APPENDIX A

LEARNING OPPORTUNITIES

Plan for a Landscape Management Experiment on Restoring and Protecting Late Successional Forest Habitat after the Biscuit Fire

LEARNING OPPORTUNITIES

A large amount of late successional habitat was lost as a result of the Biscuit Fire. There is a high degree of uncertainty about how to restore that type of habitat. Four of the seven alternatives call for setting aside a portion of the Recovery Area to compare different landscape-scale strategies for restoring late successional habitat.

Included in this appendix is the management study plan put forth from the USDA Forest Service Pacific Northwest Research Station that explains the primary method the Forest Service will use to meet the learning need identified in the Biscuit Fire Draft Environmental Impact Statement; "there is a need to learn how to recover from the Biscuit Fire by comparing different management strategies."

This management study is a 36,000 acre replicated landscape-scale management experiment. It is an attempt to help meet both the resource and adaptive-management goals of the Northwest Forest Plan (1994), and thus it must sometimes balance conflicting resource and learning objectives. Focused on questions facing land managers, the study will be implemented as normal business for the Siskiyou National Forest, with limited support from the Corvallis Forestry Sciences Laboratory and other research organizations. The approach is based on adaptive management concepts, using a parallel-learning model (Bormann et al. 1999).

Appendix A

UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

Pacific Northwest Research Station

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

by

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Adaptive Management Strategy

In this document, we describe a management study included as part of the draft environmental impact statement (DEIS) for the Biscuit Fire Recovery Project (*the DEIS is not included with this peer-review draft of the study plan because it has not been released*). The study is the primary method the Forest Service will use to meet the learning need identified in the EIS: "There is a need to learn how to recover from the Biscuit Fire by comparing different management strategies" (DEIS, Chapter I.) This plan is being independently peer-reviewed during the comment period for the draft EIS; copies of the reviews and a reconciliation report will be placed on file at the Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR. Changes responding to the *peer review will be included in the final EIS.*

The management study—contained in three of the DEIS alternatives—is a 36,000-acre, replicated, landscape-scale management experiment. The experiment is large, covering about 7% of the area in the Biscuit Fire perimeter and 23% of the late-successional reserves (the Reserves) in the fire area. The experiment does not include any designated roadless areas. The study is an attempt to help meet both the resource and adaptive-management goals of the Northwest Forest Plan (the Plan, ROD 1994) and thus it must balance sometimes conflicting resource and learning objectives. Focused on questions facing land managers, the study will be implemented as normal business for the Siskiyou National Forest, with limited support from the Corvallis Forestry Sciences Laboratory and other research organizations. Funding for research projects that may help in interpreting the study will also 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:

- The questions have been officially posed by managers (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 (Shrader-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 and associated learning is based on concepts of options forestry (Bormann and Kiester, in review). The Biscuit Fire recovery DEIS and experiment follows the approach implemented in the Five Rivers watershed (ROD 2003) on the Siuslaw National Forest (www.fsl.orst.edu/5rivers).

Background—knowns and unknowns

The western Siskiyou Mountains of southern Oregon have fire-adapted forests 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). Many fire cycles are thought to have been missed in forests at lower elevations and in those the eastern part of the fire area. The western third of the area is thought, however, not to have missed a fire cycle, even with fire suppression.

Fire behavior is highly 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 what happened in 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 fast as 1.5 miles an hour through the wilderness in 2 days, a distance that took the Silver Fire about 2 weeks. The intensity was quite low in some places but also 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).

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

Recovery of biotic regulation after fires 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 hinder development of the large conifers needed for late-successional habitat. Although fire prepares the site for conifer regeneration, hardwoods can dominate and persist without conifer seed sources (Helms and Tappenier 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 10 large trees per acre—needed to meet late-succession standards—will likely 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 shrub-dominated area resulting from the Silver Fire in the wilderness may have reburned at lower intensity in the Biscuit Fire than conifer-dominated areas (Sessions et al. unpublished, fig. 1).

