Appendix A

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Plan for a Landscape Management Experiment on Restoring Late Successional Forest Habitat After the Biscuit Fire

by

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PLAN FOR A LANDSCAPE MANAGEMENT EXPERIMENT FOR RESTORING LATE-SUCCESSIONAL HABITAT AFTER THE BISCUIT FIRE

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Study Goals and Objectives

The Late-Successional Reserves (the Reserves) on the Rogue-Siskiyou National Forest and Medford District BLM lands burned in the Biscuit Fire are the focus of this study. This study plan was written to guide learning—in the normal course of management—about how to accelerate the recovery of Reserves burned in large wildfires and how to protect developing and current late-successional habitat according to the Standards and Guidelines of the Siskiyou Land and Resource Management Plan (LRMP) and the Medford District BLM Resource Management Plan. The many strongly held opinions on what should be done indicate large uncertainties and make clear the need for this study. Should burned trees be salvaged? Should burned areas be planted? Should planted stands be intensively tended to control competing shrubs? How should fuels be managed? These are a few of the more contentious questions.

The primary objective of the study is to compare different post-fire management strategies (pathways) designed to restore and protect habitat for late-successional and old-growth related species. Three different pathways will be tried on 12 3000-acre contiguous areas of forest landscape (experimental areas) for the purpose of comparing the social and economic costs and benefits of each pathway and the ability of each pathway to produce Late-Successional Reserve habitat on these variously managed landscapes. These pathways reflect three different views on how to proceed. All have a reasonable chance of success and all are within the range of scientific uncertainty. Studying mechanisms that explain the landscape responses is not a focus of the management study, but associated research (retrospective and possibly small-scale experiments) will hopefully address some of the potential mechanisms.

Adaptive Management Strategy

The study is the primary method the Rogue-Siskiyou National Forest and the Medford District BLM will use in Alternatives 3, 5, and 7 to address the uncertainties in the Biscuit Fire Recovery EIS Purpose and Need related to restoration of late-successional habitats and protection of those habitats from future high intensity wildfire. This plan was reviewed by 9 independent peers (in a "blind" review); copies of the reviews and a reconciliation report are available from the review coordinator, Dr. John A. Laurence, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.

This management experiment is replicated and landscape-scale (36,000 acres), covering about 7% of the area in the Biscuit Fire perimeter and 17% of the Reserves in the fire area. The experiment does not include any Inventoried Roadless Areas (IRAs). The study is an attempt to help address both the resource and adaptive management goals of the Northwest Forest Plan (the Plan, ROD 1994) and thus it must balance sometimes-competing resource and learning objectives. In this case, some timber salvage volume is being forgone in one of the study pathways for the sake of learning. Focused on questions facing land managers, the study will be implemented as normal business for the Rogue-Siskiyou National Forest and Medford District BLM, with limited support from the Pacific Northwest Research Station and other research organizations. Funding for research projects that may help in interpreting the experiment will be sought. This approach is based on active adaptive management concepts, using a parallel-learning model (Bormann et al. 1999).

The management study differs from a traditional research study in important ways:

- Managers posed the questions (with some input from others), and answers are being sought by comparing alternative pathways applied as part of management.
- The study applies some techniques normally reserved for research studies, including a study plan, hypotheses, an experimental design, replication, random allocation of treatments, and peer review.

The alternative pathways are considered "treatments" in a statistical sense, and monitoring is considered as measuring response to treatments. Applied forestry research experiments often focus on constrained effects of single practices; these sets of practices, combined in time and space, are confounded in the chosen design. Confounding is removed when the pathways, rather than individual practices, are considered as the treatments. Cause and effect is difficult to establish in all field ecological research, although qualitative information on management effects is likely, if sufficient emphasis is given to study design (Schrader-Frechette and McCoy 1993).

This form of adaptive management—where different approaches are tried at the scale of management—also helps to reduce the risk of large-scale failures, of "putting all the eggs in one basket." This type of management diversification, or hedging, and associated learning is based on concepts of options forestry (Bormann and Kiester, in press). This approach to adaptive management is itself largely untried, and learning how to learn from this approach is a secondary project goal. The Biscuit Fire Recovery FEIS management study follows the approach being implemented in the Five Rivers watershed (ROD 2003) on the Siuslaw National Forest (www.fsl.orst.edu/5rivers). Success in implementing management experiments will be compared based on criteria developed in Bormann and Kiester (in press).

Background—knowns and unknowns

The forests of the western Siskiyou Mountains of southern Oregon are highly adapted to fire, with fire return intervals estimated at 30 to 115 years (LRMP 1989; Agee 1991, 1993; LSRA 1995). Fire-exclusion policies are generally thought to have led to dense stands of trees, large fuel accumulations, and ladder fuels— increasing the potential for severe, uncontrollable, and expensive wildfires (Neuenschwander et al. 2000), particularly in forests with short fire return intervals. Several fire cycles may have been missed in forests at lower elevations in the eastern part of the Biscuit-Fire. The western third of the Biscuit Fire, however, has probably not missed a fire cycle, even with fire suppression. Fire has been and will always be an important natural process in the Siskiyous, and is in part responsible for many forest attributes that people associate with the Siskiyous.

Fire behavior is very complex because of the many interacting factors controlling it, including, ignitions; weather; fuel moisture, types, and distribution; terrain; and access. Planning for the next fire based on what happened in the last fire, therefore, would be a mistake because each fire is unique in many ways. For example, the behavior of the Biscuit Fire was quite different from the 1987 Silver Fire. Besides the Biscuit Fire's immense size, its rate of spread was frighteningly faster than thought possible. On July 30 and 31, it moved as much as 1.5 miles an hour, and covered a distance that took the Silver Fire about 2 weeks. The intensity was quite low in some places but extreme in others, with evidence of sustained superheated gases (over 660°C) affecting extensive areas—based on melting of aluminum tags across 2-ha long-term ecosystem productivity plots (www.fsl.orst.edu/ltep/Biscuit /Biscuit_files/frame.htm; see Initial results slide).

Uncharacteristically severe fires are thought to have large environmental consequences, and they can clearly endanger human communities and fire fighters. Effects include mortality of large and small trees, plants, animals, and microbes; loss of seed sources; degraded late-successional habitat; changes in water infiltration; erosion and loss of nutrients through volatilization and leaching (Raison et al. 1985, Brown and DeByle 1987, DeBano et al. 1998). Quantification of severe fire effects has been hampered by lack of pre-fire data.

Recovery of biotic regulation of hydrologic and nutrient cycles after a fire likely depends on the speed that surviving fungi, root sprouts, seed and spore banks, and invaders recolonize. Sprouting evergreen hardwood trees and shrubs—for example, tanoak and madrone—may play a critical role in maintaining ecto- and VA-mycorrhizal inoculum, important for re-establishing many shrubs and trees (Amaranthus and Trappe 1993, van der Heijden et al. 1998). Hardwoods may also play an important role in absorbing water and nutrients from deep soil and bedrock (Zwieniecki and Newton 1994). Ceanothus, a symbiotic nitrogen-fixing shrub, may play a key role in restoring nitrogen and carbon in the soil. These legacies, along with charred logs and snags, will likely speed long-term ecosystem development after the fire (Perry 1994).

