Research Contribution 46

College of Forestry Integrated Research Project:

Ecological and Socioeconomic Responses to Alternative Silvicultural Treatments

edited by

Chris C Maguire and Carol L Chambers

with GIS support by Debora L Johnson and cartography by Jennifer J Thatcher

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The Editors

Chris C Maguire is is Research Assistant Professor, Department of Forest Science, Oregon State University, Corvallis (for current affiliation, see p. 161). Carol L Chambers is Associate Professor, School of Forestry, Northern Arizona University, Flagstaff, Arizona.

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Chris C Maguire

Carol L Chambers (editors)

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Abstract

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The College of Forestry Integrated Research Project (CFIRP) is an on-going experiment in the eastern Coast Range foothills of western Oregon. Started in 1989, a team of scientists, resource managers, and students at Oregon State University designed and implemented silvicultural alternatives to clearcutting. These silvicultural practices aimed to create and retain features of mature and old-growth Douglas-fir (*Pseudotsuga menziesii*) forests while also producing timber. Fine-, moderate-, and large-scale natural disturbance patterns served as the basis for prescriptions. The study includes replicates of three silvicultural treatments (n = 27 stands) wherein 33% to 95% of the timber volume was removed, three non-replicated demonstration treatments wherein 33% of timber volume was removed in variable sized and shaped patches, and untreated controls (n = 3 stands). Additionally, clumped or randomly distributed snags were created from green trees in each stand. In this book, CFIRP scientists describe harvest challenges and economics; short-term (10-yr) responses of vegetation, wildlife, and humans to silvicultural treatments; and additional studies conducted using CFIRP study sites. A synopsis of past and present research and management directions also is included. Work continues on CFIRP today, and data collected from previous studies are available to other researchers. By comparing characteristics of forests managed under different silvicultural systems, we will be better able to assess their potential economic, social, and ecological contributions to managed forest landscapes.

Keywords: ambrosia beetles, CFIRP, coarse woody debris, disturbance, harvest operations, Oregon Coast Range, plant communities, recreation, regeneration, silvicultural systems, snags, socioeconomics, tree genetics, wildlife

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Foreword

This book is about a large, long-term, interdisciplinary research effort to learn more about the interaction between the forest, forest management, and wildlife. The subject and focus of the book is apparent from the table of contents and the first chapter. What may not be so apparent is the vision, courage, hard work, and perseverance that all of this reflects. Let me explain.

In the 1980s the Pacific Northwest was racked with controversy over presumed conflicts between forest management activities and the welfare of wildlife. While most prominent with respect to the northern spotted owl and the marbled murrelet and old-growth timber harvest, it was very strong as well with most other wildlife species and forest harvesting in general. Brenda McComb and John Tappeiner had the *vision* to see that better information on this topic would better inform the debate, and possibly result in decisions better meeting the diverse needs of the region. They formulated the basic experimental thrust of effort in one year, and their enthusiasm quickly got the several other chapter authors of this book involved in designing, refining and carrying out the research reported here. Then Dean Brown had the *courage* to allocate a large portion of the College of Forestry McDonald-Dunn Forest to the research envisioned by McComb and Tappeiner. The courage was needed because of the controversial nature of the topic and because it committed a significant portion of McDonald-Dunn Forest to this particular enterprise. The courage was also required because there was no long-term prescription for the stands involved beyond that which was part of the initial treatment. The science leaders said future manipulations depend on results. The Dean agreed to this important beginning.

Hard work came on all fronts. The scientists, College Forests leadership and staff, graduate students, and supporting technical and administrative staff made this research effort happen, from conception, through installation of treatments, data collection and analysis, and the reporting of the results. While all have persisted, it is the persistence of the editors that have made this book what it is: a valuable documentation of what was done and found, and a guidepost to the future research that is possible now that the initial installation and 10 years of post-treatment data have been collected, analyzed, and reported.

We are in the debt of those whose vision, courage, hard work, and perseverance made this research and the documentation of it a reality.

Logan Norris
Emeritus Forest Science Department Head
February 2005

Chapter 1. Introduction

Brenda C. McComb and Carol L. Chambers

In the Pacific Northwest, millions of hectares that were once dominated by mature and old-growth Douglas-fir (*Pseudotsuga menziesii*) forest have been clear cut and are now in plantations that are 0- to 40-yr-old. These actions resulted in a suite of land management policies on federal, state, and private lands that tended to polarize land allocations into reserves and even-aged stands with varying levels of retention. The College of Forestry Integrated Research Project (CFIRP) was designed to help our understanding of the tradeoffs associated with a set of alternative management approaches representing a spectrum of conditions: from even-aged with retention to uneven-aged to uncut mature forests. Thoughtful management of existing mature stands may accelerate the development of some habitat elements important to some late-successional associates (McComb 2001)—thereby increasing the effectiveness of the reserve system—but active management of mature stands has been controversial. Nonetheless, the regeneration of these mature stands in a manner that allows the stand to recover its function for late-successional values quickly may allow active timber management over a larger portion of the landscape than currently exists. Further, it is unclear whether many existing plantations will ever develop characteristics of late-successional forests important for a range of ecosystem functions and wildlife species. The high market value of Douglas-fir has led to rotations as low as 40 yr on some private lands and harvestable tree size has dropped to 17.5 cm (7 in.) dbh (Sessions 1990). It is possible that plantations harvested at these young ages may never provide the structural and compositional features utilized by some wildlife species. Alternative regeneration approaches may provide more favorable tradeoffs between timber production and other resource values on ownerships where multiple resource values are important. CFIRP was designed to create and/or retain stand structures present in mature or old-growth forests while simultaneously accommodating timber harvest.

CFIRP Experimental Design and Objectives

In 1989, CFIRP was initiated in western Oregon to compare costs and biological and human responses among a control and three silvicultural alternatives to clearcutting that retained some of the structural features found in old-growth Douglas-fir forests. Three levels of disturbance were created in a replicated design that represented attempts at recreating structural attributes that might imitate those caused by large-, moderate-, and fine-scale disturbances. The study also included three unreplicated group-selection treatments where similar timber volumes were extracted, but the pattern of extraction differed. Overlain on the entire study were two snag treatments; snags were created from green trees on each treatment unit in either clumped or randomly distributed patterns.

The major objectives of CFIRP were to

(1) identify the logging design and layout requirements for six types of stand management treatments

(2) determine logging productivity and cost for each treatment

(3) assess growth rates of residual mature Douglas-fir in each treatment

(4) monitor growth and survival of planted and naturally regenerated Douglas-fir and grand fir seedlings within each treatment

(5) compare relative abundances of terrestrial vertebrates among modified clearcut, two-storied, small patch group-selection, and uncut stands both pre- and post-treatment

(6) compare snag use by cavity-nesting birds between two spatial arrangements of snags on all treatments

(7) determine aesthetic, recreation, and adjacent landowner responses to treatments.

The alternatives that we tested incorporated into the stand prescriptions the structural elements that typically result from natural disturbances (McComb et al. 1993). The results from our study provide additional information for managing mature stands in ways that would complement a reserve system designed to maintain or restore some of the values associated with late-successional forests. Such an approach may allow active management to contribute toward the recovery of conditions over a region that would eventually more closely represent the range of conditions observed historically (Landres et al. 1999).

In this chapter we present an overview of the natural disturbance regime and historic range of variability of late-seral forests in the Oregon Coast Range and describe structural elements contributing to habitat quality for many species in this region. This information provides the context in which CFIRP was created and provides the basis for the development of prescriptions leading to single-storied, two-storied, and patch-cut stands. Because of the comprehensive nature of the study, a team of scientists and students worked with managers to implement and monitor these treatments. In succeeding chapters, we describe CFIRP research conducted by this team, including methodology (Chapter 2), economic costs (Chapter 3), and short-term

(1–10 yr) responses of vegetation (Chapter 4), wildlife (Chapter 5), and humans (Chapter 6) to the CFIRP silvicultural treatments. Additional studies that have utilized CFIRP stands are also summarized (Chapter 7), and an overview of CFIRP management and future research possibilities are provided (Chapter 8). The appendices provide maps, species lists, and a bibliography of literature resulting from the project.

Natural Disturbance in Douglas-fir Forests

An overview of the role of natural disturbances in structuring forests can provide the context for understanding how management activities might contribute to recovery or maintenance of conditions typical of the historic range of variability in the Coast Range region. Disturbances occur over a range of spatial scales (Table 1-1). Coarse-scale disturbances typically occur over tens to thousands of hectares or acres, although variability in disturbance intensity often causes patchy forest conditions at smaller scales also. Fine-scale disturbances occur at scales of < 1 tree height in width. Coarse- and fine-scale disturbances have affected the establishment, development, and destruction of unmanaged Douglas-fir forests for centuries. From 25–75% of the Oregon Coast Range was predicted to have been in late seral conditions at any one time over the past several thousand years (Wimberly et al. 2000). The remaining landscape was dominated by stands recovering from those disturbances (e.g., young stands with high levels of dead wood). Disturbances imposed by timber management deviate from natural disturbances to varying degrees, and these deviations likely influence habitat quality for wildlife, aesthetics, and timber value. By comparing the function of naturally disturbed forests with forests managed through silvicultural systems incorporating disturbance-related characteristics, as in CFIRP, we will be better able to assess whether managed stands can contribute to ecological functions while also contributing to economic values.