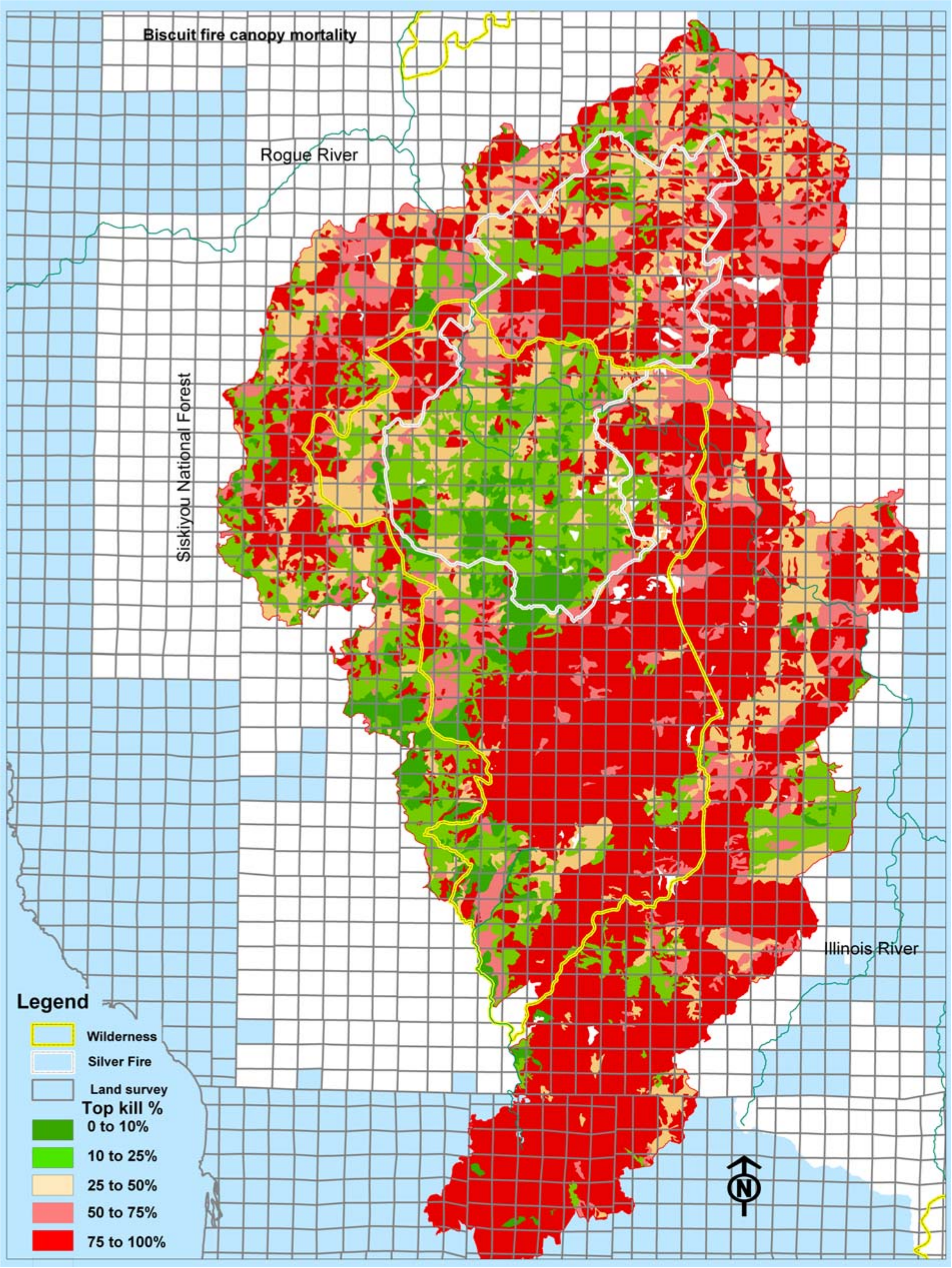


Figure 1. Canopy mortality based on aerial-photo interpretations. Note the lower mortality inside the wilderness where the Silver Fire burned in 1987, and the scale of variation in the northeast sector.

Managing wildfire-affected land to recover previous objectives is also uncertain. What happens when dead trees are removed is not clear (McIvar 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).

Recovery from the Biscuit Fire must address emerging questions: for example, Is regeneration harvesting feasible here, given the apparently frequent and severe fires that destroy most of the clearcut-origin plantations before they become fire resistant? and Can an extensive late-successional forest ever be achieved here? These questions suggest the extent of uncertainties awaiting those who will decide how to move forward. Perhaps the most important emerging lesson is, that people tend to be overly optimistic in predicting when and where fires will start, what their ultimate extent will be, and how they affect the landscape. People are also likely to be overly optimistic about knowing how to manage for 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 what approach will work and what will not.

Learning Design

Questions for this management study

Many questions could be asked and answers sought by implementing the Biscuit recovery project. 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. in press). About 60% of the known spotted-owl home ranges were destroyed or degraded by the Biscuit Fire (BPFA 2003). Because the Siskiyou Reserves are an important part of the Plan's late-successional habitat network, we chose to meet the learning need with a study focused on how to restore and protect 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 and meet other resource needs, where possible:

- Can late-successional habitat be restored and protected by managing in more than one way in the Reserves (not designated as roadless) burned in the Biscuit Fire?
- How fast will various management pathways, and their interactions with natural disturbances, achieve late-succession conditions?

Selecting an experimental design

We sought an experimental design to best answer these questions. Comments received by the Forest, in response to public outreach (*will reference the EIS section*), showed that people hold widely divergent views on how to respond to the fire, and some of the same differences are found among specialists inside the Forest Service. An initial set of EIS alternatives—including no action, as required by NEPA—were developed to reflect this diversity of opinion and, at the same time, to legitimately seek to meet management objectives.

