grid hairline is superimposed over the photographic image of the trees), enlarge the photo such that the dominant, codominant and intermediate trees can be readily distinguished, and print the photo of each treatment unit in 12" x 12" photo segments. Photo segments will be covered front and back with clear contact film for use in the field. One 12" x 12" clear Mylar ® overlay will be taped to each photo with masking tape. Onto each overlay root disease and dwarf mistletoe (optional) infected and bark beetle infested trees will be mapped, UTM grid corners and grid cell alphanumeric codes will be scribed for reference, and unit boundaries will be plotted for later registration to the 1:12,000 digital orthophotos. Photo scale (approx. 1:1,500 to 1:2,000) should allow resolution of individual dominant, codominant, and intermediate trees as well as some suppressed trees because overstory crown cover is typically less than 70-80%. Infected and infested trees will be individually mapped on the Mylar overlays to the full extent of the drip line.

2.3. Treatment units. Aerial photos will be taken from the 1992 flight unless a current year flight is scheduled and implemented in time. The 1992 photo numbers are listed by area and treatment unit:

1) Poison, Slawson, and Tripp Canyon area:

Units: Slawson #8, Tripp #9, and Poison #6:

flightline #32, photo numbers 1192-95, 1192-96, 1192-45, 1192-46.

2) Crow and Pendleton Canyon area:

Units: Crow #1, Crow #6, Crow #3, and Pendleton #30:

flightline #32, photo numbers 1192-25, 1192-26.

3) Deer Park Springs area:

Units: Little Camas #11, Spromberg #4, Ruby.

flightline #32, photo nos. 492-181, 492-180, 492-179, 492-185, 492-184.

4) Sand Creek area:

Units: Sand #2, and Sand #19:

flightline #33, photo numbers 1192-43, 1192-42, 1192-98.

Treatments Assigned by Unit Number:

Control Units: Sand #19, Crow #3, Pendleton #30.

Thin Units: Slawson #8, Crow #6, Crow #1.

Burn Units: Poison #6, Sand #2, Spromberg #4.

Thin/Burn Units: Tripp #9, Little Camas #11, Ruby.

3. Pathology Protocols

For both the pathology and entomology pre- and post-treatment surveys, we will be implementing a 100% field survey and mapping of existing root disease and dwarf mistletoe infected trees and infection centers, and individual bark beetle affected trees and mortality centers. In the GIS, disease and bark beetle centers will be later geo-referenced as separate coverages to rectified 1:12,000 resource aerial photographs by means the 40-m UTM grid. Each photo overlay will be marked with the GPS-ed treatment unit boundary, where applicable, and the 40-m reference grid cell corners. Disease and bark beetle centers will be mapped on Mylar® overlays on the magnified color aerial photo reprints. Individual diseased and bark beetle infested or killed trees will be mapped to the full extent of the drip line of each affected tree. Hand-drawn maps of insect and disease centers on Mylar overlays will be later scanned at the lab to produce digital files, and edited and edge matched in ArcEdit.

During the pre- and post-treatment surveys, we will identify and map all trees showing new symptoms or mortality associated with a root disease pathogen. Root pathogens of interest will be *Phellinus weirii* (PHWE), the cause of laminated root rot, *Heterobasidion annosum* (HEAN) (both S- and P-groups), the cause of annosum root disease, *Armillaria* spp., especially *A. ostoyae* (AROS), the cause of Armillaria root disease, and *Leptographium wageneri* (LEWA), the cause of black stain root disease. We will also identify and map all trees infected by a dwarf mistletoe (*Arceuthobium* spp.) species (optional). Dwarf mistletoes of interest to the FFS study will be *A. campylopodum* (ARCA), the cause of western dwarf mistletoe of ponderosa pine, and *A. douglasii* (ARDO) the cause of Douglas-fir dwarf mistletoe.

3.1. Root pathogens. Minimally invasive root and root collar excavations will be used to locate and identify root pathogens in symptomatic trees. Root pathogens will be identified by the characteristic signs and symptoms associated with disease using the published survey procedures of Hadfield and others (1986). When a symptomatic tree is identified, we will examine a major lateral root to a distance of 1-m from the root collar, in at least two cardinal directions.

3.1.1. Special methods for identifying Armillaria spp.. *Armillaria* spp. are particularly difficult to diagnose to the species level in the field because they share many signs in common. In addition, researchers have discovered in recent years that *Armillaria* spp. community ecology is quite complex; i.e., several species may be found in the same infection centers and occasionally in the same trees, and some saprophytic species may act as biological control agents by cross-protecting the host against pathogenic species. For these reasons, it is imperative to use reliable markers or indicators when attempting to differentiate *Armillaria* spp. Standard methods include somatic compatibility assays using tester cultures. More recently researchers have attempted to use molecular techniques to differentiate *Armillaria* spp.