Coarse-scale Disturbances

Except in coastal forests, fire historically was the most frequent and widespread coarse-scale disturbance in the Douglas-fir region of western Oregon and Washington; fire impacts here have occurred at scales up to 10,000 ha (25,000 ac). Return frequencies for stand-replacement fires ranged from about 200 yr in the central Oregon Cascades (Morrison and Swanson 1990) to about 450 yr at Mount Rainier National Park in the Washington Cascades (Hemstrom and Franklin 1982). Smaller ground fires that killed relatively few trees returned between 100 and 150 yr (Stewart 1986; Morrison and Swanson 1990). It is quite likely that fire frequency on the margin of the Willamette Valley where CFIRP was conducted was very high prior to European settlement, resulting in a more savannah-structured forest. Following European settlement and fire control, the area became dominated by Douglas-fir and grand fir (*Abies grandis*), which is more typical of other Coast Range sites along the valley margin.

Although many mature stands in the Oregon Coast Range are dominated by one age class, some old-growth Douglas-fir stands in the Coast Range may have developed under multiple disturbance events (Tappeiner et al. 1997), as reflected by tree ages of 100–420 yr. After the initial stand-replacing event—such as fire or wind—followed by stand establishment, a second, medium-intensity disturbance may allow the development of a second cohort of trees, forming a two-aged stand. A third disturbance could increase the patchiness and number of age classes in the stand, resulting in an old-growth stand composed of several shade-intolerant and -tolerant conifer species, gaps, shrubs, and standing and down dead wood. We used this conceptual framework to design a silvicultural system that would produce two to three tree size classes and result in a two-story stand (for example, diameter distributions; see McComb et al. 1993). These stands could develop an inverse, J-shaped diameter distribution typical of uneven-sized old stands and imitate an incomplete burn (Spies and Franklin 1988). With subsequent disturbances, an uneven-sized diameter distribution could develop. We also recognize that there are relatively even-aged mature stands that have resulted from stand-replacement fire in the Coast Range; therefore, we included this condition within our suite of management systems.

Coarse-scale disturbances affect the density and development of habitat elements within stands (McComb 2001). Dead wood density following a fire, for instance, often increases because of tree death following the event. But over time, the wood decays and dead wood density decreases until the new stand develops to the point where trees die from suppression. At that time, dead wood biomass begins to increase. This dead wood trend probably occurred over a 400- to 700-yr cycle in Douglas-fir forests of the Pacific Northwest (Spies et al. 1988; Spies 1998). Other elements such as plant species diversity, vertebrate species diversity, and spatial heterogeneity of understory species are likely to follow this U-shaped response pattern (Spies 1998). Hence we felt it was important to include standing and fallen dead wood as an element of our one-storied and two-storied stands. Not all forest elements respond similarly to coarse-scale events. Large trees, forest floor depth, vertical foliage diversity, and live-tree biomass gradually increase over time and then stabilize several hundred years after the disturbance event. These characteristics follow an S-shaped response pattern (Spies 1998). We hope to be able to monitor stand dynamics in these stands and assess the development of habitat elements over time.

Fine-scale Disturbances

Fine-scale disturbances, such as suppression mortality, root rot (e.g., *Phellinus* spp.), localized windthrow, and light ground fires, also influence stand dynamics in natural stands (Smith 1986; Stewart 1986; Spies et al. 1990). These disturbances lead to the death of individual trees or small tree groups, and may produce an inverse J-shaped diameter distribution typical of an uneven-aged stand (Smith 1986: 17). Patches with large amounts of dead wood remain after these disturbances (Spies et al. 1988). We used this type of disturbance as a model for our patch-cut stands. Small gaps form at relatively low rates in old-growth Douglas-fir stands (0.1%–0.8% of the stand area per year may become gaps; Spies et al. 1990) compared with other old-growth forest types (Runkle 1985). However, canopy gaps are sites of dead wood production and tree regeneration for shade-tolerant species that are released by gap formation (Table 1-1; Stewart 1986; Spies et al. 1990).

Table 1-1. Generalized comparison of natural disturbances and three hypothetical examples of silvicultural systems that consider both timber removal and wildlife associated with mature forests in Douglas-fir forests of the Pacific Northwest.

	Natural disturbance		Managed stand		
	Coarse	Fine	Coarse		Fine
Characteristic			Single-storied	Few-storied	Many-storied
Disturbance size[1]					
Patch[2] (ha)	>10	<0.5	>10	>10	0.5-2.0
Stand (ha)	>10	>100	>10	>10	>100
Disturbance intensity at the stand scale					
Live trees	Low to moderate	High	Low	Moderate	High
Dead wood	Moderate to low	High	Low	Moderate	Moderate to high
Range of tree cover throughout the disturbance cycle (%)	10-95	80-90	10-95	25-95	80-90
Disturbance frequency					
Disturbance rate (average % of stand disturbed per year)	0.5- 1.0	0.1-0.8	1.3	0.4-1.5	0.5-1.0
Return frequency (years) to disturbed portions of the stand	100-500+	100-500+	75-100	75-140	100-200
Harvest entries per 100 years			1-2	1-2	4-10

[1] Sizes are generalized. Considerable variation exists in natural systems and in the economy of conducting management on small areas.

[2] Patch refers to the area disturbed. Stand refers to the area that includes the patch. In many coarse-scale disturbances, patch size and stand size are the same.

Historical Perspective of Silviculture in the Region

Compared with Douglas-fir forests after natural disturbance, stands established after clearcutting have significantly reduced representation of many elements. Clearcutting has not always been the dominant approach to management of Douglas-fir stands in the region, however. Selective harvest was tried in the Pacific Northwest in the early 1900s (Lord 1938; Isaac 1956). In the 1930s, diameter-limit cutting that removed about 35% of the volume in old-growth stands produced mixed results in western Oregon and Washington Douglas-fir forests (Isaac 1956). Some stands sustained high damage to residual stems, especially to thin-barked species; others had high levels of windfall (Munger 1950). These strategies did not follow selection regeneration systems designed to maintain uneven-aged stands (Smith 1986). Growth rates remained stable or decreased following cutting (Munger 1950). For these and additional reasons, such as concerns about inadequate natural regeneration (Cleary et al. 1978), clearcutting and planting became the accepted harvest technique in the early 1950s and continues to be used today.

Typically, stands at least 8 ha (20 ac) in size are harvested with cable systems or tractor logging, and sites are prepared for planting by applying herbicides and/or burning. Artificial regeneration, often planted at densities of 750 trees/ha (300 trees/ac), is used to assure replacement of the original stand with Douglas-fir as the principal species. Deadwood retention has been practiced to varying degrees on public lands primarily since the 1970s.

Following passage of the National Forest Management Act of 1976 and pursuant regulations (36CFR), land managers on national forests were presented with a new set of management objectives that included the maintenance of biological diversity in addition to timber production. As a result, special treatments were proposed to mitigate loss of mature forest habitat (Neitro et al. 1985). Eventually, "New Forestry" practices, in which trees, snags, and logs were retained during harvest with the intent of carrying these features through the next rotation, gained acceptance (Franklin 1989). Currently, silvicultural alternatives to short-rotation clearcutting are required on federal lands in the Pacific Northwest (USDA Forest Service and USDI Bureau of Land Management 1994). Long-rotation, even-aged with green-tree retention, and uneven-aged silvicultural systems have been suggested as management options (USDA Forest Service and USDI Bureau of Land Management 1994).

Until recently, most silvicultural research in western Oregon has focused on short-rotation clearcutting and even-aged management systems with little attention given to other regeneration methods. Consequently, as forest managers begin to use more varied silvicultural prescriptions, the comparative evaluation of management systems relative to effects on timber production and on other forest resources is largely lacking. CFIRP addresses this information void.

What types of regeneration systems other than clearcutting should be used? If we can determine the scales, intensities, distributions, and frequencies of natural disturbances that once occurred in unmanaged forests, can we use the disturbance regime as a template for designing silvicultural prescriptions? Implementation of these prescriptions would then have the potential to produce a landscape that in structure and composition may more likely fall within the range of natural variability of the landscape that occurred prior to significant European influence (Landres et al. 1999).

Ecological Considerations of Natural and Human-caused Disturbances

Size and Shape

Disturbance size (Rosenberg and Raphael 1986; McGarigal and McComb 1995) and shape (Temple 1986) can influence responses of plants and animals to disturbance. We hypothesize that an organism can be displaced by disturbances larger than its home range (the area over which the organism secures resources), but that an organism might not be displaced if the disturbance is small relative to its home range size. We suspect that species selecting mature Douglas-fir forests have been able to persist by either (1) including the fine-scale disturbances that lead to enhancement of stand complexity within their home ranges (fine-scale creation of snags, logs, or vertical structure) or (2) recolonizing stands of sufficient size that regrow to maturity and contain residual trees and dead wood following coarse-scale disturbances. Logistics restricted CFIRP to implementation within small stands. Consequently, the scope of responses that we could detect was limited to those processes and species that operate at the stand scale.

Intensity

Disturbance intensity influences the amount of organic material destroyed or redistributed by the perturbation (Table 1-1). Residual organic material remaining after disturbance can influence the direction of succession and the rate of subsequent stand development (Harmon et al. 1986). Structures created from or surviving the disturbance might directly or indirectly provide habitat for mature-forest species. The creation of gaps in mature and old-growth forests produces snags and logs, and subsequent vegetative growth enhances vertical complexity in the stand (Hunter 1990; Spies et al. 1990). We incorporated dead wood management into all of our treatments.