In contrast, experience with conifer regeneration in southwestern Oregon suggests that sprouting hardwoods may hinder development of the large conifers needed as a component of late-successional habitat. Although fire prepares the site for conifer regeneration, hardwoods can dominate and persist without conifer seed sources (Helms and Tappeiner 1995) or reduce the growth of planted conifers (Harrington and Tappeiner 1997) by as much as 45% (Atzet et al. 1992), especially after a planting delay (Helgerson et al. 1992). Achieving a minimum number of large trees per acre in the short-term may be initially slowed by shrub competition, but long-term reversal of effects is also possible. Further, the role of hardwoods in fire propagation is uncertain: they appear to act as fuel ladders under some conditions, but are reported to reduce severity in others (Perry 1994). The hardwood-dominated area resulting from the Silver Fire in the Kalmiopsis Wilderness may have reburned at lower intensity in the Biscuit Fire than conifer-dominated areas (Sessions et al. unpublished, fig. 1).

Managing wildfire-affected land to recover previous objectives is also uncertain. What happens when dead trees are removed is not clear (McIver and Starr 2000). Although large burned snags do not contribute much to the fuel load, they may hinder firefighting and might help spread burning embers in future fires (Sessions et al. unpublished). Alternatively, snags may provide some shade for regenerating plants and may benefit aquatic systems in the long term, when added to streams by landslides (Reeves et al. 1995). The effectiveness of thinning and mechanical-fuels-reduction treatments is also uncertain, largely because of a lack of rigorous evidence from experimental studies (Carey and Schumann 2003).

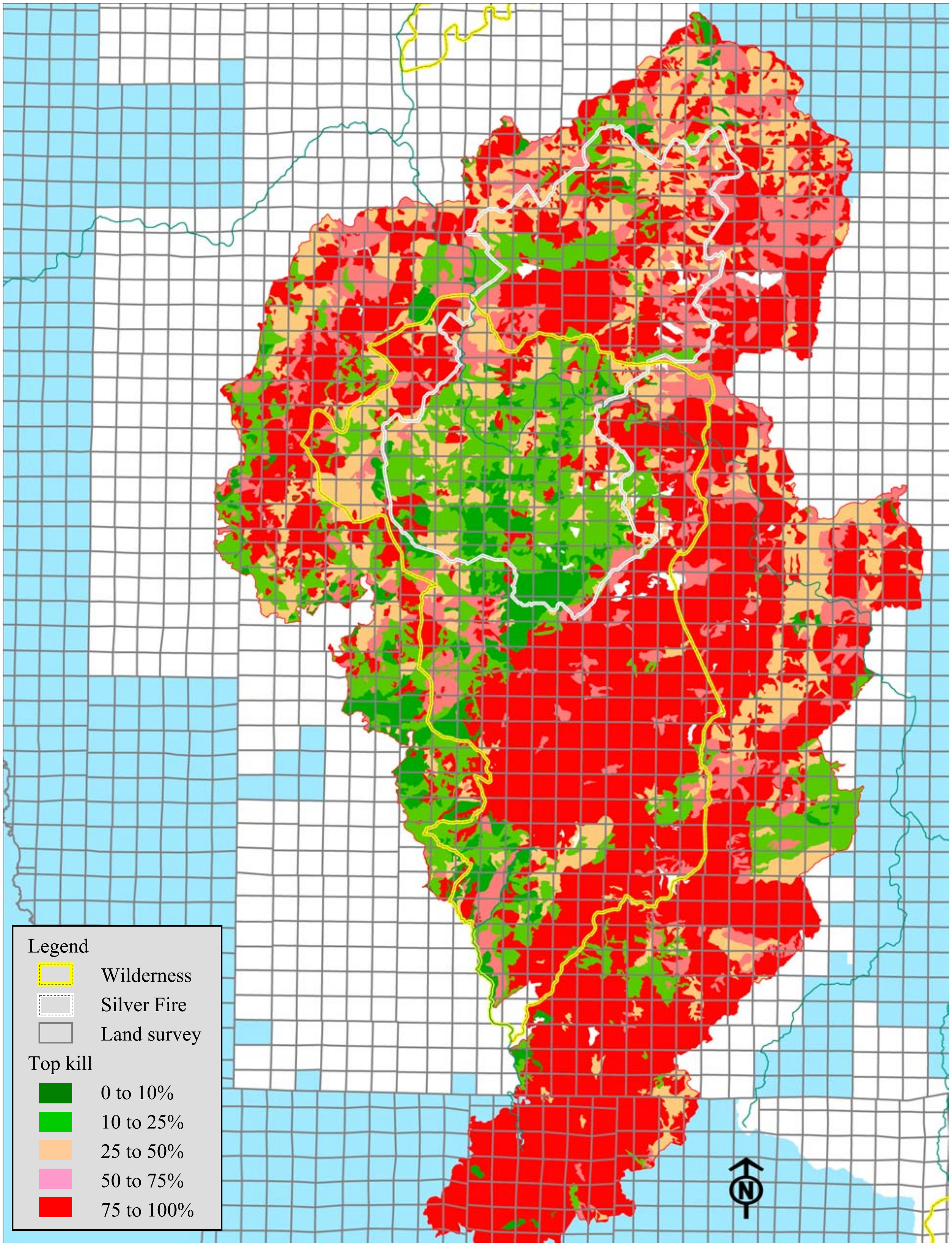


Figure 1. Canopy mortality based on aerial-photo interpretations. Note the low mortality inside the wilderness where the Silver Fire burned in 1987, and the scale of variation in the northeast sector.

Recovery from the Biscuit Fire must address emerging questions: for example, Is an even-aged regeneration system feasible here, given the apparently frequent and severe fires that destroy most of the clearcut-origin plantations before they become fire resistant? and Can desired levels of late-successional forest ever be achieved here? The extent of uncertainties indicated by these questions suggests that caution be taken in deciding how to manage for future forests and future fires. Such high uncertainty—where no two fires are likely to be similar—justifies trying a range of approaches because no one is likely know in advance when and where fires will start, what their ultimate extent will be, how they affect the landscape, or what management approaches will or will not work.

Learning Design

Questions for the management study

Many questions could be asked and answers sought through implementation of the Biscuit recovery project. Questions related to managing matrix lands might focus on alternative silvicultural methods to redevelop timber-producing stands, as has been proposed in the Timbered Rock Fire DEIS (Anderson et al. 2003). About 60% of the forest in known spotted-owl home ranges was destroyed or degraded by the Biscuit Fire (BPFA 2003). Because the Reserves are an important part of the Forest Plan's late-successional habitat network, we chose to meet the Biscuit Recovery EIS learning need with a study focused on how to restore late-successional habitat after a high-severity fire and how to protect developing and current late-successional habitat. This learning need is restated in two questions to be answered by creating and comparing a set of management pathways, all geared to achieve late-successional habitat conditions and to meet other resource needs, as required by Forest Plan Standards and Guidelines:

- Can late-successional habitat be restored after high-severity fire by managing in more than one way in the Reserves (outside of Inventoried Roadless Areas) burned in the Biscuit Fire?
- How fast will various management pathways, and their interactions with natural disturbances, achieve late-successional conditions?
- Can developing and current late-successional habitat be protected from future stand-replacing fire?