In this study, when putative *Armillaria* species are encountered in the survey, as identified by crown symptoms, mycelial fans, rhizomorphs, resin-soaked straw-colored decay with characteristic flecking, basal resinosus, and resin-soaked bark, "*Armillaria* spp." (ARxx) will be provisionally recorded, and fresh specimens of infected roots will be collected. One 2-3" root specimen with mycelial fan and the outer bark solidly attached will be removed and placed in a Ziploc® bag, with treatment unit number, UTM grid cell alphanumeric, and tree number recorded as the sample identification (*e.g.*,

Crow_6, Cell_D4, Tree_3). Samples will be cold stored in a styrofoam ice chest with dry ice until the cooler is approximately ¾ full, and then taken to the laboratory for temporary cold storage and shipping.

Rhizomorphs will be collected when they are found adjacent to or on an infected or non-infected root of a symptomatic tree. Rhizomorphs will be collected, stored immediately in plastic tubes, and placed at days end in the cooler on dry ice. Rhizomorph specimens will be tagged and numbered in the same manner as the bark specimens.

Isolations from infected root samples and rhizomorphs will be conducted using published protocols and standard cultural media by personnel at the Moscow FSL. Isolates will be ultimately be identified to genet and North American Biological Species (NABS) by our cooperator Geral McDonald, Principal Plant Pathologist using established tester cultures and amplified RFLP (restriction fragment length polymorphism) molecular assays. To determine the total number of unique genets (clones of each *Armillaria* species) in each treatment unit, personnel at the Moscow Lab will conduct somatic compatibility tests of all fungal isolates within and among units. The total sample of unique genets will come from mycelial fan and rhizomorph materials. Unique genets will then be submitted to RFLP evaluation. To conduct the RFLP evaluations, sample DNA from the fungal cultures will be extracted and amplified using PCR (DNA polymerase chain reaction) technology, sequenced at a commercial lab in Pullman, WA, and sequence assembly (contiguity analysis) will be conducted at the Moscow Lab. Restriction fragment length polymorphisms among isolates will be compared for the IGS region to differentiate unique genets and species of the *Armillaria* complex.

Tree and site attribute data collected when symptomatic *Armillaria* root diseased trees are located will include: plant association, elevation, aspect, treatment unit number, UTM grid cell, tree number, tree height, d.b.h., tree species, putative root pathogen(s), tree live crown ratio (LCR), radial growth (measured in 20^{ths} of an inch for the last 10 years growth, e.g., $13/20^{ths}$), bark beetles, woodborers, extent of any woodpecker work, identity of saprotting fungi, and extent of saprot. These data may be later used to parameterize the FVS growth model coupled with the western root disease extension to determine long term effects of treatments on root disease spread from residual infected trees.

In addition to collecting samples from all visibly symptomatic trees, trees without visible symptoms of root disease or other damaging agents will be surveyed in a systematic

random sample for *Armillaria* spp. at a rate of at least 5 trees ha^{-1}. When a nonsymptomatic tree is randomly sampled, crews will map the tree on the Mylar overlay, record the site and tree attribute data, and examine one major lateral root to a distance of 1-m from the root collar, in at least two cardinal directions. When signs (mycelial fans, rhizomorphs, resin-soaked straw-colored decay with characteristic flecking, basal resinosus, and resin-soaked bark) of *Armillaria* spp. infection are evident on nonsymptomatic trees, a bark specimen will be removed and placed in a Ziploc® bag with treatment unit number, UTM grid cell alphanumeric, and tree number recorded as the sample identification, and cold stored as described above for later identification. Tree and site attribute data collected when *Armillaria* spp. are located on nonsymptomatic trees will be the same as above: plant association, elevation, aspect, treatment unit number, UTM grid cell, tree number, tree height, d.b.h., tree species, root pathogen(s), LCR, radial growth, bark beetles, extent of any woodpecker work, and identity of saprotting fungi. When no visible signs (including rhizomorphs) or symptoms are detected, the sampled tree is still mapped on the photo overlay with all tree and site data recorded (but in the column for 'Root pathogen', *none* will be indicated).

Rhizomorphs will be also collected where they are present on or adjacent to an exposed root of any nonsymptomatic tree in the random sample, placed in plastic tubes with treatment unit number, UTM grid cell alphanumeric, and tree number recorded as the sample identification, and cold stored as described above for later identification. Rhizomorph specimens will be tagged and numbered in the same manner as before, and all tree and site attribute data will be recorded for the sampled tree.

3.1.2. Special methods for identifying annosum root disease. When annosum root disease is identified in trees in the field according to its unique symptoms and signs (reddish incipient decay, white-spongy rot advanced decay, stomatal flecking in the advanced decay, small buff-colored popcorn fruiting bodies, surface mycelium, laminated decay with pitting on one side of the laminae), the infection will be provisionally recorded as HEAN on the data record for that tree. We will then remove one root core from the infected root with an increment borer, place the sample in a soda straw, seal both ends of the soda straw with masking tape or by lightly melting with a lighter, identify the sample by its treatment unit number, UTM grid cell alphanumeric, and tree number, and cold store the samples as described above for later identification. As before, samples will be stored in a styrofoam ice chest with dry ice until the cooler is approximately ¾ full, and then taken to the laboratory for temporary cold storage and shipping. Samples will be

shipped to the Moscow Lab for further processing and identification. Tree and site attribute data to be collected when annosum root diseased trees are located will be the same as above. These data may be used later to parameterize the FVS growth model coupled with the western root disease extension to determine long term effects of treatments on root disease spread from residual infected trees.