Frequency

Disturbance frequency will influence tree species composition and the amount of live and dead organic material present on the site over time (Harmon et al. 1986: 205–209; Spies et al. 1988). Frequent coarse-scale disturbances can delay the onset of mature forest development or even preclude it. Infrequent fine-scale disturbance may delay the development of multi-layered stands, large snags, and large logs in a stand (Spies et al. 1990) because gaps produce snags and logs, and subsequent vegetative growth enhances vertical complexity (McComb 2001). Continued monitoring of the stands will allow us to understand how resources change under stand recovery and future stand disturbances.

Habitat Associations

Terrestrial wildlife associated with late-seral forests have significantly affected forest policy in the Pacific Northwest. CFIRP was designed to understand how some wildlife species might respond to management alternatives. We know that certain habitat elements contribute to the diversity of wildlife species in a stand or a landscape. How do disturbance regimes affect these elements? If we assume that animals inhabiting Douglas-fir forests withstood natural disturbances and survived the habitat patterns that were created, then recreating those patterns is a logical step toward maintaining diversity and productivity of forest wildlife, including species associated with mature forests (Landres et al. 1999; Table 1-2). This approach was taken at the stand scale in CFIRP. We hypothesize that the most frequently occurring natural disturbances in mature forests can be simulated, at least in part, by alternative silvicultural techniques (Table 1-3).

In addition to abiotic habitat features such as soil, topography, and elevation, species associated with mature forests use a variety of stand structures: large trees of several species (both conifers and hardwoods), multi-layered canopies, large snags and logs, and deep forest floor litter (Ruggiero et al. 1991; McComb et al. 1993). To meet the needs of wildlife associated with mature forests, the maintenance and creation of these habitat structures should be objectives of silvicultural systems. We specifically considered these habitat elements in CFIRP.

Table 1-2. Comparison of biological effects shortly after disturbance in two natural disturbance patterns and three hypothetical examples of silvicultural systems that consider both timber removal and habitat for wildlife associated with mature forests.

	Natural disturbance		Managed stand		
	Coarse	Fine	Coarse		Fine
Characteristic			Single-storied	Few-storied	Many-storied
Plant community effects at the stand scale					
Early seral shrubs and herbs	Abundant	Rare	Abundant	Common to rare	Abundant
Shade tolerance of regeneration	Tolerant/intolerant	Tolerant	Intolerant	Intolerant	Tolerant/intolerant
Effects on habitat elements following disturbance					
Vertical structure	Low to moderate	High	Low	Moderate	High
Edge effects[1]	Moderate	Low	High	Moderate	Low
Horizontal patchiness	Moderate to high	High	Low	Moderate	High
Forest floor and below-ground impacts	Low to moderate	Low	Moderate	Moderate	High

[1] Assuming adjacent stands are mature forest.

Table 1-3. Management activities that can be used to provide habitat in managed stands for wildlife associated with mature forests.

	Coarse		Fine
Habitat element	Single-storied	Few-storied	Many-storied
Large tree size	Extend rotation	Extend rotation	Large target-tree size
Snags and logs	Reserve at harvest	Reserve at harvest	Reserve at each cutting cycle
Vertical complexity	Thinning and mixed	Density control	Density control/species planting
Horizontal patchiness	Non-uniform thinning	Non-uniform thinning	Non-uniform thinning
Edge effects	Green tree retention	Green tree retention	Scatter gaps
Forest floor	Cable yard, helicopter	Cable yard, helicopter	Designate skid roads
Human disturbance	Gate roads/infrequent entry	Gate roads/infrequent entry	Gate roads/skid roads

Incorporating Characteristics of Natural Disturbances into Managed Forests

No single stand-management system will precisely match the variability inherent in natural stands that resulted from a variety of disturbances. But some of the variation can be incorporated into managed landscapes by using a variety of silvicultural systems (Table 1-3; McComb et al. 1993). The choice of systems will depend on the biological, social, and economic objectives for the stand and the landscape. Natural disturbances occur over a range of sizes, shapes, frequencies, intensities, and patterns across landscapes. These parameters can be varied using silvicultural systems that produce both coarse- and fine-scale disturbances (Table 1-3). Variation in managed stands can be achieved by altering the sizes and shapes of stands, the frequency of entry, the levels of residual living and dead wood, and the arrangement of stands on the landscape (Tables 1-2 and 1-3).

Summary

As society's demands for forest resources extend beyond timber to a myriad of other extrinsic and intrinsic values, alternatives to timber-intensive management should be explored; however, we will need to understand the costs associated with production of these diverse values. An integrated team of scientists allows us to develop coordinated data sets that can be synthesized to allow a more thorough assessment of the tradeoffs associated with management techniques. The techniques that we tested and compared were based on the best available information at the time the experiment was developed. Information gained in this and other research since that time may suggest different alternatives that should be tested. Nonetheless, the synthesis of information from this study should allow managers to make decisions regarding management alternatives with information that is integrated among disciplines and values.

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Chapter 2. Study Area and Methods

Carol L. Chambers, Rebecca L. Johnson, Loren D. Kellogg, J. Scott Ketchum, and
William H. Emmingham

CFIRP was implemented on Oregon State University's 4800-ha (10,117-ac) McDonald-Dunn Forest in Benton County, Oregon. The forest is on the eastern edge of the Coast Range, approximately 24 km (15 mi) north-northwest of Corvallis (Figure 2-1), and is situated in an abrupt transition zone between the generally flat Willamette Valley and the Coast Range. Two plant association types have been recognized within this zone: Douglas-fir/hazelnut/bromegrass (*Pseudotsuga menziesii/Corylus cornuta californica/Bromus vulgaris*) and Douglas-fir/vine maple/salal (*Pseudotsuga menziesii/Acer circinatum/Gaultheria shallon)* (Franklin and Dyrness 1973). Although both associations are commonly found across the CFIRP study sites, treatments were assigned irrespective of plant association.

Figure 2-1. Location of the Oregon State University McDonald-Dunn Forest within western Oregon

Three replicates (blocks) consisting of 11 stands each were selected at the following locations:

- Saddle—Township 11S, Range 5W, Willamette Baseline and Meridian (W. M.), Sections 4, 8, 9, 16, 17
- Peavy—Township 10S, Range 5W, W. M., Sections 25, 35, 36
- Dunn—Township 10S, Range 5W, W. M., Sections 14, 22, 23, 27 (Figure 2-2; Appendix A).

The Dunn area tended towards younger stands than Saddle and Peavy (Table 2-1). Replicates are approximately 3–6 km (1.9–3.7 mi) apart. Elevation within replicates ranges from 120–400 m (395–1320 ft). The study sites are located over this entire range of elevations, on nearly all cardinal aspects as well as on a variety of slopes. Precipitation averages 100 cm/yr (39.4 in./yr) and occurs primarily from November to May. Summers tend to be hot and dry with mean June to August temperatures of 27.1°C (80.8°F) and an average of 47 mm (1.9 in.) of precipitation. Site index ranges from 28–40 m/50 yr (92–130 ft/50 yr) over the study area (King 1966).

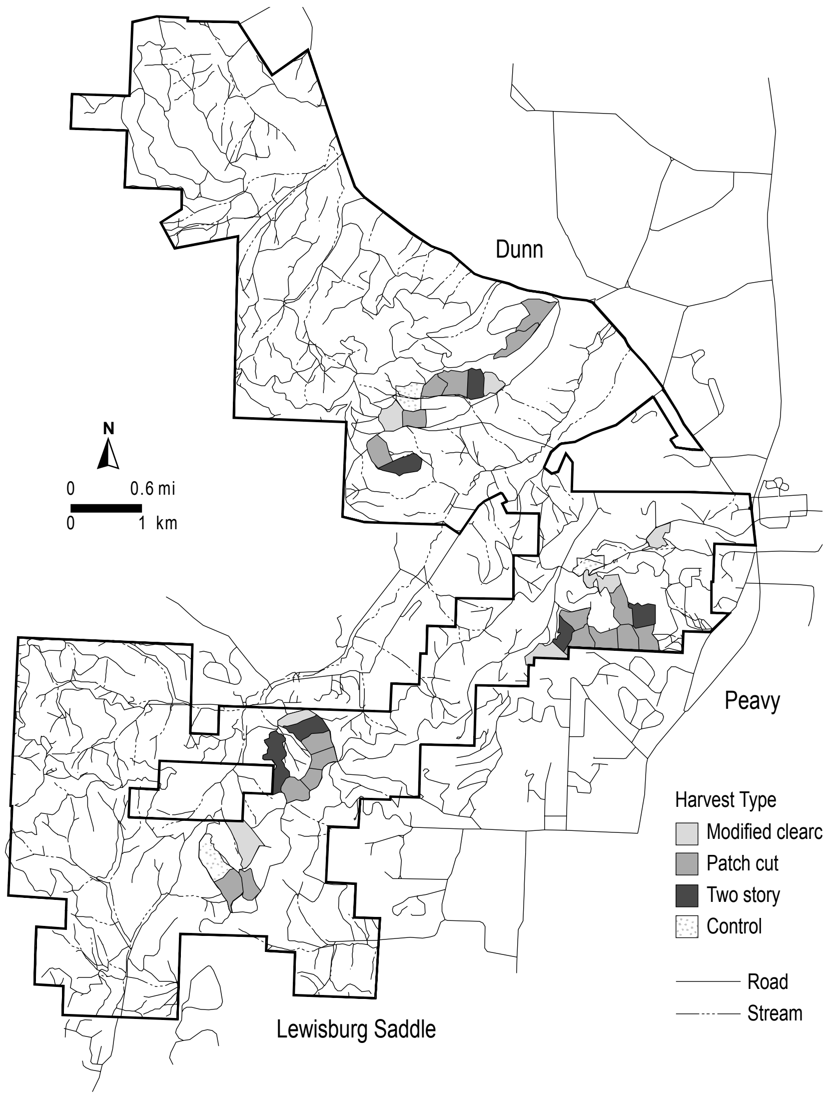

Figure 2-2. Location of the three CFIRP replicates (blocks) within McDonald-Dunn Forest, Oregon.