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

- **Pathway A.** Manage by salvaging many of the dead trees, reducing fuels in managed areas (may include broadcast and pile burning and lop and scatter), and planting and managing conifers to grow quickly.
- **Pathway B.** Manage by promoting natural recovery processes, planting where seed sources are more than 0.1 miles away, and adding 200-ft fuels-management zones around the unit perimeters, with limited prescribed burning near these zones.
- **Pathway C.** Manage by re-establishing landscape-scale, low-intensity fire (mostly on south-facing slopes); salvaging dead trees only in severely burned areas; and adding 400-ft fuels-management zones around the unit perimeters.

The treatments chosen by the EIS team reflect the diverse opinions of what the Forest considers legitimate approaches to achieving the goals of the Northwest Forest Plan for the Biscuit recovery area. A no-action experimental treatment was specifically excluded as a treatment because no action is unlikely to meet project needs in the roaded Reserves. Although some researchers may define no action as a needed control, we think a design that compares three pathways will yield useful and appropriate comparisons. Those interested in the effects of no action may be able to study areas in the Wilderness or other unmanaged areas. They will be able to compare these effects to that found in the managed Reserves, but these comparisons will fail to yield much convincing evidence, because experimental rigor would be lacking.

The inherent variability of soils, vegetation, past management, and fire effects requires a minimum of four replications to have a reasonable chance of detecting differences between three treatments. The target design of 3 treatments and 4 replicates was set, requiring 12 experimental units.

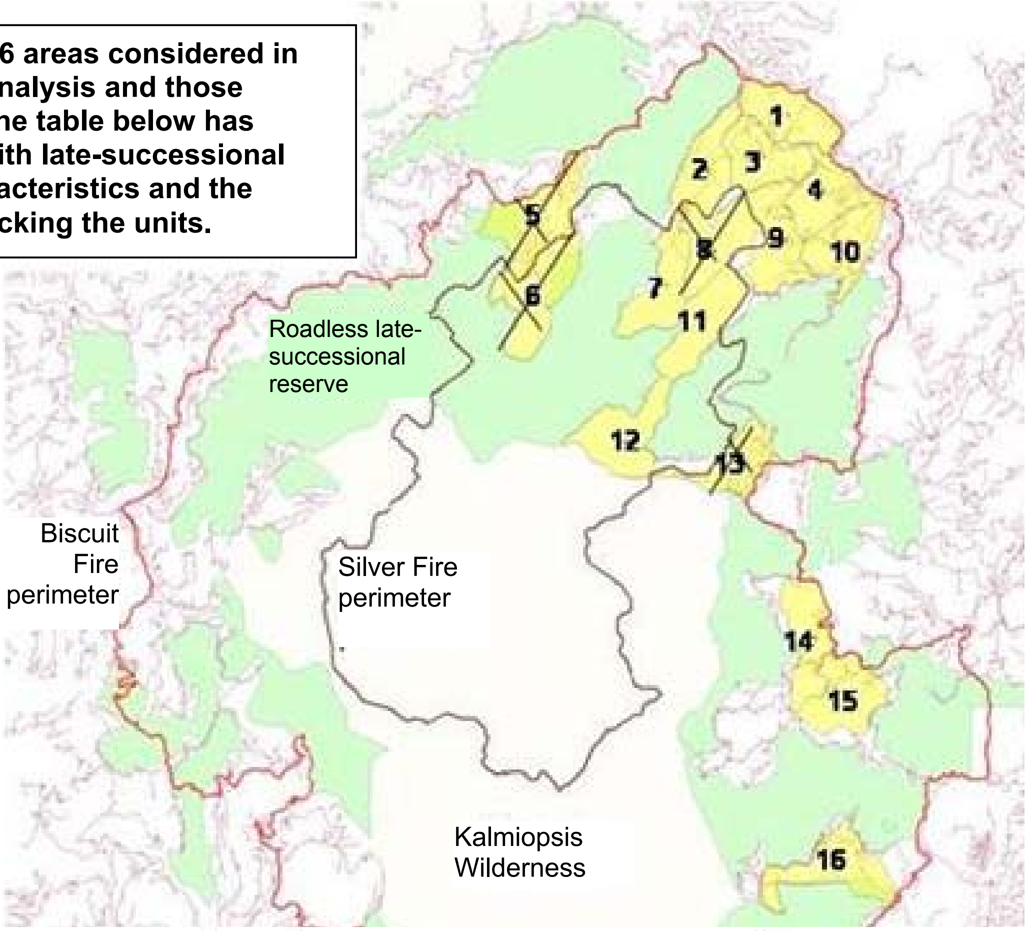
Selecting experimental units

We selected experimental units from the roaded Reserves (excluding those designated as roadless) inside the Biscuit-fire perimeter to best answer the primary question. The major area of roaded Reserves is found in the northeast sector of the Forest, including some BLM land. We developed a system selecting potential experimental units in this area, and then grouping them, based on an analysis of their similarity. First, 16 potential experimental units were selected (fig. 2) based on four factors:

- A size of about 3000 acres;
- Inside or outside the Silver Fire boundary;
- No areas with serpentine-adapted or high-elevation plant associations; and
- Boundaries that followed 7th-field watershed lines, where possible.