Isolations from HEAN infected root cores will be conducted using published protocols and standard cultural media by personnel at the Moscow FSL. The *S*- and *P*-group identities will be identified by our cooperator at the Moscow Lab. To determine the total number of unique genets (clones of each HEAN *S*- and *P*-group), personnel at the Moscow Lab will conduct somatic compatibility tests of all fungal isolates within a treatment unit. The total sample of unique genets will come from fungal material isolated from root cores. Unique genets will be submitted to RFLP evaluation as before. Again, sample DNA from the fungal cultures will be extracted, PCR amplified, sequenced at the lab in Pullman, and sequence assembly will be conducted at the Moscow Lab. Restriction fragment length polymorphisms among unique genets will be compared for the ITS region to differentiate the *S*- and *P*- and *S/P* hybrid pathovars. *S*- and *P*-group identities among unique genets will then be associated back to the original sampled and mapped trees.

In addition to collecting samples from visibly symptomatic trees, trees without visible symptoms of root disease or other damaging agents will be surveyed in a systematic random sample for HEAN at a rate of at least 5 trees per ha^{-1}. These nonsymptomatic trees will be the same trees that are randomly sampled for *Armillaria* spp. When a nonsymptomatic tree is randomly sampled, crews will map the tree on the Mylar overlay, record the site and tree attribute data, and examine one major lateral root to a distance of 1-m from the root collar, in at least two cardinal directions. Whether signs of HEAN infection are evident on these nonsymptomatic trees or not, the tree will be mapped on the photo overlay, data will be recorded on the tree as outlined above, and a root core will be removed and placed in a soda straw, the straw will be sealed with treatment unit number, UTM grid cell alphanumeric, and tree number recorded as the sample identification, and cold stored as described above for later identification.

3.2. Dwarf mistletoes (optional). *Plan A.* When a dwarf mistletoe-infested live tree is identified in the field, infection severity will be recorded by estimating a Hawksworth dwarf mistletoe rating (DMR) for that tree. Dwarf mistletoe infections will be identified

by the presence of mistletoe-induced witches brooms in the host, and by the presence of the male (stamenate--pollen producing) and female (pistillate--seed producing) plants of the parasite. We will record the DMR of each infected dominant, codominant, and intermediate tree >8" d.b.h. DMRs will be obtained by dividing the stacked live crown vertically into equal thirds and each third is assigned a rating of 0, 1, or 2:

0 = no visible branch infections (mistletoe plants) or witches' brooms are located anywhere in the third;
1 = < ½ of the branches in the third are infected or with brooms;
2 = > ½ of the branches in the third are infected or with brooms.

In ponderosa pine, a large witches' broom (*i.e.*, the broom is the single dominant feature) in any crown third is sufficient to give that third a rating of 2. In Douglas-fir, mistletoe plants are often too small to see from the ground, and DMR ratings are based almost entirely on visible brooms in infected branches. The maximum DMR score is 6 for any tree, the minimum score is 0.

Tree and site attribute data collected when dwarf mistletoe-infested trees are located will include: plant association, elevation, aspect, treatment unit number, UTM grid cell, tree number, tree height, d.b.h., tree species, tree live crown ratio (LCR), radial growth, DMR. Some of these data may be used at a later date to parameterize the FVS growth model coupled with the dwarf mistletoe extension to determine long term effects of treatments on dwarf mistletoe spread and intensification from residual infected trees.

Plan B. Since the characterization of pretreatment dwarf mistletoe conditions is not addressed in the national protocols, collection of the pre- and post-treatment dwarf mistletoe data is completely optional in our study plan. In the event that dwarf mistletoe infection centers are widely distributed in treatment units, we may choose to adopt a point sampling method of mistletoe data capture. This would involve randomly placing a single variable plot (BAF 20) in every UTM grid cell, spaced 10-m to the SW (225^{o}) from the NE corner of the UTM cell as indicated on the rectified aerial photo. Plots would be placed in grid cells until 60 plots had been measured. As before, we would record the tree and site data, and DMR of each infected dominant, codominant, and intermediate tree >8" d.b.h. All trees >8" d.b.h. in each variable plot would be mapped to the Mylar photo-overlay and attributed regardless of whether the tree was mistletoe infested.

4. Entomology Protocols

During the pre- and post-treatment surveys we will identify and map all trees showing new symptoms or mortality associated with tree-killing bark beetles (Coleoptera: Scolytidae, *Scolytus*, *Dendroctonus*, and *Ips* spp.). In Douglas-fir, we will be looking primarily for the Douglas-fir beetle, *Dendroctonus pseudotsugae*. In ponderosa pine, we will look for the mountain pine beetle, *D. ponderosae*, the western pine beetle *D. brevicomis,* the red turpentine beetle, *D. valens,* and pine engraver beetles, *Ips* spp. In grand fir, (we expect to find grand fir only in adjacent riparian areas and valley bottoms) we will be looking for the fir-engraver, *Scolytus ventralis*. Bark beetles will be identified by the host species attacked, the characteristic gallery patterns, the presence and appearance of pitch tubes, the presence and color of boring frass, by the presence and number of gallery ventilation holes (uni- versus bi- or multi-ramous), and by examining living and dead callow adults that may be present in the galleries. Galleries will be examined by removing a section of bark with an axe or Pulaski in the vicinity of pitch tubes, pitch streaming, and boring frass.