Prior to treatment, stands were similar in plant species composition and habitat characteristics (Chambers 1996). Douglas-fir basal area averaged 38 m^2/ha (165 ft^2/ac) and grand fir basal area averaged 1 m^2/ha (4.5 ft^2/ac). Hardwoods, including bigleaf maple (*Acer macrophyllum*), Oregon white oak (*Quercus garryana*), Pacific madrone (*Arbutus menziesii*), Pacific dogwood (*Cornus nuttallii*), red alder (*Alnus rubra*), Oregon ash (*Fraxinus latifolia*), and bitter cherry (*Prunus emarginata*) comprised the remaining 14 m^2/ha (61 ft^2/ac) basal area. Live tree densities (trees ≥20 cm [8 in.] dbh) averaged 537 trees/ha (217 trees/ac) for conifers and 165 trees/ha (67 trees/ac) for hardwoods. Snag densities (hardwood and/or conifer snags ≥30 cm [12 in.] dbh) averaged <1.9 snags/ha (0.8 snags/ac) prior to treatment. Stands were 45- to 150-yr-old and many were the outcome of natural regeneration after the elimination of burning by Native Americans following Euro-American settlement. Stands ranged from 5.5 to 17.8 ha (14 to 45 ac) in size; however, different sizes were equally represented among treatments and replicates (Table 2-1).

Overstory conifers and hardwoods were reduced in harvest treatments, particularly in the two-story and clearcut stands (Table 2-2). Understory species (herbaceous cover, low shrub cover) remained the same or increased in percent cover.

Silvicultural Treatments

Each location replicate included at least one stand of the basic silvicultural treatments (Table 2-1). Basic treatments were as follows:

(1) Small patch—33% of wood volume removed in 0.2-ha (0.5-ac) circular to square patches.

(2) Two-story—75% of volume removed resulting in 20 to 30 green trees remaining per hectare (8 to 12 green trees/ac) scattered uniformly throughout the stand. Note that these

Table 2-1. Stand characteristics and treatments across the three CFIRP replicates in McDonald-Dunn Forest, Oregon.

Replicate[1] Stand number	Size in ha (ac)	Average age (yr)	Silvicultural treatment[2]	Snag treatment	Harvest system	PSME[3] Basal area in m^2/ha (ft^2/ac)	PSME[3] %[4]	ABGR[3] Basal area in m^2/ha (ft^2/ac)	ABGR[3] %[4]	HWDS[3] Basal area in m^2/ha (ft^2/ac)	HWDS[3] %[4]
Saddle											
1	6.9 (17.0)	119	Clearcut	Scattered	Ground	50 (218)	84	2 (9)	3	7 (30)	13
2	11.6 (17.0)	119	Two-story	Scattered	Ground	50 (218)	84	2 (9)	3	7 (30)	13
3	9.6 (23.7)	119	Small patch	Scattered	Ground	50 (218)	84	2 (9)	3	7 (30)	13
4	7.6 (18.8)	96	Small patch	Scattered	Ground	39 (170)	84	1 (4)	3	6 (26)	13
5	6.1 (15.1)	73	Small patch	Scattered	Ground	42 (183)	83	1 (4)	1	8 (35)	16
6	10.4 (25.7)	108	Small patch	Clumped	Ground	48 (209)	82	1 (4)	2	9 (39)	16
7	17.8 (44.0)	117	Two-story	Clumped	Cable/ground	52 (226)	86	2 (9)	2	7 (30)	12
8	15.0 (37.0)	144	Clearcut	Clumped	Cable/ground	52 (226)	88	2 (9)	4	5 (22)	8
9	8.0 (19.8)	95	Small patch	Clumped	Ground	36 (157)	89	2 (9)	5	2 (9)	6
10	12.5 (30.9)	136	Small patch	Clumped	Ground	35 (152)	85	2 (9)	4	4 (17)	11
11	12.0 (29.6)	88	Control	No treatment	No treatment	31 (135)	91	1 (4)	1	3 (13	8
Peavy											
1	8.3 (20.5)	131	Control	No treatment	No treatment	44 (192)	80	5(22)	10	5 (22)	10
2	9.7 (24.0)	134	Clearcut	Scattered	Ground	38 (165)	93	0 (0)	0	3 (13)	7
3	11.1 (27.4)	130	Small patch	Scattered	Cable/ground	39 (170)	85	0 (0)	0	7 (30)	15
4	10.3 (25.4)	111	Two-story	Scattered	Ground	42 (183)	94	1 (4)	1	2 (9)	5
5	9.6 (23.7)	109	Small patch	Scattered	Ground	36 (157)	93	0.5 (2)	1	3 (13)	6
6	9.8 (24.2)	109	Small patch	Scattered	Ground	41 (179)	90	1 (4)	2	4 (17)	8
7	9.9 (24.5)	104	Small patch	Clumped	Ground	39 (170)	89	1 (4)	1	4 (17)	10
8	8.1 (20.0)	114	Small patch	Clumped	Ground	27 (118)	64	0 (0)	0	15 (65)	36
9	8.4 (20.7)	127	Small patch	Clumped	Cable	60 (261)	79	1 (4)	1	15 (65)	20
10	7.8 (19.3)	124	Two-story	Clumped	Cable	35 (152)	83	1 (4)	1	7 (30)	16
11	5.5 (13.6)	118	Clearcut	Clumped	Cable	35 (152)	83	1 (4)	2	6 (26)	15
Dunn											
1	16.1 (39.8)	77	Two-story	Clumped	Ground	33(144)	77	1 (4)	1	9(39)	22
2	11.4 (28.2)	70	Large patch	Clumped	Ground	31(135)	73	0.5 (2)	1	11(48)	26
3	10.7 (26.4)	124	Clearcut	Clumped	Cable/ground	37(161)	81	1 (4)	2	8(35)	17
4	7.9 (19.5)	76	Strip	Clumped	Cable	25(109)	77	1 (4)	2	7(30)	21
5	13.5 (33.3)	141	Control	No treatment	No treatment	36(157)	76	2 (9)	5	9 (40	19
6	7.3 (18.0)	67	Wedge	Scattered	Cable	30(131)	81	1 (4)	2	7(30)	17
7	11.7 (28.9)	59	Small patch	Scattered	Cable/ground	33(144)	80	0.5 (2)	1	8(35)	19
8	9.0 (22.2)	58	Two-story	Scattered	Cable/ground	29(126)	81	0.5 (2)	1	7(30)	18
9	6.7 (16.5)	45	Clearcut	Scattered	Ground	18 (78)	75	0 (0)	0	6(26)	25
10	9.8 (24.4)	58	Large patch	Scattered	Cable/ground	21 (91)	68	1 (4)	3	9(39)	29
11	10.9 (26.9)	60	Small patch	Clumped	Cable	26(113)	70	1 (4)	2	10(44)	28

[1] Saddle harvested in 1990; Peavy harvested in 1991; Dunn harvested in 1992.

[2] See text for detailed description of treatments.

[3] Pre-harvest species: PSME = Douglas-fir (*Pseudotsuga menziesii*); ABGR = grand fir (*Abies grandis*); HWDS = all hardwoods including Pacific madrone (*Arbutus menziesii*), Pacific dogwood (*Cornus nuttallii*), red alder (*Alnus rubra*), Oregon ash (*Fraxinus latifolia*), and bitter cherry (*Prunus emarginata*).

[4] Percent of total basal area

Table 2-2. Vegetation characteristics averaged for three bird count points in each stand by treatment prior to (Year 1) and following (Year 2) treatments for the three CFIRP replicates in McDonald-Dunn Forest, Oregon (data from Chambers 1996). Because different vegetation plots around the bird count points were randomly selected for measurement each year, there was some annual variation between years.

	Control		Small Patch		Two-Story		Clearcut	
Variable	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Basal area and tree density								
Conifer basal area m²/ha (ft²/ac)	41 (179)	39 (170)	38 (166)	29 (126)	38 (166)	12 (52)	40 (174)	2 (9)
Hardwood basal area m²/ha (ft²/ac)	19 (83)	24 (105)	12 (52)	10 (44)	13 (57)	1 (4)	11 (48)	1 (4)
Snag basal area m²/ha (ft²/ac)	3 (13)	4 (17)	3 (13)	2 (9)	3 (13)	2 (9)	3 (13)	3 (13)
Large (>55-cm dbh) conifers/ha (ac)	226 (92)	286 (116)	258 (105)	242 (98)	341 (139)	99 (40)	414 (168)	13 (5)
Large (>55-cm dbh) hardwoods/ha (ac)	3 (1)	22 (9)	10 (4)	10 (4)	13 (5)	0 (0)	19 (8)	0 (0)
Cover[1] (%)								
Douglas-fir	49	47	49	31	52	8	53	3
Sawtimber	57	62	56	45	62	10	58	6
Pole	42	33	38	24	28	4	36	2
Tall shrub	26	23	34	18	42	7	37	6
Low shrub	25	22	27	33	46	51	36	42
Herbaceous	60	64	53	50	44	39	54	52

[1] Herbaceous cover included non-woody plants < 1-m tall; low shrub cover included woody shrubs 0–1.3 m tall; tall shrub cover included woody shrubs >1.3–4 m tall; pole cover included trees > 4–20 m tall; sawtimber cover included trees > 20-m tall; Douglas-fir cover included Douglas-fir trees > 20-m tall.

stands resemble the shelterwood regeneration method; however, the intent is to retain the overstory trees through time and not remove them as regeneration develops.