The experimental-unit size of 3000 acres was based on an analysis of the scale of the patterns in tree mortality (topkill) in the northeast sector of the Biscuit Fire (fig. 1). By superimposing section lines on the topkill map, about 4 or 5 sections (2500-3200 acres) must be combined before the average percent topkill for the group of sections reflected what generally happened in this area. Larger areas would be needed to set up units in other parts of the fire. Further analysis suggested that areas burned by the Silver and then the Biscuit Fire were likely different from

Figure 2. The 16 areas considered in the similarity analysis and those rejected (X). The table below has percent area with late-successional and other characteristics and the rational for blocking the units.



Number (above)	Live habitat	Inocula	Small or burnt	High elevation Fir	Serpentine veg	Helicopter yarded	Assigned block	Rationale (and description) for blocking assignments	Randomly assigned treatment
7	8%	14%	78%	0%	0%	54%	Fishhook	**Silver Fire; low habitat potential; few roads;** non-matrix; low elevation veg.; non-BLM.	A
11	8%	21%	71%	0%	0%	82%	Fishhook		B
12	2%	9%	89%	0%	1%	79%	Fishhook		C
1	43%	22%	34%	2%	0%	0%	Sourgrass	Non-Silver; **highest habitat potential; many roads;** non-matrix; non-serpentine; 1 BLM unit	C
3	37%	21%	42%	1%	0%	7%	Sourgrass		A
4	20%	39%	39%	6%	0%	8%	Sourgrass		B
2	24%	30%	46%	4%	0%	7%	Hobson	Non-Silver; moderate habitat potential; many roads; non-matrix; minor high elev. serpentine veg.; 1 BLM unit.	C
9	9%	19%	71%	2%	5%	10%	Hobson		A
10	13%	33%	54%	1%	1%	0%	Hobson		B
14	7%	30%	63%	0%	2%	17%	Briggs	Non-Silver; moderate to low habitat potential; many roads; non-matrix; minor serpentine.	C
15	16%	35%	49%	0%	1%	13%	Briggs		B
16	13%	29%	57%	3%	2%	3%	Briggs		A
5	14%	26%	60%	0%	12%	0%	Rejected	Matrix	
6	17%	23%	60%	2%	2%	52%	Rejected	Poor fit: in Silver	
8	15%	27%	57%	0%	0%	74%	Rejected	Poor fit: in Silver	
13	4%	26%	70%	1%	22%	0%	Rejected	Poor fit: low live habitat, matrix	

areas burned in the Biscuit Fire alone, so these areas were kept separate. Because serpentinite soils cannot produce desired late-successional conditions and high-elevation plant associations were considered to be substantially different, these areas were excluded from the experiment, as much as possible. Finally, experimental-unit boundaries were chosen along 7th-field watershed lines where building fuels-management zones was deemed feasible.

Similarity analysis methods

A similarity analysis was developed to discard the most dissimilar 4 (of 16) units, leaving 12 for the experiment; and to block remaining units into groups of 3. One purpose of blocking units 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 protecting forests 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; *will refer to EIS section*) combined with pre-fire tree size and canopy closure data:

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

Will helicopter yarding be needed? Cable yarding of dead trees is usually possible when stands are within 2000 ft of a road; beyond this distance, harvest by helicopter is the only choice. Similarity in area of the 2000-ft road buffer in a unit was thought to be the second most important consideration because of the potential economic and ecological effects of different yarding methods.

Will matrix-designated areas be included? To choose a large set of potential experimental units of around 3000 acres each, some units were selected that had substantial areas designated as matrix. 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.

What proportion is in serpentine and high-elevation plant associations? Plant associations were analyzed to confirm that serpentine and high-elevation associations did not dominate selected units. Groups of plant associations were defined: serpentine-adapted, high-elevation, and all remaining associations. The variables used were percentage of area in a unit with the various association groups.

Are the areas managed by the BLM or the Forest Service? A last similarity variable, management by the BLM or Forest Service, was chosen because the agencies past practices have differed somewhat; we thought mixing units with different management histories should be avoided, if possible.

Grouping units based on the similarity analysis

Units were blocked of into similar groups, as follows:

- Units burned by the Silver Fire were examined first. The three most similar, in proportional area with live habitat, were obviously grouped (fig. 2), allowing us to discard the other two Silver Fire units. This grouping also fits well with area far from roads (needing helicopter yarding) and areas of specialized vegetation types. The name given this group is Fishhook.
- Remaining units not burned in the Silver Fire were arrayed from the smallest to largest small or burnt (opposite of live habitat plus inocula), and a group of three units was obvious: those units with the highest live habitat. This group has no serpentine vegetation and few areas requiring helicopter yarding. The name given this group is Sourgrass.
- In the remaining 8 units, we next sought two groups of three similar units. Many of these units appeared roughly similar, and we chose to discard the two units with substantial matrix designation.
- Several ways to group the remaining six units were explored. Because none of these appeared to be better than any others, the final selection considered proximity. The names given these groups are Briggs and Hobson.