We will record woodpecker activity ('Woodpecker extent', 'Woodpecker scaling', 'Woodpecker hits') and rate the level of foraging on individual bark beetle infested trees using standards provide by Gaines. We will also record evidence of saprotting fungi ('Saprot species', 'Saprot extent') such as *Cryptoporus volvatus* and *Hirschioporus abietinum* by the presence and extent of basidiome fruiting. Such evidence may be useful to wildlife interpretations that are concerned with the treatment effects on the future availability of soft snags.

5. Analysis

5.1. Inferential statistics. When pre- and post-treatment surveys have been completed, we will evaluate the truth of the null hypothesis that there are no significant differences in the extent of bark beetle effects among the control, thin, burn, and thin/burn treatments by analysis of variance (ANOVA) or other equivalent nonparametric test in the event that data are not normally distributed. Potentially significant differences in bark beetle mortality effects will be compared by Tukey's-W or other similar nonparametric multiple comparison procedure. Initial effects by treatment will be detectable by the close of the study. We will evaluate pre- to post-treatment trends among replicate mean incidence levels for all treatments. Evaluation of root disease short term treatment effects will be

accomplished in the same manner, but evaluating the effect of treatment on the long-term disease manifestation will take more time than the study allows. To that end, we will evaluate long-term effects of treatment by FVS simulation, time and money allowing. We will compare short and long-term effects in the same manner, *i.e.*, as the replicate mean incidence level of root disease after 2, 10, 50, and 100 years.

5.2. Spatial statistics. Because we are geo-referencing the pre- and post-treatment aerial photos and mapping insect and disease mortality centers to these same photos, and because the 40-m reference grid will be GPS-ed, we will be able to populate the grid with spatial data items. We will also be able to populate the spatial layers with any data from the reference grid either as continuous maps or as data averaged to some patch type of interest. For example, pre- and post treatment depth of O-horizon and fuelbed may be extrapolated to a continuous map across each treatment unit using a stratification scheme given by Drs. Zabowski and Agee, or statistically via an interpolation algorithm such as kriging or co-kriging. We can then rasterize the treatment unit to a 30-m grid and select several hundred pixels at random and submit them as sampling points to treatment effects analysis. This will significantly increase the power of analysis by enhancing replication by at least one and perhaps two orders of magnitude. We can also use spatially continuous data layers to evaluate fragmentation and contagion relations of treatment effects because we can apply spatial pattern metrics from a pattern analysis program such as FRAGSTATS. Finally, we can develop transition analyses in the GIS that reflect transitions by grid cell for any variables of interest. For example, we can evaluate transitions among combinations of pre- and post-treatment fuelbed depths and O-horizon depths. This will assist us in explaining mechanisms behind treatment effects.

Plant Associations: *Wenatchee NF Guide*

Code:	**Latin and Common names:**
PSME/AGSP	*Pseudotsuga menziesii/Agropyron spicatum* Douglas-fir/bluebunch wheatgrass
PSME/CARU	*Pseudotsuga menziesii/ Calamagrostis rubescens* Douglas-fir/pinegrass
PSME/CARU/AGSP	*Pseudotsuga menziesii/Calamagrostis rubescens/Agropyron spicatum* Douglas-fir/pinegrass/bluebunch wheatgrass
PSME/PUTR	*Pseudotsuga menziesii/Purshia tridentata* Douglas-fir/bitterbrush
PSME/PUTR/AGSP	*Pseudotsuga menziesii/Purshia tridentata/Agropyron spicatum* Douglas-fir/bitterbrush/bluebunch wheatgrass
PSME/PUTR/CARU	*Pseudotsuga menziesii/Purshia tridentata/Calamagrostis rubescens* Douglas-fir/bitterbrush/pinegrass
PSME/SPBEL	*Pseudotsuga menziesii/Spirea betulifolia* Douglas-fir/shiny-leaf spirea
PSME/SPBEL/CARU	*Pseudotsuga menziesii/Spirea betulifolia/Calamagrostis rubescens* Douglas-fir/shiny-leaf spirea/pinegrass
PSME/SYAL	*Pseudotsuga menziesii/Symphoricarpus albus* Douglas-fir/common snowberry
PSME/SYAL/AGSP	*Pseudotsuga menziesii/Symphoricarpus albus/Agropyron spicatum* Douglas-fir/common snowberry/bluebunch wheatgrass
PSME/SYAL/CARU	*Pseudotsuga menziesii/Symphoricarpus albus/Calamagrostis rubescens* Douglas-fir/common snowberry/pinegrass