(3) Modified clearcut—1.2 green trees/ha (0.5 trees/ac) retained.

(4) Control—not harvested.

The Dunn replicate contained an additional three types of demonstration silvicultural treatments focused on the shape of harvested patches within stands:

(1) Large patch—33% of wood volume removed in 0.6-ha (1.5-ac) circular to square patches

(2) Wedge—33% of wood volume removed in 0.8- to 1.2-ha (2- to 3-ac) wedge cuts

(3) Strip—33% of wood volume removed in 0.8- to 1.2-ha (2- to 3-ac) strip cuts.

Snag Treatments

Snags were created at a level predicted to be sufficient to support 40% optimum populations of primary cavity nesters (3.8 snags/ha [1.5/ac]) using the Snag Recruitment Simulator (SRS) model of Marcot (1991) (information in the model is based on Neitro et al. 1985). This snag level was consistent with the recommendations of public land management agencies at the inception of CFIRP. Green trees (Douglas-fir and scattered grand fir) were topped with a chainsaw within 6 mo of stand harvest to create most of the snags, resulting in a mean snag height of 17 m (56 ft); mean snag dbh was 75 cm (30 in.). Some snags retained live branches after topping (Chambers et al. 1997).

Snags were not created in control stands so these stands could be used to compare the effects of creating snags on cavity-nesting birds. In the remaining stands, snags were created in two spatial arrangements: clumped in groups of 8 to 12 snags (N = 523 total snags) or scattered throughout the stand (N = 515) (Table 2-1). In stands with any type of patch-cut treatment, snags were created in the remaining forest matrix rather than in the harvested patches. An effort was made to avoid placing snags within 30.5 m (100 ft) of skid trails, skyline corridors, and landings to lessen the potential of snags becoming safety hazards during future logging entries. Tree tops were left on the ground to provide a consistent level of log cover across stands, and a numbered aluminum tag was nailed to each snag to identify it for future monitoring.

Implementation

One location replicate was harvested each year for 3 yr between fall 1989 and summer 1991. Treatments were installed as follows: Saddle harvested fall 1989 through spring 1990 and planted spring 1990, Peavy harvested fall 1990 through spring 1991 and planted spring 1992, and Dunn harvested late summer 1991 and planted spring 1992. Both ground skidding and cable logging systems with manual chainsaw felling were used for harvest; ground skidding was employed on terrain with less than 30% slope. In patch-cut treatments, each individual patch was numbered to allow for the monitoring of activities, planned or natural, and system responses that might vary among patches (Appendix B). Following harvest, slash was piled and burned as needed for regeneration, and, typically, 1-1 and P-1 Douglas-fir seedlings were planted in a range of 3.4- to 4.0-m (11- to 13-ft) spacing. More detailed planting information about specific stands is kept on file with the Reforestation Forester in the Oregon State University College Forests Office, and the initial planting data are available to future CFIRP researchers upon request.

Research Strategy

Harvest and Economics Research

Harvest Study No. 1

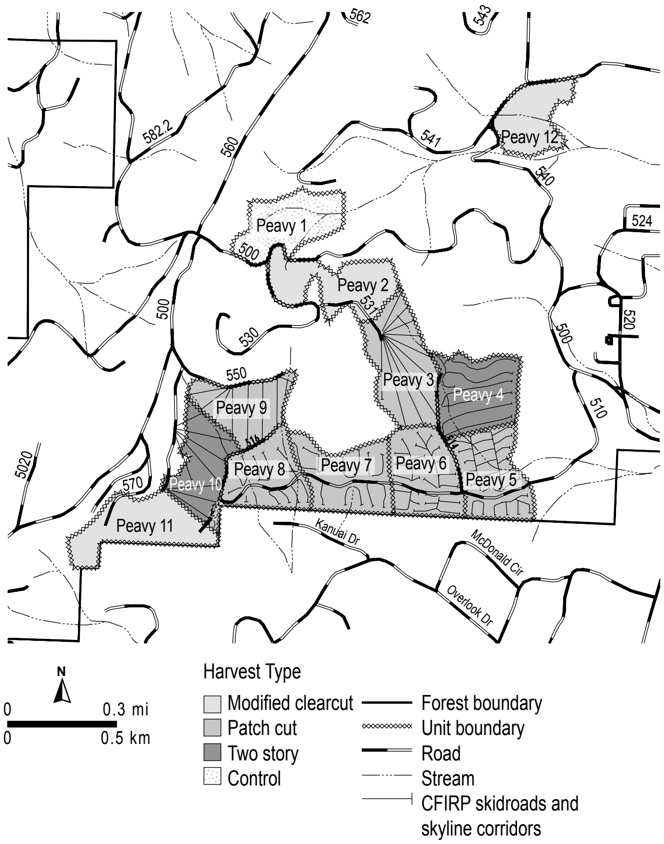

Figure 2-3. Pattern of long-term planned skidroads and skyline corridors within the various silvicultural treatments in the CFIRP Peavy replication.

The first harvest study was conducted on the Peavy replication from June 1990 through February 1991. Objectives were to compare the costs and operational challenges of ground skidding versus cable logging with manual chainsaw felling across the three basic silvicultural treatments: clearcut, two-story, and small patch cut. The small patch treatment was designed for a three-entry cutting cycle, with one-third of the unit area harvested in each entry (see Chapter 3, Figure 3-1).

Ground skidding was utilized on terrain with primarily less than 30% slope (Table 2-1). Designated skid trails spaced approximately 46 m (150 ft) apart were identified prior to felling and used in one two-story (Peavy 4) and four small patch stands (Peavy 5 through 8); designated skid trails were not utilized in clearcuts (Figure 2-3). Two clearcuts were studied: Peavy 2 with variable terrain, and a clearcut not in the original CFIRP design labeled Peavy 12 that had mostly flat terrain. Landings and skid trails were flagged by the researchers and reviewed by the logging contractor. A John Deere 648 grapple skidder was used in the clearcut and patch-cut units. The grapple skidder was also used for skidding logs on designated skid trails in the two-story stand. A FMC 220 and FMC 210 tractor with a winch line were used for pulling logs to the skid trails and skidding to the landing in the two-story stand.

Uphill cable yarding was utilized on units where a significant portion of the terrain was greater than 30% slope. Skyline roads spaced approximately 62- to 77-m (200- to 250-ft) apart were laid out prior to felling and used for cable yarding in one two-story (Peavy 10) and two (Peavy 3 and 9) small patch stands (Figure 2-3). Landings and skyline roads were flagged by the researchers and reviewed by the logging contractor. In clearcuts, skyline roads were selected by the logger during the logging operation.

A Thunderbird TTY-50 mobile yarder was used for skyline yarding. Four operating lines were used for the standing skyline system with a mechanical slackpulling carriage (MSP). The MSP skyline carriage allowed for lateral yarding distances up to approximately 38 m (125 ft) on each side of the skyline. All skyline roads were logged as a single span; some required tailtrees to obtain necessary log lift and skyline deflection.

The following information was obtained for each stand:

(1) Shift-level forms to track timber volume production and to assess work productivity—completed daily by loader operators and lead cutters.

(2) Labor rates—obtained from USDA Forest Service (1990).

(3) Equipment operating costs—determined using the PACE software program (Sessions and Sessions 1986).

Harvest Study No. 2

The second harvest study was conducted on the Dunn replication from June to September 1991. Objectives were to compare costs and operational challenges of cable logging with manual chainsaw felling for five silvicultural treatments and two skyline placement patterns. Comparative treatments were as follows (Figure 2-4):

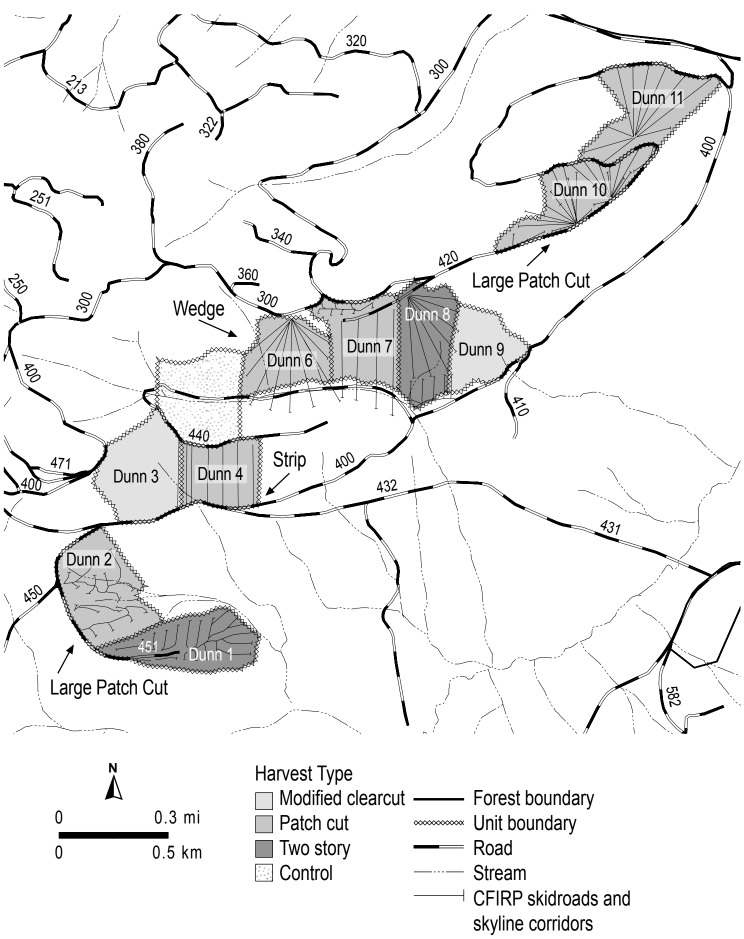

Figure 2-4. Pattern of long-term planned skidroads and skyline corridors within the various silvicultural treatments in the CFIRP Dunn replication.