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 units passed. A GIS layer with projected salvageable timber was also examined to see if major differences existed within the groups. Most groups had similar proportions of areas with salvageable timber, although some moderate variation was noted in the Hobson block. Finally, a coverage was developed that showed areas where underburning was more feasible and desirable (roughly south-aspects). The proportion of units in south 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 units within each block (fig. 3). Random assignment of a treatment within blocks (groups of similar experimental units) 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).

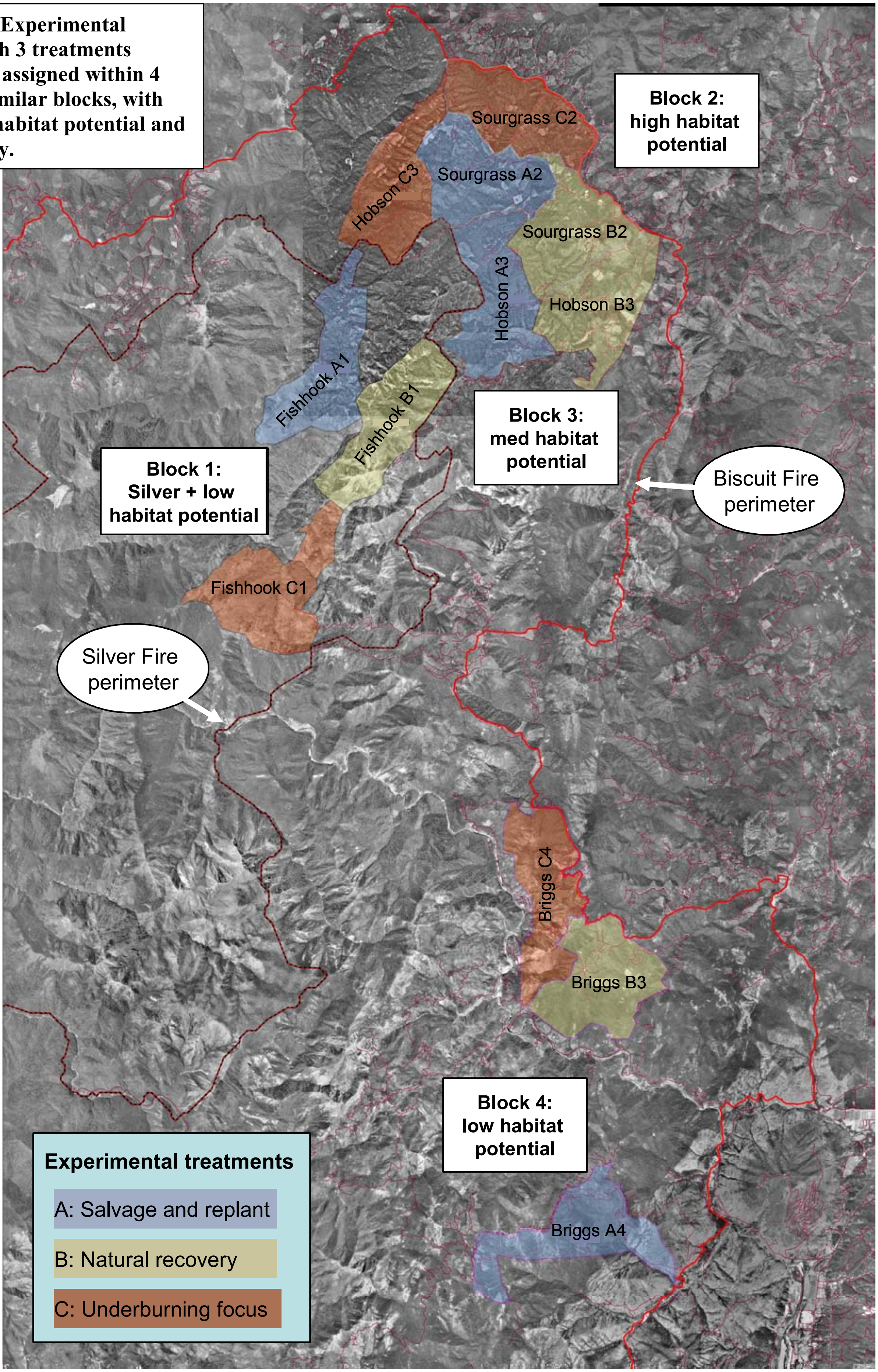
Alternate Pathways to Restoring and Protecting the Reserves (Experimental Treatments)

The Biscuit EIS team developed three pathways to meeting resource needs identified in chapter 1 (*of the DEIS*), based on public comments on the assessment (BPFA 2003) and from their expertise, experience, and understanding of the applicability of available science. These pathways (treatments) are described briefly and—to help design a monitoring strategy—a discussion of their uncertainties is included for each pathway. The pathways represent legitimate strategies for meeting, or are otherwise consistent with, the 7 stated resource objectives: provide commercial wood products, protect firefighters and communities, protect late-successional habitat from high severity fire, restore and plant and animal habitat, reforest conifers stands, restore water quality and fish habitat, and learn by comparing different strategies. From the perspective of the quality of the comparison and resulting conclusions, the treatments must be different enough that their effects will become detectable fairly quickly. The pathways were developed both to explore different ways to restore and protect late-successional habitat in the Reserves, and to avoid putting "all the eggs in one basket," given the high uncertainties in how to achieve these goals. 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. Pathways are described and analyzed in more detail in the DEIS.