Tree species:

Code:	**Latin name:**	**Common name:**
PSME	*Pseudotsuga menziesii*	Douglas-fir
PIPO	*Pinus ponderosa*	ponderosa pine
ABGR	*Abies grandis*	grand fir

Tree status:

Code:	Means:	Characteristics:
NonS	Nonsymptomatic	Tree appears green and healthy; all of the following NOT OBSERVED: foliar chlorosis, needle stunting, distress cone crop, foliage reddening, basal resinosus, needlecast (shedding of older needles with only recent one or two years retained)
Symp	Symptomatic	Any one of the following OBSERVED: foliar chlorosis, needle stunting, distress cone crop, foliage reddening, basal resinosus, needlecast
CurK	Current year killed	Mid to late summer--Cambium is all or partially dead, all foliage is red and fully retained, tree may be freshly blue-stained, fine branches are fully retained, bark is completely solid with no evidence of saprotters or their fungal fruiting structures, there may be evidence of current ambrosia beetle activity (white boring dust is highly visible on bark plates), there may be evidence of fresh bark beetle activity (recent pitch tubes, reddish-brown boring dust is highly visible on bark plates, with viable pupae, older larvae, teneral adults)
CurA	Current year attack	Spring to early summer--Cambium is all or partially alive, all foliage is green, green fading to yellow or red or yellow-orange or brown, all foliage is fully retained, tree may be partially blue-stained, fine branches are fully retained, bark is completely solid, no evidence of saprotters or their fungal fruiting structures, no evidence of current ambrosia beetle activity, there is evidence of fresh bark beetle activity (reddish-brown boring dust is highly visible on bark plates, pitch tubes and clear pitch streaming are visible, bark underside with viable pupae, larvae, teneral adults)
Dead	Tree recently killed	Cambium is dead, red foliage may be partially, or not retained, tree may be blue-stained, most fine branches are retained, there may be evidence of recent wood borer (flat-

		headed or roundheaded) activity, bark is mostly solid but may be removed easily, there may be evidence of older bark beetle activity (reddish-brown boring dust no longer visible, shotholes are widely apparent where beetles emerged)
Snag	Tree NOT recently killed	Tree is sap-rotted, bark is NOT solid, some bark has been sloughed, evidence of significant old wood borer galleries, fine branches have been lost, top may have broken out, evidence of bark beetles is old, attacking bark beetle species may no longer be recognizable, may have evidence of woodpecker work (foraging holes or cavity excavation)

Tree DBH:
Tree diameter at breast height (DBH, 4.5 ft. above the ground, high side of tree) is recorded with a D-tape to the nearest $1/10^{th}$ inch for all symptomatic trees with evidence of root disease or bark beetle attack, and for randomly sampled nonsymptomatic trees.

If a tree has been dead so long that it is impossible to accurately record the attacking root pathogen and/or bark beetle species, it is likely a snag. For trees such as these, record all data as usual, record tree status as 'Snag', and for the *root pathogen* and *bark beetle* items, record 'UNK' for unknown.

Tree height:
Tree heights are recorded to the nearest whole foot using a clinometer or a Spiegel Relaskop. Heights are recorded for all symptomatic trees with evidence of root disease or bark beetle attack, and for randomly sampled nonsymptomatic trees.

Radial growth:
Radial growth of the last 10 annual rings is recorded using the scale provided on the side of the Silva Ranger compass, and is measured in 20^{ths} of an inch. For example, the radial growth of a measured tree may be $13/20^{ths}$ of an inch. Radial growth measurements are recorded for all symptomatic trees with evidence of root disease or bark beetle attack, and for randomly sampled nonsymptomatic trees.

Live crown ratio (LCR):

The LCR will be recorded for each live symptomatic tree with evidence of root disease or bark beetle attack, and for randomly sampled nonsymptomatic trees. LCR is the ratio: [height of the live crown/total tree height] x 100. LCR will be measured to the nearest 5% for trees with balanced and symmetrical crowns as well as those with imbalanced crowns and isolated branches. Before LCR is estimated on trees with imbalanced crowns, the

observer will eliminate any imbalance by virtually stacking the live crown until it is symmetrical, and then estimate the LCR of the virtually symmetrical crown.

Elevation:
Elevation is recorded using an altimeter. Altimeters will be calibrated each morning at a landmark of known elevation or survey monument. Elevation is recorded in feet. For metric altimeters, the conversion from meters to feet is to multiply meters X the conversion factor 3.28084. For example 1080 m = 3543 ft.

Aspect:
Aspect is recorded as an azimuth to the nearest degree using a Silva Ranger compass. Declination for the Mission Creek study will be 20.5^{o} East.