Selecting an experimental design

We sought an experimental design to best answer these questions. Comments received by the Forest, in response to public outreach, showed that people hold widely divergent views on how to respond to the fire. Some of the same differences are found among specialists inside the Forest Service and among scientists. An initial set of approaches were developed to reflect this diversity of opinion and, at the same time, to legitimately seek to meet Reserve management objectives.

Some of these initial approaches were developed into three experimental treatments or management pathways (described in more detail later and analyzed in the EIS):

Pathway A. Manage by salvaging dead trees in Vegetation Change Classes 2, 3, and 4 where consistent with Reserve Standards and Guidelines, reducing fuels and fuel continuity after management activities (may include broadcast and pile burning and lop and scatter) consistent with Standards and Guidelines, and planting and managing conifers to grow to a large diameter quickly. Once enough large diameter trees are obtained, manage to develop other late-successional habitat attributes.

Pathway B. Manage by promoting natural recovery processes, planting where seed sources are more than 0.1 mile away, and adding 400-foot-wide Fuels Management Zones around the perimeters, with limited prescribed burning near these zones. Manage regenerating post-fire stands to encourage survival and growth of conifers that result from either natural regeneration or planting.

Pathway C. Manage by re-establishing – where appropriate - landscape-scale, low-intensity fire (mostly on south-facing slopes); salvaging dead trees in Vegetation Change Classes 3 and 4 where consistent with Reserve Standards and Guidelines; and adding 400-foot-wide Fuels-Management Zones around the perimeters. Manage post-fire stands to maintain them in a suitable Fuel Model until the trees have the bark thickness and crown characteristics to allow them to survive at least a moderate intensity fire.

The three pathways reflect a diverse range of approaches—all considered legitimate—to achieve the goals of the Northwest Forest Plan for the burned Reserves in the Biscuit recovery area (ROD 1994, B-5). The target condition for the Reserves is to restore important components of late-successional habitat quickly, but in a way that is likely to persist. Achieving pre-fire-suppression, pre-European, or pre-Indian conditions may not even be possible or desirable. For example, climate is thought to have been cooler and wetter about 200 years ago and may have influenced pre-Biscuit conditions, and future climates are uncertain. Another out-of-control wildfire threatening communities is not acceptable, regardless of the range of historical conditions. The landscape, greatly altered by harvesting, roads, planting, and fire suppression, creates current conditions far from any likely historical condition.

Rejecting no-action as an experimental treatment

A no-action pathway was specifically excluded as an experimental treatment because it was determined by the Forest Supervisor to be unlikely to meet the EIS Purpose and Need in the roaded Reserves. Although some researchers define no action as a needed control, we think a design that compares three pathways will yield useful and appropriate comparisons, but only among chosen pathways. Without a no-action treatment, no inference on what will happen if nothing is done is available. The only way to begin to get that inference will be to qualitatively compare no-action and action areas. But given likely differences in management and ecological history, such a comparison would be based on dissimilar initial conditions and subject to much skepticism. For this reason, the study plan does not include such a comparison

Selecting experimental areas

We do not have sufficient data to determine in advance the number of replicated areas needed to detect statistically significant differences between pathways, if they emerge. We approached this problem by identifying the size of the area needed to answer the questions, exploring potential locations in the roaded LSR burned in the fire, and then seeking to reduce variation by selecting a set of experimental areas that were as similar as possible to each other. In the end, four replicates were found—this number is more than usual for large-scale experiments.

We started by choosing an experimental area size of approximately 3000 acres based on the scale of the patterns in tree mortality (topkill) in the northeast sector of the Biscuit Fire (fig. 1). The major area of roaded Reserves is found in the northeast sector of the Biscuit Fire, which includes some BLM land. To assess the scale of variation in topkill, we estimated how many Sections (640 acres each) were needed to capture enough variation to have areas with roughly equal amounts of area with <50% and >50% top kill. Our visual analysis suggested that about 4 or 5 sections (2500-3200 acres) must be combined to have topkill proportions that were nearly equal. Larger areas would be needed to set up experimental units in other parts of the fire.

Because the forests burned by the Silver Fire and then again by the Biscuit Fire were likely different from those burned in the Biscuit Fire alone, we drew potential experimental units inside one or the other areas. Because serpentinite soils cannot produce desired late-successional conditions (primarily canopy closure) and high-elevation plant associations were considered to be substantially different in terms of response, these areas were excluded from the experimental areas as much as possible. Finally, experimental area boundaries were sought along 7th-field watershed lines where building Fuels Management Zones was deemed feasible. With these methods, we found 16, roughly 3000-acre, potential experimental areas in the roaded Reserves (fig. 2). This allowed us to eliminate 4 outlier areas and establish a design with 3 treatments and 4 replicates.

Similarity analysis methods

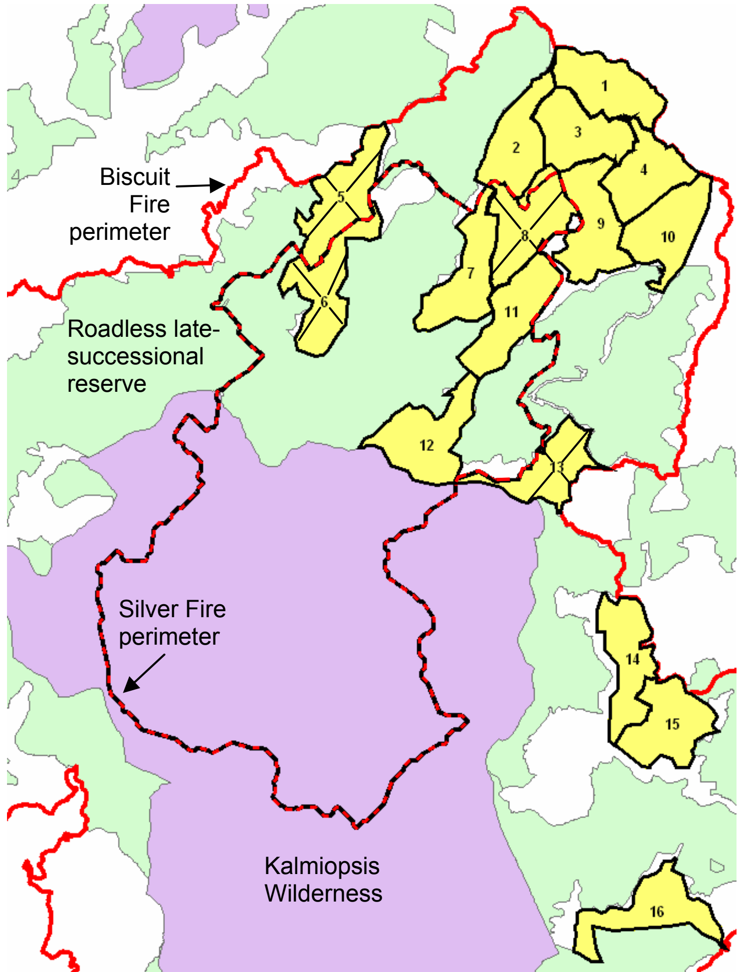
The similarity analysis was developed to discard the 4 most dissimilar experimental areas (out of 16), leaving 12 for the experiment; and to block remaining experimental areas into 4 groups of 3. One purpose of blocking areas into similar groups is to remove variation in initial conditions as much as possible. When results from different management pathways are compared (after some years of monitoring), we want to increase our confidence that the differences result from the treatments and not initial conditions. This confidence is further buoyed by having multiple blocks or replicates. In essence, this experimental approach gains statistical power for inference about treatment differences by limiting variation in initial conditions and effects of other factors not under control of managers. We selected a set of five variables to determine similarity, listed below in priority order along with our reasoning.