Pathway A

This pathway is based on a hands-on philosophy that emphasizes salvaging dead trees, treating fuels created by management activities, replanting, and stand culturing to produce large conifers quickly. Salvage would occur where assumed to be beneficial to late-successional-habitat objectives and economically feasible (within 2 miles of a road in areas where pre-fire crown closure was greater than 40% and the post-fire crown closure was less than 40%). Standing-dead and downed trees would be left in accordance with the Siskiyou Forest Plan to accelerate developing 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 actions, including broadcast and pile burning and lop and scatter, as needed. Unlike the other two pathways, fuels-management zones are not included because of the widespread fuels reduction across the units. Salvaged areas would be replanted and intensively cultured (through control of competing vegetation) to produce large-diameter conifers as quickly as possible. Although the pathway is largely modeled after aspects of the Sessions et al. (unpublished) report, control of competing vegetation with herbicides, if necessary, would require writing a separate NEPA document. Burned plantations within 2 miles of a road would have site preparation, if needed, and would be followed by planting and culturing to produce large-diameter conifers as quickly as possible. Other recovery activities (riparian planting, meadow restoration, oak woodland and savannah restoration, Port-Orford-cedar planting, road

Figure 3. Experimental layout with 3 treatments randomly assigned within 4 initially similar blocks, with different habitat potential and fire history.



decommissioning, culvert replacement, and so on) would be handled case by case in the areas receiving this treatment. Uncertainties with pathway A include these questions:

- Will removing standing dead trees influence future landscape fire behavior?
- Will planted Douglas-firs grow fast enough to survive a low to medium intensity fire?
- Will control of competing vegetation (primarily evergreen hardwoods) promote or hinder future fires and development of late-successional habitat?
- Will planted stands take on late-successional characteristics from adjacent lightly burned forest?
- Will unit-based fuels management increase the effectiveness of future fire suppression efforts?

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 200-ft fuels-management zones around their perimeter to help control and fight future fires. 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. 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. Uncertainties with pathway B include these questions:

- Will retained standing dead trees influence future fire behavior?
- Will competing plants shade out naturally regenerating conifers or facilitate their establishment (though slowing their initial growth)?
- Will competing pioneer and sprouting plants replace more lost soil organic matter and nutrients than would conifers?
- Will naturally regenerating landscapes be more—or less—susceptible to future fires?

Pathway C

This pathway is based on a hands-on philosophy emphasizing reintroducing landscape-scale, low-intensity fire; salvaging dead trees only on severely burned sites; replanting conifers and reducing fuels to restore and protect late-successional habitat. Treatment C differs from A by using prescribed fire at a landscape scale and by limiting salvage to 1 mile from a road and stands with high mortality; leave trees and down wood would be the same as for treatment A. Fire-resistant pines (mostly ponderosa and sugar), rather than Douglas-fir will be planted on most southern exposures, and fire reintroduced only after these trees are large enough to withstand it. Low-intensity, prescribed fires would be repeated on southerly exposures about every 10 years to keep fuels low to help stop future wildfires like Biscuit. 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. Fuels-management zones (modeled after Agee et al. 2000) 400 ft. wide, will be created to contain landscape-scale underburning and facilitate fighting of future wildfires. Uncertainties with pathway C include these questions:

- Will the intermediate extent of salvaging of dead trees influence future fire behavior?
- Will prescribed fire behave as expected or accidentally burn adjacent unintended areas?
- Will the landscape underburned (south-facing slopes) with pines stop the advance of another large fire?
- Will repeated underburning further reduce soil organic matter and nutrients?

An important question in any experimental design is the extent to which treatments will affect the experimental units and be different from one another. Management on burned sites in the Reserves will not cover entire units; they will be highly focused on the areas intensively affected by the fire or perceived to need management to reduce future catastrophic fire (table 1).

The EIS team was able to plan activities that are fairly consistent with pathway philosophies; for example, the A treatments average 0; B, 6; and C, 25% of the area taken up by fuels-management zones. Decadal landscape burning will be applied only on treatment C, and these acres are consistently larger than the perimeter burning on treatment B. The proportion of area salvaged is higher in treatment A than C, and is consistent by block. Perimeter burning near the Biscuit Fire perimeter, is less consistent. Units B1 and B3 have small or no Biscuit perimeter. Perimeter burning is thought to be needed as protection for private lands in adjacent unburned forest. Further adjustments in proportions will be possible before the final EIS is released.