(1) Modified clearcut, with a centralized landing and fan skyline roads (Dunn 3).

(2) Small patch, with a centralized landing and fan skyline roads (Dunn 11).

(3) Small patch, with parallel skyline roads (Dunn 7).

(4) Large patch, with a centralized landing and fan skyline roads (Dunn 10).

(5) Wedge, with a centralized landing and fan skyline roads (Dunn 6).

(6) Strip, with parallel skyline roads (Dunn 4).

Each group-selection stand was designed for a three-entry cutting cycle (see Chapter 3, Figure 3-1) and all skyline roads were planned in advance of harvest for all treatments except the clearcut and wedge. Researchers completed logging planning and layout activities and timed them to the nearest 15 minutes.

Strip and wedge sizes were designed with skyline yarding capabilities in mind. Each strip or wedge was located on one skyline road, with the width of the strip (approximately 62 m [200 ft]) or wedge (approximately 77 m [250 ft] at the wide end) determined by the slackpulling carriage feasibility limit. Skyline roads in the small patch and large patch treatments were located so that the maximum distance to the edge of any patch was less than 38 m (125 ft).

In the clearcut treatment, green retention trees and trees designated for snags were marked as leave trees. In small patch treatments, all trees inside the patch openings were marked for harvest. In strip, wedge, and large patch treatments, harvest boundaries were marked and all trees inside the boundaries were cut.

One lead timber faller with 18 yr of experience was timed exclusively to study felling production in each treatment. Each felling cycle was measured with a stopwatch to the nearest 0.1 second. A felling cycle included preparation, felling, limbing, measuring, bucking, and delays. A total of approximately 1100 felling cycles were timed for all sample areas combined. In addition, shift-level data were collected as a crosscheck to the detailed time study.

All yarding was done with a Thunderbird TMY-70 mobile yarder system rigged in a standing skyline configuration. A haulback line was used for outhaul. The carriage was a Danebo S-35 drum-lock mechanical slackpulling carriage, and slack for the dropline in the carriage was pulled by the slackpulling line on the yarder (Studier 1993). The logging contractor had 18 yr of experience in partial cutting operations, and his crew had 4- to 22-yr experience in cable logging.

Yarding production rates for each treatment were measured to the nearest centi-minute using a handheld computer with a time study program. Approximately 1150 total yarding cycles for all sample areas were timed. A yarding cycle consisted of carriage outhaul, lateral outhaul, hook, lateral inhaul, carriage inhaul, unhook, carriage reposition, and delays. Shift-level data were collected to crosscheck the timed results, and to provide truck load and volume information. Finally, all changes in skyline road and landing use also were timed.

Vegetation Research

Baseline overstory data were collected post-harvest on two-story and patch-cut stands. Age, diameter, height, and crown condition of trees typically were measured on six 0.4-ha (1-ac) plots for each of the two silvicultural treatments per location replicate (N = 33). Tree data are stored in the Oregon State University, Forest Science CFIRP database and are available to future CFIRP researchers for comparative purposes. Tree measurements for control stands are available in the McDonald-Dunn Forest inventory database housed at the College Forests office. Residual green trees on clearcuts were not measured.

Vegetation Management

Four vegetation management treatments were used in conjunction with the four basic silvicultural treatments to assess tree regeneration and plant community responses to the combined treatments. The goal of vegetation treatment was to achieve 2 yr of vegetation control. Treatments consisted of the following:

(1) Herbicide—application of a variety of herbicides by hand in a 0.9-m (3-ft) radius around seedlings (two-story and small patch units) or aerially across the entire unit (clearcuts).

Type of herbicide applied varied depending on vegetation to be treated. (Information about specific herbicides used and rates applied is available from the Reforestation Forester in the College Forests office.)

(2) Manual—placement of mulch paper around seedlings and manual slashing of competing shrub vegetation each year in late spring.

(3) Intensive—application of the herbicide treatment, scalping of vegetation within a 1-m (3.3-ft) radius around seedlings, and use of vexar tubing to protect seedlings from browse.

(4) No treatment—no vegetation control.

Three 0.1-ha (0.25-ac) replicates of each vegetation treatment were divided among the stands of each silvicultural treatment within each study location, for a total of nine vegetation treatment replicates per silvicultural treatment type across the entire CFIRP study area (Table 2-3). Only the no treatment vegetation control was used in unharvested control stands. Fifteen Douglas-fir and 10 grand fir 1-1 seedlings were planted in each vegetation plot across all harvest treatments except uncut controls.

Table 2-3. CFIRP stands used to study tree regeneration and vegetation community responses to silvicultural and vegetation management treatments.

		Vegetation treatment[1]			
Replicate	Silvicultural treatment	Herbicide[2,3]	Manual	Intensive[3]	None[2]
Saddle	Clearcut	3	3	3	3
	Two-story	3	3	3	3
	Small patch	3	3	3	3
	Control	0	0	0	3
Peavy	Clearcut	3	3	3	3
	Two-story	3	3	3	3
	Small patch	3	3	3	3
	Control	0	0	0	3
Dunn	Clearcut	3	3	3	3
	Two-story	3	3	3	3
	Small patch	3	3	3	3
	Control	0	0	0	3

[1] Numbers represent the number of vegetation treatment plots (plot size = 0.1 ha [0.25 ac]) within stands of each silvicultural treatment.

[2] Plots used in the vegetation community response study.

[3] Plots used in the resampling of planted seedlings in 1995.

Plant Community Responses

Only the herbicide and no treatment plots were used to assess plant community responses to the vegetation and silvicultural treatments. Percent ground cover and cover of individual plant species were estimated ocularly into one of five percent cover classes (0–5, 6–25, 26–50, 51–75, 76–100) within fifteen 2-m^2 quadrats in each vegetation treatment plot at Saddle and Peavy, and within 10 quadrats at Dunn. Average vegetation height was estimated also. Plants were grouped for analysis; groups consisted of native versus exotic grass, annual herbs, perennial herbs, and shrub categories. Sampling occurred in 1992 in late spring and early summer across all units resulting in Saddle data collected 2 yr following harvest, Peavy data collected 1 yr following harvest, and Dunn data collected 6 to 9 mo following harvest.

Artificial Regeneration

Planted seedlings were measured in all vegetation treatment plots in fall 1993. Saddle, Peavy, and Dunn trees were 5-, 4-, and 4-yr old, respectively, at the time of data collection. Measurements included: seedling height, diameter at 10 cm (4 in.), and percentage of seedling browse. Seedlings were remeasured in fall 1995. However, due to an operational oversight in 1994 that resulted in the eradication of manual and no vegetation treatment seedlings in the clearcuts, only seedlings in herbicide and intensive vegetation treatments were resampled.

Natural Regeneration

All harvested CFIRP stands were treated with herbicides in areas devoid of vegetation management plots. Three to four years following harvest in spring 1994, ten 11-m (36-ft) transects were randomly established in areas receiving herbicide treatment in each silvicultural treatment except controls across the three location replicates. All natural Douglas-fir seedlings located within one meter of the transect were counted, and number of seedlings per hectare was estimated.

Seed fall was measured in eight seed traps randomly placed in the harvested areas of small patch, two-story, and clearcut units studied in each CFIRP location replication. Traps were set out prior to seed fall in early fall 1991, and seed was collected four times through spring 1992. Additional information about the seed traps is located in Ketchum (1995).

Statistical Analysis

A randomized block split-plot ANOVA (analysis of variance) and Fisher's least significant difference (LSD) means comparison test were used to test for differences in vegetation and seedling response to silvicultural and vegetation management treatments. Additional information on the statistical analyses used in the CFIRP vegetation studies can be found in Ketchum (1995).

Wildlife Research

Objectives of CFIRP wildlife research were to compare relative abundances of diurnal breeding birds, small mammals, and amphibians among silvicultural treatments both pre- and post-treatment, and to compare snag use by cavity-nesting birds between two spatial arrangements of snags across all treatments. In addition to the four basic and three demonstration silvicultural treatments designed into CFIRP, the wildlife research also used an uneven-aged stand for comparative purposes. In 1992, an 8.8-ha (22-ac) stand in McDonald-Dunn Forest (Stand # 020514) in the vicinity of the Dunn replicate (Appendix A-3) underwent uneven-aged management. This stand was chosen for treatment because the 1962 Columbus Day storm, salvage operations, and natural succession created a 100- to 130-yr-old Douglas-fir stand with high densities of Douglas-fir and grand fir seedlings in the understory. The stand surrounds an area known as Forest Peak, with slopes averaging 40%. Elevation ranges from 265 to 455 m (875 to 1500 ft). Based on a 1991 pre-harvest inventory, the overstory (trees > 20-cm dbh) was 94% cubic volume Douglas-fir with scattered grand fir. Quadratic mean diameter was 62.5 cm (25 in.) and height of dominant and codominant trees averaged 41.8 m (138 ft). Over 89% of overstory tree basal area was in the dominant or codominant crown class. Of the 150 overstory trees/ha (60 trees/ac), 75% were Douglas-fir, 14% were grand fir, and 11% were hardwoods. In the understory (trees < 20-cm [8-in.] dbh), there were 1750 trees/ha (700 trees/ac). Douglas-fir (43%) dominated the composition, while grand fir (25%) and big leaf maple (25%) made up significant components.