Similarity analysis variables

What is the potential for rapidly achieving late-successional conditions? We chose potential for speedy development of late-successional habitat as the primary variable on which similarity would be based, given the principal management objective of restoring and late-successional habitat in the Reserves. Three variables chosen to represent this potential were based on a vegetation-change, remote-sensing analysis (before and after satellite images representing active transpiration) combined with pre-fire tree size and canopy closure data:

- Percent area with surviving large conifers, greater than 21-inch average DBH, and >40% crown closure (“**live LS habitat”**)—experimental areas with more live habitat were thought to have the highest late-successional-habitat potential;
- Percent area with at least some habitat potential such as live, medium-sized conifers or larger trees with <40% crown closure (“**OG inocula”**)—experimental areas with more inocula were thought to have intermediate habitat potential through faster reestablishment of elements of late-successional forest; and
- Percent area of stands with little or no surviving conifers other than trees less than 9 inches DBH (**“low OG potential”**)—experimental areas dominated by small or burnt stands were assumed to have the lowest potential.

Figure 2. The 16 areas considered in the similarity analysis and those rejected (X'd out). The table below has the percent area of each variable in priority order, the name and rationale for blocking the units, and the random treatment assignments within blocks.



Area number	Live LS habitat	OG Innocula	Low OG potential	Agency or matrix	Far from road	High Elevation Fir	Serpentine veg	Name and rationale for blocking assignments (rejected units are not part of the experiment).	Randomly assigned treatments (DEIS)	Randomly assigned treatments (FEIS)
7	8%	14%	78%	FS	54%	0%	0%	**Fishhook:** **Silver fire; low OG potential; few roads;** non-matrix; low elev. veg.; non-BLM; most western	Fishhook A1	Fishhook A1
11	8%	21%	71%	FS	82%	0%	0%		Fishhook B1	Fishhook B1
12	2%	9%	89%	FS	79%	0%	1%		Fishhook C1	Fishhook C1
3	37%	21%	42%	FS	7%	1%	0%	**Sourgrass:** Non-Silver; **highest OG potential;** many roads; non-matrix; non-serp; **non-BLM;** most northern	Sourgrass A2	Sourgrass A3
1	43%	22%	34%	FS	0%	2%	0%		Sourgrass C2	Sourgrass B2
2	24%	30%	46%	FS	7%	4%	0%		Hobson C3	Sourgrass C2
9	9%	19%	71%	BLM	10%	2%	5%	**Hobson:** non-Silver; **moderate OG potential;** many roads; non-matrix; minor high elev. serp. veg.; **all BLM**	Hobson A3	Hobson A3
4	20%	39%	39%	BLM	8%	6%	0%		Sourgrass B2	Hobson B3
10	13%	33%	54%	BLM	0%	1%	1%		Hobson B3	Hobson C3
16	13%	29%	57%	FS	3%	3%	2%	**Briggs:** non-Silver; moderate to low OG potential; many roads; non-matrix; minor serp; non-BLM; **most southern**	Briggs A4	Briggs A4
15	16%	35%	49%	FS	13%	0%	1%		Briggs B4	Briggs B4
14	7%	30%	63%	FS	17%	0%	2%		Briggs C4	Briggs C4
5	14%	26%	60%	FS-M	0%	0%	12%	**Rejected:** matrix, high serpentine		
6	17%	23%	60%	FS	52%	2%	2%	**Rejected:** in Silver and unpairable		
8	15%	27%	57%	FS	74%	0%	0%	**Rejected:** in Silver and unpairable		
13	4%	26%	70%	FS-M	0%	1%	22%	**Rejected:** low live LS, matrix		

Are the areas managed by the BLM or the Forest Service or in matrix? The second similarity variable, management by the BLM or Forest Service, was chosen because we thought mixing experimental units with different management histories should be avoided. Also some initial units were selected with substantial areas designated as matrix to achieve a large set of potential experimental units. Initially, the early stages of restoration and recovery were thought to be similar enough that these areas could be included as part of the experiment. Over the long term, however, prescriptions would likely deviate, and excluding these areas would benefit the experiment. This criteria was the fourth priority in the DEIS study plan. Several BLM specialists made us aware of differences in past management practices on BLM compared to Forest Service lands after the DEIS was published. This change to second priority was needed to incorporate new information, and does not affect the design because treatments were randomly assigned a second time in the new blocks as described in fig. 2, and below.

Will helicopter yarding be needed? Cable yarding of dead trees is usually possible when stands are within 2000 feet of a road; beyond this distance, harvest by helicopter is the only choice. Similar proportions of potential helicopter yarding ("**far from road**") in an experimental area was thought to be the third most important consideration because of the potential economic and ecological effects of different yarding methods.

What proportion is in serpentine and high-elevation plant associations? Lastly, plant association groups were analyzed to confirm that serpentine and high-elevation associations did not dominate selected experimental areas. Groups of plant associations were defined: serpentine-adapted, high-elevation, and all remaining associations. The variables used were percentage of area in an experimental area with the various association groups ("**high elevation fir**" and "**serpentine veg**").

Grouping experimental units based on the similarity analysis

Experimental areas were blocked off into similar groups, as follows:

Fishhook: Experimental areas burned by the Silver Fire were examined first. The three most similar were obvious, looking at proportional area with live LS habitat (2 to 8%; fig. 2), allowing us to discard the other two Silver Fire areas (15 to 17% live LS habitat). The experimental areas selected for this group also have similar proportions of potential helicopter yarding and similar proportions of high elevation fir and serpentine vegetation.

The remaining 11 experimental areas were then arrayed with ascending or descending values of each similarity variable, in priority order.

Hobson: The next group to emerge was the 3 BLM areas, which had reasonably similar moderate old-growth potentials (9 to 20% live LS habitat), helicopter logging potential, and inclusions of serpentine or high elevation vegetation.

Many of the 8 remaining areas appeared roughly similar, and we chose to discard the two areas with substantial matrix allocations. The last 6 separated nicely into 2 blocks.

Sourgrass: One group of three had the highest OG potential (24 to 43% live LS habitat) in the north end of the Biscuit Fire area.

Briggs: The last group of three had moderately low OG potential (14 to 17% live LS habitat), low potential helicopter logging, and minor serpentine inclusions.

Blocks were exposed to several other tests before being adopted. The feasibility of building Fuels Management Zones was checked in more detail, and all selected experimental areas passed. A GIS layer with potential timber salvage was also examined to see if major differences existed within the groups. Most groups had quite similar proportions of areas with potential salvageable timber (Briggs: 31 to 46%; Fishhook: 6 to 10%; and Hobson: 33 to 43%), although moderate variation was noted in the Sourgrass block (4 to 18%). Finally, a GIS coverage was developed that showed areas where underburning was more feasible and desirable (primarily on south-facing aspects). The proportion of experimental areas in south-facing aspects ranged from about one-third to two-thirds. The variation in all of these additional variables was deemed acceptable, and the final grouping was officially adopted (table in fig. 2).