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

Management activity	**Pathway A Hands-on salvage and replant focus**				**Pathway B Aided natural recovery focus**				**Pathway C Hands-on underburning, and salvage focus**			
	A1	**A2**	**A3**	**A4**	**B1**	**B2**	**B3**	**B4**	**C1**	**C2**	**C3**	**C4**
Fuels-management zones	0%	0%	0%	0%	3%	9%	<1%[a]	10%	12%	22%	36%	28%
Perimeter burning	0%	0%	0%	0%	0%[b]	27%	4%	20%[c]	0%	0%	0%	0%
Landscape burning	0%	0%	0%	0%	0%	0%	0%	0%	15%[d]	72%	38%	80%
Salvage combined types	9%	11%	44%	40%	0%	0%	0%	0%	<1%	4%	14%	34%

[a] More zones are likely to be added in the final EIS to make this unit more like the others.
[b] No Biscuit perimeter is in this Silver Fire unit.
[c] Proportional area of perimeter fire does not match areas listed in the DEIS; changes will be made in the final EIS.
[d] Landscape burning might be increased to up to 30% on this unit, given the terrain limitations.

Monitoring

Deriving variables to be monitored

The learning objective can be met only if monitoring of the landscape experiment can demonstrate successes or failures of these pathways. We start by focusing on the question at hand: Can late-successional habitat be restored and protected in more than one way by managing differently in burned portions of the Reserves? Variables to be monitored are specified (tables 2a and 2b). The most direct measure of success is how known late-successional-dependent species respond to different treatments. Because spotted owls have a home range of about 2000 acres, connecting their behavior to treated 3000-acre units will be limited (Pers. Comm., Eric Forsman). This experiment has sufficient scale to monitor owl prey and changes in habitat thought critical to owl survival at the landscape scale—few other studies can do this. Variables indicating these changes include trajectories in tree sizes and density, stand and landscape structural diversity, plant and animal diversity and abundance, and fundamental changes in long-term soil productivity (tables 2a and 2b).

Variables to help understand how well the experimental units are being protected from fire can also be derived. Measures of changes in live and dead fuels and their distribution could be compiled into fire-risk models (for example, Finney 1988) so that hypothesized risks could be stated. Ultimately, future fire behavior in the experimental units will teach us how well the different strategies and models worked.

Other effects, secondary to the study questions, need to be monitored as well. For example effects of different pathways on aquatic conservation and social and economic values are also needed to inform future decisions. Variables could include practicality and costs of various management activities, benefits to the local economy, public perceptions, and effectiveness of learning strategies.

Monitoring recovery

A three-pronged monitoring strategy is proposed to fully meet the learning need (tables 2a and 2b). We first identify a minimum set of variables that the Forest can currently commit to, pending selection of an alternative containing the experiment (column 1). The Forest 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, established needs of sensitive species and risks of disturbances. The Forest would then establish permanent—but otherwise standard—plots on treated and untreated areas in each unit 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. The Forest commits to establishing a minimum (perhaps 10 plots) in each experimental unit, representing both managed and unmanaged areas (120 plots total). Initial condition of areas within units will be classified with remote sensing of aerial photos and satellite before- and after-fire images, and all classes will be monitored to some extent. Although many of the measurements will be taken on stand-scale permanent plots, plots will be drawn from a population of stands in the entire experimental unit. Relatively more plots will be assigned to treated portions of the units to concentrate on direct management effects. Given the 3000-acres in these units, a special emphasis will be placed on extending plot responses to the entire unit with remote sensing and GIS. The Forest will constantly seek to reduce monitoring costs as these technologies continue to evolve.

A second set of monitoring variables is identified that goes beyond typical Forest monitoring, and would require additional support (column 2). If Forest 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

Table 2a. 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	1. Commitment of the Siskiyou National Forest	2. Potential Forest commitment, given additional funding	3. Potential research commitment, given additional funding
Increasing understanding of the Biscuit Fire's behavior and effects	Make all historical and current data available to researchers and others.	Digitize all historical air photos and Government Land Office records and make into GIS layers (about $50k).	Coordinate ongoing research and retrospectively study the context leading to observed effects of the fire—as pretreatment data for the experiment ($100 to $1000k)[a].
Restoring habitat—trees and stand structure	Monitor species, growth trajectory of dominant trees, and stand structure with standard exams. Use permanent plots[b] monitored at years 0, 1, and 3 years after the pathways are established and remote sensing to draw inferences on unit 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 (about $100k per experiment per sample period).	Study the relative effects of competing understory species on growth of planted and residual conifers (see Tiller Fire study plan).
Restoring habitat—snags and coarse woody debris	Monitor size and numbers per acre of burned and insect-created snags and logs with standard exams and remote sensing (unknown cost).	Monitor effect of shade from snags on planted and natural tree seedlings (about $15k).	Study decomposition of, and bark-beetle and cavity nesting responses to, woody debris including pheromone trapping; study effects of logs on erosion (unknown cost).
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).	Establish unit-sized areas outside the fire boundary and in unmanaged areas to track changes in landscape patterns qualitatively compared to experimental units (about $100k).	Study the effects of proximity to old-growth inocula (scattered "legacy" trees and structures) compared to proximity to unburned large-tree stands (unknown cost).
Restoring habitat—plants	Monitor plant biodiversity and exotic weeds on permanent plots and use sampling and remote sensing to infer unit responses (unknown cost).	Expand the sample size to evaluate effects on rare species (about $50k).	Study the ecology of pioneer, fire-adapted, exotic, and rare and endangered plant species (about 50k).
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 (about $75k).	Study changes in neotropical bird populations; and early-succession-related species (elk, deer, bears; unknown cost).
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 (unknown cost).	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 (about $75k).	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 (about $75k).