Because the stand had high levels of stocking in regeneration and large diameter classes, but relatively little mid-story, the stand was marked to reduce overstory stocking and promote development of understory into mid-story and move it towards an uneven-aged structure. Overstory trees that looked susceptible to wind damage were marked for removal to create a wind-firm overstory. The stand was not marked using a specific Q factor.

In late summer 1992, the stand was partially logged with chainsaw felling and yarded with a skyline cable system. Approximately 33% (157 m^3/ha; 14 mbf/ac Scribner board feet) of the original 482 m^3/ha (43 mbf/ac) overstory timber volume was removed. Basal area was reduced from 52 m^2/ha (227 ft^2/ac) to 35 m^2/ha (153 ft^2/ac) with most basal area (16 m^2/ha [70 ft^2/ac]) removed in >20-cm (>8-in.) dbh size classes. Average diameter 63 cm (25 in.) of residual trees was only slightly reduced to 60 cm (24 in.). Large old-growth Douglas-fir trees and hardwoods were retained in the stand. Although up to 40% of the understory trees suffered some damage, their recovery was good, and as of 2002, the regeneration had responded to the overstory removal by doubling in height. The operation was a commercial success, and the stand has moved closer to an uneven-aged structure. This stand likely will be treated by 2007 to further encourage growth into the mid-story.

Avian Studies

Diurnal Breeding Bird Surveys

Diurnal breeding birds were sampled 1-yr pre-harvest and 2- to 4-yr post-harvest on all CFIRP stands. In addition, surveys were conducted 1 yr prior to treatment (1992) and 1-yr post-treatment (1993) in the uneven-aged stand. Birds were sampled from three variable circular plots, or VCP (Reynolds et al. 1980), established in each stand with plot centers ≥100 m (330 ft) from the stand edge and from other VCP centers. Bird counts began at sunrise and continued through mid-morning (0500 to 1000) from early May through mid-July, 1989–1993. Counts were halted by rain or by winds > 15 km/h (9 mi/h). Each VCP was visited six times during the breeding season; order of visitation was alternated among stands to account for seasonal variation in breeding phenology and hourly variation in bird activity.

Counts began two minutes after arrival at the VCP to allow for resumption of normal bird activity and they lasted eight minutes. During the sample period, birds seen or heard singing in the stand were identified to species, their distance from the VCP center was estimated, and their approximate location was mapped. Distances were recorded to the nearest meter for birds < 10 m (33 ft) from the VCP and to the nearest 5 m (16 ft) for birds > 10 m (33 ft). Locations of active bird nests found during bird counts or while walking between VCP stations also were recorded.

Abundance (number of observations per 5 ha [12.3 ac]) for each species was averaged among VCPs within stands each year. Species richness (total number of species) was averaged among stands within each treatment by year. Similarity of bird communities in harvested stands was compared with pretreatment communities using a percent similarity index (Brower et al. 1990).

Post-harvest Winter Bird Surveys

Birds were sampled from December 1994 through March 1995 using the same basic procedures as those outlined for breeding bird surveys. During winter surveys, however, VCPs were visited three times between 0900 and 1600, and each count lasted 15 minutes. Winter surveys were not conducted in the uneven-aged stand.

Post-harvest Nest Predation Study

A subset of 21 CFIRP stands was used to study nest predation across the four basic silvicultural treatments: control, small patch, two-story, and modified clearcut. Three artificial ground and three artificial shrub nests were positioned in each stand during four post-harvest nest predation trials. For each trial, one ground and one shrub nest were paired within a 10-m (33-ft) diameter circle; nest pairs were placed ≥ 100 m (330 ft) from stand edges and other nest pairs. Predation trials occurred: (1) 2–8 June 1992, (2) 25 June–1 July 1992, (3) 3–9 July 1996, and (4) 24–31 July 1996. These dates represented active nesting periods for diurnal breeding birds. Nests (6-cm [2.5-in.] diameter, 10-cm [4-in.] depth) were constructed from 2.5-cm (1-in.) mesh chicken-wire, sprayed with flat black paint, and lined with leaf litter or other vegetation found on site. Shrub nests were attached with florist wire 0.1 to 1.5 m (0.3 to 5 ft) above ground in shrub interiors at least 0.4 m (1.3 ft) from the outer edge of the shrub (see Yahner and Cypher 1987). Ground nests were placed in a shallow depression in the soil and concealed under vegetation, slash, or logs. Two quail (*Coturnix chinensis*) eggs were placed in each nest. Rubber gloves were worn when handling nests and eggs to minimize human scent, and no markings or flagging were used that might identify nests to predators (Yahner and Cypher 1987). Nests were checked after six days for signs of disturbance. A nest was considered disturbed if at least one of the two eggs was missing or broken. Egg fragments or eggs with holes were considered indicators of mammalian disturbance. Missing eggs were considered indicators of avian disturbance (Yahner and Cypher 1987). Eggs and nests were removed at the end of each trial.

Avian Snag Use Study

Data were collected on 13 characteristics for each snag (Table 2-4) immediately and 5 yr after snag creation. All snags were examined during the nesting season, May through July, both years to determine their use by cavity-nesting birds. If a cavity was in use, nest height, aspect, and bird species using the cavity were recorded. In addition, intensive nest searches were conducted from 1 June to mid-July 1995 (n = 42 nests) and 1996 (n = 104 nests). Nests were located by observing bird movement and listening for nestling begging calls.

Table 2-4. Characteristics of snags measured during the CFIRP wildlife studies.

Variable	Definition
DBH	Snag diameter at 1.4-m (4.5-ft) height above ground
Height	Snag height
Dead	Snag condition: dead or alive (≥1 live branch present)
Bark cover	Percent of bole bark cover
Scorch	Percent of bole with scorch
Excavated cavities	Number of excavated cavities
Forage cavities	Number of foraging cavities
Natural cavities	Number of natural cavities
Dead limbs	Number of dead limbs > 10-cm diameter, > 30-cm length (> 4-in. diameter, > 1-ft length)
% slope	Percent slope of ground averaged from 20-m (~ 65-ft) upslope and downslope from snag
Lean	Degrees of lean of snag from perpendicular to ground
Decay class	Decay class (see Cline et al. 1980)
Standing	Snag condition: standing or fallen

Numbers of excavated and natural cavities were counted in all snags to evaluate their use as avian nesting habitat or foraging substrate. We defined an excavated cavity as (1) any circular opening that appeared to a ground observer to have adequate depth for a nest for the house wren (*Troglodytes aedon*), the smallest cavity nester in the study area or (2) a rectangular opening created by a pileated woodpecker (*Dryocopus pileatus*). Natural cavities were centered at limb breaks. Foraging substrate was identified by the presence of a foraging cavity: an irregular opening that appeared to be (1) on the surface of the snag, (2) too small for a house wren, or (3) ≥ 7.5 cm (3 in.) in diameter. Most foraging cavities are located in a line along the bole or scattered at the snag base.

Small Mammal and Amphibian Studies

Small Mammal and Amphibian Summer Study

Because small mammal capture efficiency differs among trap types (Williams and Braun 1983; McComb et al. 1991), we used both pitfall (double-deep number 10 tin cans) and Sherman (8- x 9- x 23-cm [3- x 3.5- x 9-in.]) traps to assess small mammal abundance across the CFIRP silvicultural treatments. Pitfall traps also were used to capture amphibians. The uneven-aged stand was not surveyed for small mammals or amphibians.

The three VCPs established in each stand for the avian surveys were used as center points for small mammal and amphibian sampling. One Sherman and one pitfall trap were placed at the VCP center and 10 m (33 ft) from the VCP center in each of the four cardinal directions, for a total of 10 live traps per VCP and 30 traps per stand. Pitfall traps were buried flush with the ground along logs, snags, or other natural drift fences when available; Sherman traps also were placed along natural drift fences. Traps were opened for four consecutive days per stand once pre- and post-harvest during July and August for a total of 120 trap nights per stand per year. Captured individuals were marked by toe-clipping, then released. Capture rates for species were standardized by calculating number of individuals captured per 1000 trap nights for each stand and year. Additional details about the trapping protocol are located in Chambers (1996).

Post-harvest Small Mammal Winter Study

Small mammals were sampled on a subset of CFIRP stands (two each of control, small patch, two-story, and modified clearcut stands in Peavy and Saddle replicates) once in December 1991. The same protocol as that used in the summer small mammal study was followed with the exception that all stands were trapped simultaneously.

Coarse Woody Debris Study

To assess small mammal and amphibian associations with coarse down wood, we established one or two 5 x 5 trapping grids with 10-m (33-ft) spacing in each of the six CFIRP clearcut stands. Clearcuts with scattered snags (n = 3) were sampled with one randomly placed grid. Clearcuts with clumped snags (n = 3) were sampled with two grids; one grid was centered on a snag clump and the second was positioned > 50 m (164 ft) from any adjacent snag clump. Stands represented log volumes of 44–936 m^3/ha (635–13,525 ft^3/ac) for logs > 15 cm (6 in.) in diameter and > 1-m (3.3-ft) long. One Sherman and one pitfall trap as described above were placed at each grid point. A 3 x 3 trapping grid with 20-m (65-ft) spacing was superimposed on the 5 x 5 grid and one Tomahawk live trap (20 x 20 x 90 cm [8 x 8 x 36 in.]) was placed at each of the 15 points in the nested grid. All nine grids were sampled simultaneously from 31 May to 9 June 1995. Traps were set for four consecutive nights, closed for two nights, and then set for an additional four consecutive nights.