Assigning treatments randomly

In the last step, we randomly assigned treatments to the three similar experimental areas within each block (fig. 3). Random assignment of a treatment within blocks (groups of similar experimental areas) is also needed to increase confidence in how treatment responses are interpreted. This step eliminates any overt or inadvertent attempt to bias the results by placing a preferred treatment in the presumed best place (or the reverse).

Alternate Pathways to Restore Reserves (Experimental Treatments)

The Biscuit EIS Interdisciplinary Team developed three pathways designed to restore the burned Reserve habitat and to protect developing and current late-successional habitat. These pathways are based on public comments and from the Biscuit Recovery team's expertise, experience, and understanding of the applicability of available science. The pathways were developed both to explore different ways to restore late-successional habitat in the Reserves given the high uncertainties in how to achieve this objective. We expect each pathway will have positive and negative effects—and also unexpected effects; that will likely change through time. Inferences from these comparisons will be far stronger than if a single pathway or no design was chosen. An important question in any experimental design is the extent to which treatments will affect the experimental areas and be different from one another. Management on burned sites in the Reserves will not cover the entire experimental area; it will be highly focused on the places intensively affected by the fire or perceived to need management to reduce future catastrophic fire (table 1). This study adds no additional activities to the FEIS Alternatives; it utilizes the area proposed for restoration activity in the FEIS to set up a structure that allows meaningful comparisons to occur. Pathways are described and analyzed in more detail in the EIS.

Even if this management study is not implemented, the salvage, planting, and stand tending in these areas would still occur in some of the EIS Alternatives. If the study is not implemented, additional salvage may occur in the areas identified for Pathway B (i.e. Alternative 6).

Pathway A. This pathway is based on a hands-on philosophy that emphasizes salvaging dead trees where consistent with Reserve Standards and Guidelines, treating fuels created by management activities consistent with Standards and Guidelines, replanting, and stand culturing to produce large conifers quickly. Salvage would occur where assumed to be beneficial to late-successional-habitat objectives (areas where there are at least 10 acres of dead trees and where crown closure has been reduced below 40%), and economically feasible in Vegetation Change Classes 2, 3, and 4. Standing-dead and downed trees would be left in accordance with the

Siskiyou Forest Plan to accelerate development of the conditions needed for species that depend on late-successional forests (large downed wood, snags). Fuels management would focus on treating fuels created during management activities, including broadcast burning, pile burning, and lop and scatter. Unlike the other two pathways, Fuels Management Zones are not included because fuels will be managed to meet Standards and Guidelines within management activity areas. Salvaged areas would be replanted and intensively cultured (through control of competing vegetation) to produce large-diameter conifers as quickly as possible. Burned plantations would have site preparation, if needed, which would be followed by planting and culturing to produce large-diameter conifers as quickly as possible. Landscape variability, initially driven by wildfire effects, will be reduced compared to other pathways as most burned stands will be salvaged and planted. Other recovery activities (riparian planting, meadow restoration, oak woodland and savannah restoration, Port-Orford- cedar planting, road decommissioning, culvert replacement, and so on) would be handled case by case in the areas receiving this treatment.

Pathway B. This pathway is based on a philosophy emphasizing aided natural recovery in the Reserves, partly modeled after the Beschta et al. (unpublished) report. Replanting would be limited to areas farther than 0.1 mile from a known conifer seed source. Dead trees will not be salvaged. Fuels will not be managed except in 400-foot-wide Fuel Management Zones around experimental area perimeters. Prescribed fire will be limited to these zones. This treatment is essential to compare more- and less-intensive management interventions, so any differences that emerge can be rigorously ascribed to the treatment and not to pre-existing conditions. Landscape variability will be intermediate, driven more by fire effects and natural succession in this pathway. Other recovery activities (riparian planting, meadow restoration, oak woodland and savannah restoration, Port-Orford-cedar planting, road decommissioning, culvert replacement, and so on) would be handled case by case within the areas receiving this treatment.

Pathway C. This pathway is based on a hands-on philosophy emphasizing reintroduction of landscape-scale, high-frequency, low-intensity fire; salvaging dead trees where consistent with Reserve Standards and Guidelines; replanting conifers and reducing fuels. Pathway C differs from A by using prescribed fire at a landscape scale and by limiting salvage to 2 miles from a road; leave trees and down wood would be the same as for pathway A. Fire-resistant pines (mostly ponderosa and sugar), will dominate planting on southern exposures where reintroduction of high-frequency, low-intensity fire is planned, and fire reintroduced only after these trees are large enough to survive it. Low-intensity prescribed fires would be repeated on southerly exposures about every 10 years to keep fuels at a low level. Fuels Management Zones (400 ft. wide) will be created to facilitate landscape-scale burning and assist with future fire fighting efforts. Landscape variability will be greatest in this pathway, driven by wildfire effects, salvaging of some stands, planting, and prescribed burning. Other recovery activities (riparian planting, meadow restoration, oak woodland and savannah restoration, Port-Orford-cedar planting, road decommissioning, culvert replacement, and so on) would be handled on a case by case basis within the areas receiving this treatment.