Root pathogen:
Root pathogens that may be encountered in the study are: *Phellinus weirii* (PHWE), the cause of laminated root rot, *Heterobasidion annosum* (HEAN) (both S- and P-groups), the cause of annosum root disease, *Armillaria* spp., especially *A. ostoyae* (AROS), the cause of Armillaria root disease, and *Leptographium wageneri* (LEWA), the cause of black stain root disease. More than one root pathogen may be recorded for a single tree (*Root path_1, Root path_2*)

Coding for root pathogens is as follows:
PHWE -- *Phellinus weirii* (uncommon in dry PSME habitats)
HEAN -- *Heterobasidion annosum* (common in dry PSME habitats)
ARxx -- All *Armillaria* spp. (somewhat uncommon in dry PSME habitats)
LEWA -- *Leptographium wageneri* (least common in dry PSME habitats)

Signs and symptoms for correctly identifying each root disease are provided in the Hadfield et al. publication: “Root diseases of Oregon and Washington conifers” and Harvey and Hessburg’s Tree Hazard Guide.

Dwarf Mistletoe:

Dwarf mistletoes that will be encountered in the study are: *Arceuthobium campylopodum* (ARCA), where ponderosa pine is the primary host, and *Arceuthobium douglasii* (ARDO), where Douglas-fir is the primary host. Since these dwarf mistletoes are host-specialized, the mistletoe species need not be recorded. Instead, we will record the Hawksworth dwarf mistletoe rating (DMR) of each infected tree >8" d.b.h. Dwarf mistletoe infections will be identified by the presence of mistletoe-induced witches’ brooms in the host, and by the presence of the male (stamenate--pollen producing) and female (pistillate--seed producing) plants of the parasite. We will record the DMR of each infected dominant, codominant, and intermediate tree >8" d.b.h. DMRs will be obtained by dividing the stacked live crown vertically into equal thirds and each third is assigned a rating of 0, 1, or 2:

0 = no visible branch infections (mistletoe plants) or witches' brooms are located anywhere in the third;
1 = < ½ of the branches in the third are infected or with brooms;
2 = > ½ of the branches in the third are infected or with brooms.

In ponderosa pine, a large witches' broom (*i.e.*, the broom is the single dominant feature) in any crown third is sufficient to give that third a rating of 2. In Douglas-fir, mistletoe plants are often too small to see from the ground, and DMR ratings are based almost entirely on visible brooms in infected branches. The maximum DMR score is 6 for any tree, the minimum score is 0.

Coding for dwarf mistletoe infected trees is as follows:
DMR = 0, Score = 0
DMR = 1, Score = 1
DMR = 2, Score = 2
DMR = 3, Score = 3
DMR = 4, Score = 4
DMR = 5, Score = 5
DMR = 6, Score = 6

Bark Beetles:
Bark beetles will be identified by the host species attacked, the characteristic gallery patterns, the presence and appearance of pitch tubes, the presence and color of boring frass, by the presence and number of gallery ventilation holes (uni- versus bi- or multi-ramous), and by examining living and dead callow adults that may be present in the galleries. Galleries will be examined by removing a section of bark in the vicinity of pitch tubes, pitch streaming, and boring frass. More than one bark beetle may be recorded for a single tree (*Bark beetle_1, Bark beetle_2, Bark beetle_3*).

In Douglas-fir, we will be looking primarily for the Douglas-fir beetle, *Dendroctonus pseudotsugae*.

In ponderosa pine, we will look for the mountain pine beetle, *D. ponderosae,* the western pine beetle *D. brevicomis,* the red turpentine beetle, *D. valens,* and pine engraver beetles, *Ips* spp.

In grand fir, (we expect to find grand fir adjacent only to riparian areas and valley bottoms) we will be looking for the fir-engraver, *Scolytus ventralis*.

Coding for bark beetles is as follows:
DEPS -- *Dendroctonus pseudotsugae* (very common in dry PSME habitats)
DEPO -- *Dendroctonus ponderosae* (very common in dry PSME habitats)
DEBR -- *Dendroctonus brevicomis* (very common in dry PSME habitats)
DEVA -- *Dendroctonus valens* (very common in dry PSME habitats)
Ips -- *Ips* spp. (very common in dry PSME habitats)
SCVE -- *Scolytus ventralis* (rare or absent in dry PSME habitats)

Bark beetles extent:
For this item we are recording the vertical extent of the bole with visible signs of beetle mass attack and emergence considering all bark beetle species that were noted in the previous item(s) by their characteristic gallery patterns. Bark beetle emergence holes, new and old pitch tube locations, and woodpecker foraging and scaling signatures may all be used to indicate total extent. Extent is estimated to the nearest 5 feet starting at the bottom of the tree. Binocular field glasses will be needed to complete this item.

Woodpecker scaling extent:
We will record the vertical extent of the bole with visible signs of woodpecker foraging by identifying the section(s) that display subsurface scaling or flaking of the bark. The vertical extent of woodpecker hits will be recorded in the next item. Scaling most commonly occurs on ponderosa pine that have been mass attacked by the western pine beetle, *Dendroctonus brevicomis*. This is true because late instar larvae are found migrating outward in the outer bark. Callow adults ultimately emerge from a region just beneath the outer bark surface. This *Dendroctonus* species is unique in this regard among Scolytid beetles.