[a] 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.

[b] See text for description of permanent plots.

Table 2b. Monitoring plan to assess protecting late-successional habitat and other pathway effects, with Forest commitments and potential commitments and research

Focus	Commitment of the Siskiyou National Forest	Potential Forest commitment, given additional funding	Potential Research commitment, given additional funding
Protecting habitat through time—dead fuels	Monitor dead fuels on permanent Brown line transects with traditional size-classes in treated areas (unknown cost).	Monitor dead fuels on permanent Brown line transects with traditional size-classes in untreated areas (about $25k).	
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 unit responses (unknown cost).	Monitor vertical distribution of live fuels on permanent plots in treated areas (about $25k)	
Protecting habitat through time—risks	Run fire models (fuels, resistance to control, and potential fire behavior) to predict fire risks (unknown cost).		Test fire models with data existing before the Biscuit Fire (unknown cost).
Protecting habitat through time—future fires	Evaluate how future wild and prescribed fires actually behave through different pathways and units (unknown cost).	Study intensity, duration, and containment of prescribed fires in pathway C to modify techniques for subsequent trials (unknown cost).	Examine effects of prescribed fire on the trajectory for restoring and protecting habitat (unknown cost).
Forest management costs and benefits	Record costs and benefits associated with management and monitoring (unknown cost).		Analyze costs and benefits in current and potential future market environments using monetary and nonmonetary units (unknown cost).
Other important effects—aquatic conservation	Monitor riparian habitat and organisms to meet sale-layout requirements (unknown cost).	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 (unknown cost).	
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 (unknown cost).	Develop an aquatic conservation element to the experiment, by applying different treatments to different pathways on upland areas that have potential to contribute wood and sediment to streams (could possibly add to final EIS; unknown cost).	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 (unknown cost).
Other important effects—social perceptions	Maintain a database with public comments relating to the experiment (unknown cost).	Build interpretive trails into representative parts of each management pathway (would require changes to the final EIS or a new NEPA document; unknown cost).	Conduct surveys of people, including those walking interpretive trails built into each of the three pathways (unknown cost).

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.

Interpreting results

If the management experiment shows more than one pathway achieves management objectives, the experiment can be thought of as a success. It would succeed because convincing evidence of no difference between pathways would allow managers more latitude in future decisions—for example, to meet secondary goals previously thought to be incompatible with primary goals. The interpretation therefore needs to focus on whether the conclusion of no difference is supported by the data, or whether it results from chance (type II error). Even if solid conclusions are clearly supported by data, further caution will be needed. Many processes play out over time, and changes in the ordering 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 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 3). 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.

Funding monitoring

The learning objective can be met only if the treatments are adequately implemented and monitored, which requires a commitment of resources and people. Most federal funding is annual and cannot easily be committed to long-term goals. The new stewardship contracting rules may be the best approach to maintaining a long-term commitment to maintaining the treatments and monitoring over time. If the study is properly implemented but no monitoring follows, it still may be valuable. In the past, abandoned studies have proved valuable as long as they can be relocated and remeasured. We view the retrospective synthesis as a critical background context for the study and to extract lessons immediately from the Biscuit Fire experience, but research funding is outside Forest 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 DEIS), 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 3. Simplified expectations of the effects of pathways A, B, and C on restoring and protecting late-successional habitat 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			
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 shade-out 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
Attain 10 conifers per acre	Faster, if all fires are controlled in the next 60 years; slower otherwise	Slower initially because of less planting but not hugely different because of natural regeneration	Intermediate
Snags	No difference in the Plan's minimum number per acre, less shade for emerging plants	No difference in the Plan's minimum number per acre , higher shade for emerging plants	No difference in the Plan's minimum number per acre , intermediate shade for emerging plants
Woody debris	More in near term by felling trees to meet minimum number per acre	More in the long run as snags fall to the ground	Intermediate near term and long term
Soil productivity	Intermediate	Highest because of N fixers and deeper rooting	Lowest from nutrient losses from repeated burning
Landscape habitat	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
Protecting late-successional habitat			
Dead fuels	Fewest because of salvage and fuel reduction	Highest because no salvage or fuel reduction	Intermediate short term and least long term with 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 age 60	High fire risk near term, lower later because of more diverse vegetation patterns	Lowest risk assuming underburning is successful

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