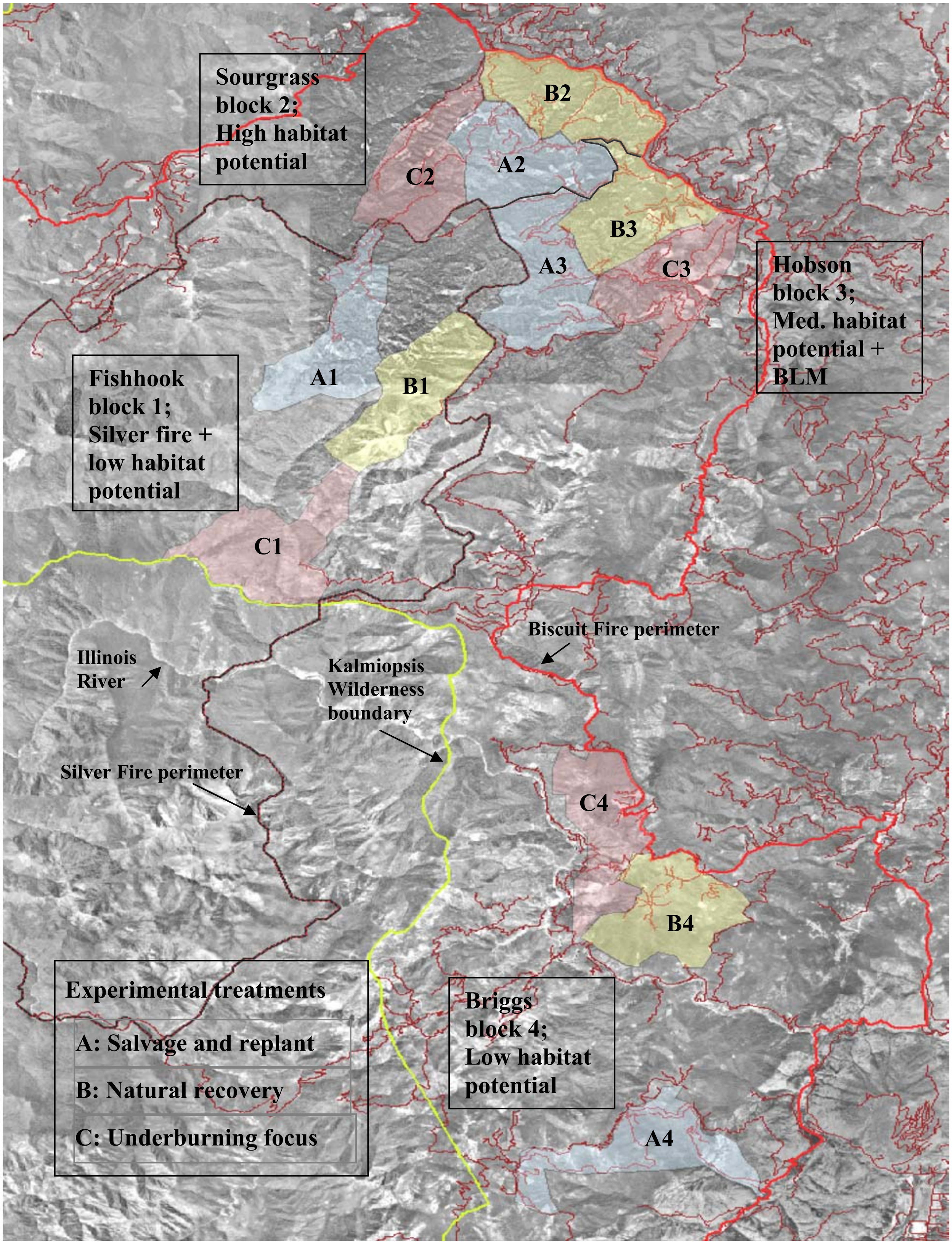


Figure 3. Experimental layout with 3 treatments (pathways A, B, and C) randomly assigned within 4 initially similar areas (blocks 1, 2, 3, and 4), with different habitat potential and fire history.

Table 1. Proportion of the ~3000 acres in each experimental unit affected by management activities; blocks of similar experimental units are 1: Fishhook (burned in the Silver Fire), 2: Sourgrass, 3: Hobson, and 4: Briggs (fig. 3)

Management activity	Pathway A Salvage and replant focus				Pathway B Aided natural recovery focus				Pathway C Underburning and salvage focus			
	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4
Fuels Management Zones (FMZs)	0%	<1%	0%	<1%	3%	6%	6%	6%	3%	12%	3%	8%
Perimeter burning (FMZ)	0%	0%	0%	0%	0%[a]	64%	28%	20%	0%	0%	0%	0%
Landscape burning	0%	0%	0%	0%	0%	0%	0%	0%	13%	38%	43%	80%
Salvage combined types & planting	6%	6%	14%	29%	0%	0%	0%	0%	<1%	12%	7%	31%
Potential planting-prior plantations	13%	17%	8%	3%	3%	12%	5%	10%	3%	12%	2%	3%

[a]No Biscuit perimeter is in this Silver Fire experimental unit.

Monitoring

Deriving variables to be monitored

The ROD for the Northwest Forest Plan (ROD, 1994) identifies the primary objective of Late-Successional Reserves: "…to protect and enhance conditions of late-successional and old-growth forest ecosystems, which serve as habitat for late-successional and old-growth related species including the northern spotted owl." The primary Reserve needs can be presented more precisely as:

- Restoring stands of suitable late-successional habitat quickly;
- Protecting current and developing stands from high-severity wildfire.

The potential tradeoffs between—and other uncertainties in how to meet—these goals are grist for our learning mill. To determine the relative efficacy of different pathways, primary variables are chosen to monitor how well these goals are met (table 2).

Table 2. Primary variables to compare pathway outcomes

Goal	Primary variables	Units	Approach
Restore late-successional habitat[a]	Conifer species and stocking	Species composition, Trees $acre^{-1}$ and canopy closure, tree imperfections	Permanent stand-exam plots extrapolated to areas with remote sensing (photo interpretation)
	Conifer diameter distributions	Trees $acre^{-1}$ by DBH class	
	Snags and logs	#s, volume $acre^{-1}$ by size class	Brown transect lines and stand-exam plots
	Canopy layers	Cover by species and layer	Permanent stand-exam plots
	Biodiversity	Occurrence of fungi, lichens, and bryophytes	Permanent stand-exam plots
Protect current and developing late-successional stands from high-severity fire	Dead fuel amounts and distribution	Tons $acre^{-1}$ by species and size class, Fuel Model	Permanent Brown transects extrapolated to areas with remote sensing (photo interpretation)
	Live fuels amounts and distribution	Tons per $acre^{-1}$ by species and size class, Fuel Model	Permanent stand-exam plots extrapolated to areas with remote sensing (photo interpretation)
	Undesired ignitions controlled	Number, acres, location	Fire response records
	Conifer bark thickness	Inches	Permanent stand-exam plots
Implement pathways according to study plan	Salvage completion, planting species mix and completion, FMZ installation, prescribed burning completion	Acres completed vs. acres planned	Standard implementation monitoring

[a]Primary variables for this goal are derived from Northwest Forest Plan ROD, p. B-5.

Secondary variables are also defined that help to better interpret the primary variable responses and their context, of other identified management needs. These variables would be monitored with National Forest, BLM, and other, as yet unidentified, funding sources.

Table 3. Additional interpretive and contextual variables.

Goal	Secondary variables	Units	Approach
Restore late-successional habitat	Fire effects on soil fertility	C, N kg acre^{-1}	Soil sampling (research protocol)
	Snag effects on regeneration	Conifers acre^{-1}	Permanent stand-exam plots and Brown transects
	Hardwoods: competition and soil effects	Biomass acre^{-1} C, N kg ha-1	Soil sampling and vegetation sampling (research protocol)
Protect current and developing late-successional habitat from high-severity fire	Fuel reduction by prescribed burning and manual fuels treatments.	Tons acre^{-1} and distribution	Compare different prescribed-fire approaches in small-scale experiments on timing, fuel conditions, weather, escapes
	Conifer mortality from prescribed fire	Trees acre^{-1}	Permanent stand-exam plots extrapolated to units with remote sensing (photo interp.)
	Hardwoods as fuel ladder or suppressant	Cover acre^{-1} by species	
Learn	Quality of monitoring and scientist-manager interactions	Options forestry criteria	(Bormann and Kiester in press)

Monitoring plan

A three-pronged monitoring strategy is proposed to fully meet the learning need (tables 4a and 4b). We first identify monitoring that the National Forest and BLM can currently commit to, pending selection of an alternative containing the experiment (column 1). The National Forest and BLM would start by repeating the Southwestern Oregon Late-Successional Reserve Assessment (LSRA 1995). The assessment would be based on existing data on habitat quantity, quality, distribution, and established needs of sensitive species and risks of disturbances. The National Forest and BLM would then establish permanent—but otherwise standard—plots on treated and untreated areas in each experimental area to supplement existing ecology, inventory, and other plots. Permanent plots or transects will use existing stand-exam, fuel survey, ecology, plant association, insect and disease, and inventory protocols, combining them in the same location where feasible.