Bole segments showing woodpecker scaling may be continuous or discontinuous. Each bole segment displaying woodpecker scaling will be recorded as a range of feet by entering the starting and ending vertical heights of the scaling on the bole. For example, a dead tree may exhibit scaling at a bole height beginning at 15' and ending at 45' (15-45') and beginning again at 55' and ending at 65' (55-65'). A range beginning with a zero indicates that woodpecker scaling begins at the base of a tree. The length of bole segment(s) should be ocularly estimated to the nearest 5 feet. To calibrate the observer's eye, ocular estimates should be regularly checked against clinometer or Relaskop measurements of the same tree.

Woodpecker 'hits' extent:

With this item we will record the vertical extent of the bole with visible signs of woodpecker foraging by identifying the section(s) that display foraging "hits" through the outer bark to the cambium and beneath. The vertical extent of woodpecker scaling is recorded in the previous item. "Hits" are associated with woodpecker foraging for bark beetles that complete their development in the cambial region between the inner bark and secondary xylem. Woodpeckers forage for most Scolytid (*Ips* spp., *Dendroctonus* spp., *Scolytus* spp.) bark beetles (excluding for the most part the western pine beetle, *Dendroctonus brevicomis*) and most woodborers (Coleoptera/Cerambycidae - "long-horned borers"; Coleoptera/Buprestidae - "metallic woodborers) in this way.

Bole segments showing woodpecker hits may be continuous or discontinuous. Each bole segment displaying woodpecker hits will be recorded as a range of feet by entering the starting and ending vertical heights of the bole segments displaying hits. For example, a dead tree may exhibit hits at a bole height beginning at 0' and ending at 5' (0-5') and beginning again at 35' and ending at 45' (35-45'). A range beginning with a zero indicates

that woodpecker hits begin at the base of a tree. The length of bole segment(s) should be ocularly estimated to the nearest 5 feet. To calibrate the observer's eye, ocular estimates should be regularly checked against clinometer or Relaskop measurements of the same tree.

Saprot species:
Two basidiomycetous saprotting fungi will be recorded when they are present, *Cryptoporus volvatus* and *Hirschioporus abietinum.* Such evidence may be useful to wildlife interpretations that are concerned with the treatment effects on the future availability of soft snags. Both species are indicated by the presence and extent of basidiome fruiting. Photos of both saprotting agents are available in Harvey and Hessburg's Tree Hazard Guide.

Coding for saprotters is as follows:
HIAB -- *Hirschioporus abietinum* (uncommon in dry PSME habitats)
CRVO -- *Cryptoporus volvatus* (quite common in dry PSME habitats)

Saprot extent:
For this item we are recording the vertical extent of the bole with visible signs (fruiting bodies) of saprot considering the saprotting species indicated in the previous item. A range beginning with a zero indicates that fruiting bodies are visible beginning at the base of a tree. The length of bole segment(s) should be ocularly estimated to the nearest 5 feet. To calibrate the observer's eye, ocular estimates should be regularly checked against clinometer or Relaskop measurements of the same tree. Binocular field glasses will be needed to complete this item.

Economics/Utilization

The protocols for economics and utilization are still under negotiation. The primary contacts are the national contacts who were contracted to complete this analysis through the University of California at Davis. The two major alternatives being considered are (1) a more regional analysis of alternative yarding techniques, including feller-buncher, cable, and helicopter, or (2) a site-specific analysis of helicopter yarding, which is the technique that will be used at our site. Decisions will be made by UC Davis team in consultation with local experts. Post-harvest age analysis of timber removed will be conducted by vegetation/fuels teams for the economics group.

BUDGET

Mission Creek Revised Budget 0118.xls

Mission Creek Budget

original 9/8/99; amended 1/18/00

Compiled by Jim Agee, UW

John Lehmkuhl, USFS

Activity Codes

pr = pre-treatment sampling
c = control sampling
m = mechanical treatments (start 2001)
b = burn treatment (autumn 2002)
ps= post-treatment sampling

Activity[1] & Budget by Year

	Year 0 pr, c FY00	Year 1 c,m FY01	Year 2 c,m,b FY02	Year 3 ps, c FY03	Year 4 ps,c FY04
Salaries and Benefits					
Scientists					
Agee (U Washington - Lead, fire & fuels)	5,000	5,000	5,000	5,000	5,000
Lehmkuhl (PNW - wildlife)	0	0	0	0	0
Gaines (USFS - wildlife)	0	0	0	0	0
Harrod (USFS - vegetation)	0	0	0	0	0
Hessburg (PNW - entomology, pathology)	0	0	0	0	0
Zabowski (U Wash. - soils)	5,000	5,000	0	5,000	5,000
Edmonds (U Wash. - soils, pathology)	5,000	5,000	0	5,000	5,000
Research associates					
Wildlife PhD avian ecologist	5,000	5,250	0	5,775	6,064
Research assistants					
Soils 2 RA at UW	38,000	38,000	10,000	19,000	0
Fire 1 RA at UW	19,000	19,000	5,000	15,000	5,000
Pathology/Microbiology	19,000	19,000	0	15,000	10,000
Technicians (terms or temps)					
Vegetation GS7 biotech (subplots)	15,600	5,000	0	16,500	6,000
Vegetation 5 GS5 biotechs (subplots)	45,000	0	0	27,000	0
Vegetation 2 GS5 biotechs (tree census)	18,000	0	0	19,100	0
Vegetation GS7 forestry tech (horse packer)	1,950	0	0	2,100	0
Wildlife small mammal GS-7 wildlife bio.	9,100	0	0	10,010	5,000
Wildlife small mammal 2 GS-5 biotechs	10,800	0	0	11,880	0
Wildlife small mammal 6 GS-4 biotechs	13,950	0	0	15,345	0
Wildlife bird GS-9 wildlife bio.	10,500	11,025	0	12,128	12,734
Wildlife bird 2 GS5 biotechs	12,600	13,230	0	14,553	15,281
Soils GS9 soil scientist	20,000	5,000	5,000	10,000	10,000