Additional monitoring, beyond that normally carried out as part of management activities, would require additional monetary support (column 2). If Forest and BLM employees directly participate in monitoring these variables—rather than contracting it to researchers or others—we expect more rapid spread of what was learned into future practices.

Having researchers from various research institutions conduct studies in the third set (column 3) will increase understanding about what can be learned with confidence from the Biscuit Fire, and improve interpretation of the experiment through studies of the ecosystem processes underlying pre- and post-fire forest development and future fire behavior. This three-pronged strategy is designed to yield mutual benefit and cohesiveness in a long-lasting management-research partnership. Based on the research project needs for post-Biscuit fire research, the design of this management study will make it very attractive to researchers who want to look at more indepth research questions.

An advantage of working at the landscape scale is that the range of inherent variability (aspect, slope, disturbance history, etc.) is often captured within experimental areas. The corresponding cost of working at this scale is the need to adequately measure the within-unit variation. Because there are 12, 3000-acre experimental areas, no affordable amount of ground measures is expected to be sufficient to generate the needed data, thus extending ground measures with remote sensing techniques will be necessary. The distribution of plots will be critical to both variables not remotely sensed and those that are. Our approach will be to classify all areas in each experimental area into one of four strata:

- Previously regenerated stands (burned or not—most were burned);
- Previously unregenerated stands with large trees (see table 2) that were mostly or completely burned (>75% canopy mortality?);
- Previously unregenerated stands with large trees that were partly or not burned (<75% canopy mortality?); and
- Previously unregenerated areas with small or few trees.

Sampling intensity will not be even among strata—following sampling methods of Thompson (2002)—because of our focus on management to restore habitat. This approach will capture the range of variation, and this will help to train remote sensing techniques. About 10% of ground measures will be reserved a priori for testing techniques. New plot locations will be randomly assigned among the strata and all data will be georectified and placed in the GIS. New strata will emerge, but only within old strata, as the experiment unfolds.

Interpreting results

Success of the experiment depends on who is looking at it. Managers, who would like more leeway to meet a wider array of societal goals, would prefer that all pathways met management objectives. Even if only one worked, that could be seen as a valuable lesson to some. If clear differences appear, then we might learn something about controlling factors. If no differences are found, with all or no pathways meeting the objectives, we could only conclude that we know less than we thought about which factors influence outcomes. As a management experiment, we are most concerned about how managers and decision makers will interpret the findings. Thus, the design needs to protect against the conclusion of no difference when a real difference exists (type II error). Even if solid conclusions are clearly supported by data, further caution will be needed. Many processes are scale-dependent and play out variably over time. Also, changes in the ranking of treatments have repeatedly been seen in long-term experiments (Silen and Olsen 1982). Interim conclusions can be helpful as long as these caveats are kept in mind. We propose to compile a database of qualitative and quantitative expectations (hypotheses), with expected results from a wide diversity of viewpoints. This hypothesis database will be used as a yardstick for results as they come in. A few initial ideas reflecting the authors' perspectives are listed as a start (table 5). Different expectations should be easy to find, given the high uncertainty—the experiment seeks to confront all of these expectations with the unfolding landscape reality.

Table 4a. Monitoring plan for assessing pretreatment conditions and effects of pathways on restoring late-successional habitat across the landscape-scale experimental units, with Forest commitments and potential commitments and research

Focus	Commitment of the Siskiyou National Forest[a]	Potential Forest commitment, given additional funding	Potential research commitment, given additional funding
Understanding the Biscuit Fire's behavior and effects	Make all historical and current data available to researchers and others. This includes georectified post-fire photos, management records, and plot data.	Digitize all historical air photos and Government Land Office records and make into GIS layers.	Coordinate ongoing research and retrospectively study the context leading to observed effects of the fire—as pretreatment data for the experiment[b].
Restoring habitat—trees and stand structure	Monitor species, growth trajectory of dominant trees, and stand structure with standard exams. Use permanent plots[c] monitored at years 0, 1, and 3 years after the pathways are established and remote sensing to draw inferences on area responses.	Extend the sampling to years 5 and 10, and every 10 years thereafter; expand the sample size of permanent plots to speed the detection of differences between pathways.	Study the relative effects of competing understory species on growth of planted and residual conifers (see Tiller Fire study plan).
Restoring habitat—snags and woody debris	Monitor size and numbers per acre of burned and insect-created snags and logs with standard exams and remote sensing.	Monitor effect of shade from snags on planted and natural tree seedlings.	Study decomposition of, and bark-beetle and cavity nesting responses to, woody debris including pheromone trapping; study effects of logs on erosion.
Restoring habitat—landscape patterns	Track changes in amount and distribution of "patches," including seral stages, interior habitat, structure, canopy density, and layering from air-photo interpretations (LSRA 1995).		Study the effects of proximity to old-growth inocula (scattered "legacy" trees and structures) compared to proximity to unburned large-tree stands.
Restoring habitat—plants	Monitor plant biodiversity and exotic weeds on permanent plots and use sampling and remote sensing to infer experimental unit responses.	Expand the sample size to evaluate effects on rare species.	Study the ecology of pioneer, fire-adapted, exotic, and rare and endangered plant species.
Restoring habitat—animals	Monitor animals directly to meet sale-layout requirements.	Track changes in behavior and reproductive success of known spotted owl pairs, prey bases, and owl predators after major losses of habitat, repeat every 10 yrs.	Study changes in neotropical bird populations; and early-succession-related species (elk, deer, bears).
Restoring LS habitat—soil productivity	Monitor soils directly only to meet sale-layout requirements, and track changes in site index with a database of all previous georeferenced site-index measures.	Monitor erosion and establish a soil-sampling grid (following long-term ecosystem productivity protocols—www.fsl.orst.edu/ltep) on burned and unburned stands with and without brush-control.	Study nutrient and organic-matter dynamics, especially nitrogen fixers and rock weathering via deep rooting, mycorrhizae of pioneer and fire-adapted plants, and changes in water-holding capacity.

[a] Includes the Medford BLM as well.

[b] Includes synthesis of ongoing federally sponsored research on the Forest ecology and inventory plots and the long-term ecosystem productivity experiment, with new analyses of available data.

[c] See text for description of permanent plots.