Fire UW crew	5,000	3,000	10,000	0	0
Entomology crew	35,000	0	0	35,000	35,000
Pathology	30,000	0	0	30,000	30,000
Econ (per FFS national protocol)	0	10,000	2,000	0	0
Total salaries and benefits	**323,500**	**143,505**	**37,000**	**273,391**	**150,078**
Travel					
National meetings - Feds	500	2,500	1,500	1,000	500
National meetings- State folks	500	2,500	1,500	1,000	500
UW Per Diem	5,000	5,000	1,500	5,000	1,000
Vegetation vehicles	8,800	6,500	0	8,000	0
Fire vehicle	2,500	0	2,500	2,000	1,500
Soils vehicles	4,000	4,000		4,000	
Wildlife vehicles	5,400	1,890	0	6,039	2,183
Wildlife travel and training	1,800	945	0	2,030	1,091
Entomology vehicle	2,500	0	0	2,500	2,500
Pathology vehicle	2,500	0	0	2,500	2,500
Total travel	**33,500**	**23,335**	**7,000**	**34,069**	**11,774**
Equipment					
Materials and Supplies					
Vegetation	4,000	0	0	1,500	0
Wildlife pitfall traps (FS Tomahawk traps)	864	0	0	950	0
Wildlife small mammal	1,500	0	0	1,650	0
Wildlife bird	1,500	1,500	0	1,500	1,500
Fire supplies	2,500	2,500			
Soils supplies	10,000	5,000	0	5,000	0
Entomology	1,000	0	0	1,000	1,000
Pathology	1,000	0	0	1,000	0
Total materials & supplies	**22,364**	**9,000**	**0**	**12,600**	**2,500**
Publication costs	0	0	1,000	2,000	2,000
Computer costs					
USFS compatible IBM pc	3,000	0	0	0	0
Analytical software	2,000	0	0	0	0
Data entry & archiving	6,000	6,200	2,000	6,600	3,500
Total computer	**11,000**	**6,200**	**2,000**	**6,600**	**3,500**
Other Direct Costs					
Aerial Photography	5,000	0	0	5,500	0
Photo Interpretation	3,500	0	0	4,000	0

Soils lab costs	15,000	5,000	0	15,000	5,000
Total Other Direct Costs	**23,500**	**5,000**	**0**	**24,500**	**5,000**
Total Direct Costs	**413,864**	**187,040**	**47,000**	**353,159**	**174,853**
Direct Costs for PNW Lab	278,364	69,040	11,500	257,159	136,853
Indirect Cost (15% PNW Station for Fed$)	**41,755**	**10,356**	**1,725**	**38,574**	**20,528**
Direct Costs for UW	135,500	118,000	35,500	96,000	38,000
Indirect Costs (10% of Pass Thru to UW)	**13,550**	**11,800**	**3,550**	**9,600**	**3,800**
TOTAL ANNUAL COST	**469,169**	**209,196**	**52,275**	**401,333**	**199,181**
TOTAL FUNDING REQUESTED	**1,331,154**				

CONTRIBUTED COSTS

Contributed Salary

Federal salary					
Lehmkuhl	9,750	6,750	7,500	11,500	16,000
Gaines	5,000	5,000	3,000	5,000	8,000
Harrod	20,000	12,000	5,000	12,000	20,000
Hessburg	5,000	5,000	3,000	5,000	5,000
GS-9 Geographer	5,000	5,000		5,000	
State salary					
Agee	10,000	10,000	10,000	10,000	10,000
Edmonds	5,000	5,000	2,000	5,000	
Zabowski	5,000	5,000	2,000	5,000	
Total Salary Contributed	64,750	53,750	32,500	58,500	59,000
Contributed Overhead by UW					
Direct costs to UW under Coop Agreement	130,000	110,500	32,500	90,000	36,500
Contributed UW Overhead 20%*	26,000	22,100	6,500	18,000	7,300
*overhead 51% but UW claims only 20%					
TOTAL CONTRIBUTED COSTS	90,750	75,850	39,000	76,500	66,300
Also new GIS equipment worth $108K					
TOTAL CONTRIBUTED OVER PROJECT	**348,400**				

Note: no salary is requested for permanent Federal employees
UW faculty funded are 9-month employees requesting summer salary only