Table 4b. Monitoring plan to assess protecting late-successional habitat from high-severity fire, and other pathway effects, with Forest commitments and potential commitments and research

Focus	Commitment of the Siskiyou National Forest	Forest commitment, pending additional funding	Research commitment, pending additional funding
Protecting habitat through time—dead fuels	Monitor dead fuels on permanent Brown line transects with traditional size-classes in treated areas.	Monitor dead fuels on permanent Brown line transects with traditional size-classes in untreated areas.	
Protecting habitat through time—live fuels	Monitor vertical distribution of live fuels on permanent plots in treated areas and use sampling and remote sensing to infer experimental unit responses.	Monitor vertical distribution of live fuels by species on permanent plots in treated areas.	
Protecting habitat through time—risks	Run fire models (fuels, resistance to control, and potential fire behavior) to predict fire risks.		Test fire models with data existing before the Biscuit Fire.
Protecting habitat through time—future fires	Evaluate how future wild and prescribed fires actually behave through different pathways and experimental units.	Study intensity, duration, and containment of prescribed fires in pathway C to modify techniques for subsequent trials.	Examine effects of prescribed fire on the trajectory for restoring and protecting habitat.
Forest management costs and benefits	Record costs and benefits associated with management and monitoring.		Analyze costs and benefits in current and potential future market environments using monetary and nonmonetary units.
Other important effects—aquatic conservation	Monitor riparian habitat and organisms to meet sale-layout requirements.	Monitor landslides and new sediment deposits along streams draining different pathways with satellite images, checked with low-elevation photographs.	Monitor changes in pools, riffles, large woody debris, using the method of Hankin and Reeves (1988), and monitor population size and species composition, using a level II survey by OR Department of Fish and Wildlife.
Other important effects—landslides	Analyze available aerial photos (every 5 years or less) for large landslides, document them on the ground, and compare them to predicted danger-class and proximity to stand and road management.		Study and model the interactions of topography, salvage, and replanting on the potential for landslides thought to improve long-term stream habitat; compare to actual landslides.
Other important effects—social perceptions	Maintain a database with public comments relating to the experiment.	Build interpretive trails into representative parts of each management pathway (would require changes to the final EIS or a new NEPA document).	Conduct surveys of people, including those walking interpretive trails built into each of the three pathways.

Funding monitoring and retrospective research

The learning objective can be met only if the treatments are properly implemented and adequately monitored, which requires a commitment of resources and people (table 6). Most federal funding is annual and cannot easily be committed to long-term goals. Stewardship contracting may be the best approach to maintaining a long-term commitment to maintaining the treatments and monitoring over time.

We view the additional commitments from the National Forest, BLM and research (tables 3, 4, and 7) as essential to beginning to understand mechanisms and to more quickly learn from happened in the past. The retrospective synthesis is critical background context for the study to extract lessons immediately from the Biscuit Fire experience, but research funding is outside National Forest and BLM control. A science-assistance team will be needed to coordinate federally sponsored research and to continue to maintain the independence and integrity of the experiment as it unfolds. Funding for an annual meeting of this team to oversee monitoring and to coordinate retrospective research on the Biscuit Fire would greatly increase how much we can learn from it.

Even when learning is added as an objective of forest managers on par with other resource objectives as identified in the EIS, special emphasis is needed to overcome tradition. Experience with adaptive management under the Northwest Forest Plan has so far failed to live up to expectations (Stankey et al. 2003). The strategies used in the Biscuit Fire recovery project seek to change this trend.

Table 5. Simplified expectations of the effects of pathways A, B, and C on restoring late-successional habitat and protecting against high-severity fire under the Northwest Forest Plan

Result	Pathway A: hands-on salvage and replant focus	Pathway B: aided natural recovery focus	Pathway C: hands-on underburning focus
Restoring late-successional habitat			
Landscape habitat extent and patterns	Best with no fires in the next 60 years	Slower initially but best with less intense fires	Best with another intense fire in the next 60 years
Economics	More jobs initially, intermediate net revenue	Fewest jobs, low net revenue	More jobs in long run, intermediate net revenue
Attain large diameter of dominant conifers	Faster when all fires are controlled in the next 60 years; slower otherwise	Slower initially but may catch up in the long term, if high intensity fires controlled	Faster with a high intensity fire before 60 years, otherwise intermediate
Maintain plant diversity	Least because of faster shading of shrubs, if fires are controlled	Intermediate, with or without fire	Most because of more variety in disturbance patterns and planted pines
Have multiple canopy layers	Faster after subsequent thinning, if medium and intense fires are controlled	More likely to have single layer where conifers shade out competitors	Intermediate
Snags	No difference in the Plan's minimum number per acre, less shade for emerging plants in salvage units	Higher shade for emerging plants	No difference in the Plan's minimum number per acre, less shade for emerging plants in salvage units
Woody debris	No difference in the Plan's minimum number per acre. Less in the long run.	More in the long run as snags fall to the ground	No difference in the Plan's minimum number per acre. Less in the long run.
Soil productivity	Intermediate due to more nutrients removed in salvage.	Highest due to very low nutrient removal.	Lowest from nutrient losses from salvage logging and repeated burning
Protecting developing and current late-successional habitat from high-severity fire			
Dead fuels	Intermediate because of salvage and fuel reduction	Highest because no salvage or fuel reduction	Fewest because of salvage and fuel reduction, plus prescribed fire.
Live fuels	Highest resulting from branches of new conifers	High hardwood fuels, some that hinder crown fires	Intermediate but more fire resistant pines are planted
Fire behavior	Most damaging to objectives	Intermediate	Least damaging to objectives
Likely future fire behavior	Extensive crown fires more likely until at least age 60	High fire risk near term, lower later because of more diverse vegetation patterns	Lowest risk assuming underburning is successful

Table 6. Timeline for Forest commitments (federal agencies cannot budget beyond current year)

Activity	2004	2005	2006	2007	2008	2009	2010
Conduct surveys as required for timber sales	XX						
Layout sales to meet study design	XX						
Publish the hypothesis database on a web page, detailing various assumptions in table 3 and model projections, and invite alternative hypotheses.	XX						
Establish permanent stand exams and transects		XX					
Redo late-successional reserve assessment on units		XX					
Take pre-treatment ground measures	XX	XX					
Take post-treatment measures (10 yr thereafter)		XX		XX			
Monitor activities and costs specific to pathways	XX	XX	XX	XX	XX	XX	XX
Develop and test remote-sensing techniques	XX	XX	XX	XX			
Track all ignitions and fire spread in and near units	XX	XX	XX	XX	XX	XX	XX
Monitor fire intensity in prescribed fires		XX	XX	XX	XX	XX	XX

Table 7. Timeline for other Forest and research commitments—these will only happen with specified additional funding ($ thousands)

Activity	2004	2005	2006	2007	2008	2009	2010
Assemble and georectify key historical data including GLO, post-fire orthophotos, management records, …	50	50					
Coordinate retrospective and other research	25	25	25	25	25	25	25
Retrospectively analyze fire behavior across stands with different pre-fire conditions in study area	120	120	120				
Retrospectively analyze pre-fire vegetation and fire intensity effects on soil fertility and sedimentation	120	120	120				
Publish retrospective study synthesis.		50			50		
Monitor landslides and sediment deposits	30					30	
Establish soil productivity and erosion plots	100						
Monitor soil changes on productivity plots[a]	100						100
Synthesize monitoring data (proximity, etc..)				50	50	50	50
Evaluate adaptive management (Five Rivers, Biscuit, others) with options forestry criteria (Bormann and Kiester in press) using Stankey et al. (2003) methods.			10				
Small-scale silviculture experiments focused on veg. control and snag removal (idealized pathways)[a]	200	50					50
Track neotropical bird and animal responses	100	100	100				100
Monitor stream reach habitat by pathway							
Build interpretive trails (1 per pathway)		50	50				
Evaluate public reactions and interpretations				75			
Sum of estimated costs	845	565	565	150	125	105	325

[a] Productivity and silviculture research might be combined

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