Table 2-5. Habitat characteristics measured in 0.03-ha (0.08-ac) plots centered on variable circular bird plots in each CFIRP stand during the summer months of 1989 through 1992.

Variables
Conifer and hardwood stems per hectare
Small conifer 0- to 19-cm (0- to 7.5-in.) dbh
Small hardwood 0- to 19-cm dbh
Medium conifer 20- to 55-cm (8- to 22.5-in.) dbh
Medium hardwood 20- to 55-cm dbh
Large conifer >55-cm (>22.5-in.) dbh
Large hardwood >55-cm dbh
Small snags per hectare
10- to 29-cm (4- to 11.5-in.) dbh, decay class 1
10- to 29-cm dbh, decay class 2–3
10- to 29-cm dbh, decay class 4–5
Medium snags per hectare
30- to 55-cm (12- to 21.5-in.) dbh, decay class 1
30- to 55-cm dbh, decay class 2–3
30- to 55-cm dbh, decay class 4–5
Large snags per hectare
>55-cm (>21.5-in.) dbh, decay class 1
>55-cm dbh, decay class 2–3
>55-cm dbh, decay class 4–5
Basal area
Conifer (20 BAF), m^2/ha (ft^2/ac)
Hardwood (20 BAF), m^2/ha
Snag (20 BAF), m^2/ha
Litter depth
Depth of litter (mm)
Small down wood//logs per hectare
10- to 29-cm (4- to 11.5-in.) large-end diameter, decay class 1
10- to 29-cm large-end diameter, decay class 2–3
10- to 29-cm large-end diameter, decay class 4–5
Medium down wood//logs per hectare
30- to 55-cm (12- to 21.5-in.) large-end diameter, decay class 1
30- to 55-cm large-end diameter, decay class 2–3
30- to 55-cm large-end diameter, decay class 4–5
Large down wood//logs per hectare
>55-cm (>21.5-in.) large-end diameter, decay class 1
>55-cm large-end diameter, decay class 2–3

continued

The nine grids were sampled again in October 1995, but only pitfall traps were used and they were set for three consecutive weeks. Pitfalls are more likely to capture insectivores, reptiles, and amphibians than Sherman traps (McComb et al. 1991), and these species groups were most likely to be associated with log volumes based on the spring analyses.

Wildlife Habitat Measurements

Breeding Bird, Small Mammal, and Amphibian Studies

Data for 53 stand features (Table 2-5) were collected between July and September on each stand each year (1989–1992) following wildlife sampling, except for the uneven-aged stand. Five 0.03-ha (0.08-ac) plots were established at each of the three VCPs per stand to measure percent cover of vegetation and density of live trees. One plot was placed at the VCP center, and four satellite plots were randomly placed 20 to 40 m (65 to 130 ft) from the VCP center in the four cardinal directions.

Vegetative cover within the 0.03-ha (0.08-ac) plots was measured using two methods. In the first method, vegetation was classified into five height categories: sawtimber trees (>20 m [~66 ft]), pole trees (4.1–20.0 m [~13.5–66.0 ft]), tall shrubs (1.3–4.0 m [~4.0–13.5 ft]), low shrubs (0.0–1.3 m [~0–4 ft]), herbs (0.0–1.0 m [~0.0–3.3 ft). Percent cover and average height were visually estimated for these layers and for dominant tree and shrub species. Live conifers and hardwoods also were tallied in three dbh classes: small (0–19 cm [~0.0–7.5 in.]), medium (20–55 cm [~8–20 in.]), and large (>55 cm [20 in.]). In the second vegetation cover method, percent cover was estimated for all vegetation within 5-m (16.5-ft) vertical intervals. This method was used to estimate changes in vegetation complexity within layers across silvicultural treatments.

In each CFIRP stand, litter depth was measured at nine random sites within the 0.03-ha (0.08-ac) plot located at the VCP center. The lengths of logs (m/ha) by diameter

Table 2-5 continued

>55-cm large-end diameter, decay class 4–5
Percent vegetation cover
Herbaceous, <1-m height
Grass
Fern (*Polystichum munitum*) (%)
Woody vine, <1-m height
Low shrub, 0.0- to 1.3-m height
Tall shrub cover, >1.3- to 4-m height
Pole tree, >4- to 20-m height
Sawtimber tree, >20-m height
Bigleaf maple (*Acer macrophyllum*), >20-m height
Douglas-fir (*Pseudotsuga menziesii*), >20-m height
Hazelnut (*Corylus cornuta*), >1.3- to 4.0-m height
Grand fir (*Abies grandis*), >20-m height (%)
Percent vegetation cover by height class
0- to 1-m (3.3-ft)
2- to 5-m (16-ft)
6- to 10-m (33-ft)
11- to 15-m (50-ft)
16- to 20-m (65-ft)
21- to 25-m (82-ft)
26- to 30-m (99-ft)
31- to 35-m (115-ft)
36- to 40-m (132-ft)
41- to 45-m (148-ft)
46- to 50-m (165-ft)
51- to 55-m (181-ft)
56- to 60-m (198-ft)

(large-end diameter) and decay class (Brown 1985) also were measured in the 0.03-ha plot. Basal areas of hardwoods, conifers and snags (using a 20 basal area factor [BAF] prism) were estimated from each VCP center. Snag counts were made within dbh and decay classes (Brown 1985) within a 0.28-ha (0.69-ac) plot centered on the VCP. Logs and snags were classified into three diameter categories (10–29 cm, 30–55 cm, and >55 cm [~4–11 in., 11–20 in., and >20 in.]) and three decay classes (class 1: little decay, classes 2 and 3: moderate decay, classes 4 and 5: heavy decay).

Coarse Woody Debris Study

Habitat characteristics were measured in July 1995 for the nine grids in clearcuts used in the coarse wood study. Log diameter (>15 cm [6 in.]), length (>1 m [3.3 ft]), and decay class (Maser et al. 1979) were tallied within 5-m radius plots centered on a grid of 5 x 5 sample points with each point 10 m from its neighbor. All dead wood was tallied by species and wood volume was estimated. We also estimated the percent cover of herbs, grasses, shrubs, slash (dead wood <20 cm [~8 in.] in large-end diameter), and bare ground within each plot.

Statistical Analyses

Avian Studies

Changes in habitat and bird abundance were assessed using methods described by Gurevitch and Chester (1986) for repeated measures experiments. Effects of silvicultural treatments and time since treatment were tested using multivariate analysis of variance (MANOVA; SAS Institute, Inc. 1989) and the univariate repeated measures analysis of variance (RMA; SAS Institute, Inc. 1992). Comparable nonparametric analyses were used when assumptions for MANOVA or RMA were not met. Only bird species with ≥30 observations ≤75 m (250 ft) to VCP centers and with home ranges or territories small enough to be included in the study stands (≤8 ha [20 ac]) were used in the analyses. Bird species abundance (number of detections per 5 ha [12 ac]), species richness, and community similarity were compared among treatments across a 3-yr period (pre-treatment, 1- and 2-yr post-treatment). Stepwise multiple regression analysis (SAS Institute Inc. 1989) was used to describe bird-habitat relationships. Analysis of covariance and logistic regression were used to evaluate avian use of snags. Additional analytical details are provided in Chambers (1996).

Small Mammal and Amphibian Studies

Analyses to assess small mammal and amphibian relationships among silvicultural treatments and habitat characteristics were similar to those performed for birds. In addition, simple linear correlation and analysis of variance were used to compare habitat characteristics and capture rates among the clearcut stands in the coarse woody debris study. Stepwise linear regression was used to identify variables that, in combination, were associated with capture rates of species with >40 captures.

Social/Recreation Research

Objectives of the CFIRP social science and recreation research were to (1) determine silvicultural treatment impacts on scenic and recreational quality, (2) assess adjacent landowners' perceptions of the silvicultural treatments, and (3) examine harvest consequences on recreational use on McDonald-Dunn Forest. Methodologies used in the three studies are outlined below.

Public Perceptions Study

In the past, studies on public perceptual preferences for various landscapes focused on scenic beauty. The scenic beauty estimation method has been applied to silvicultural treatments, natural insect damage, and disease stand damage (Ribe 1990). In the current ecosystem management movement, however, alternative silvicultural practices are expected to help shape a scientifically sound and socially acceptable forestry of the future (Salwasser 1990). Consequently, our study focused on the social acceptability rather than perceived beauty of various silvicultural treatments relative to scenic views and recreation places. It was expected that acceptability ratings would be similar to beauty ratings, with the exception that they would also reflect an additional attitudinal dimension related to the beliefs of respondents about forest management.

The public perceptions study was conducted less than 1 yr after CFIRP Saddle stands used in the study were harvested. It was composed of an on-site and an off-site phase. For the on-site phase, subjects representing a cross section of the local community were taken to a sample of CFIRP and other adjacent stands in September and October 1999 to evaluate the scenes. Comparative judgments of recreation and scenic quality of the stands were obtained from 77 students (forest management, forest recreation, and fisheries and wildlife majors) enrolled at Oregon State University and 18 non-students. Public perception ratings by students and non-students were not significantly different in 17 of 18 comparisons.

All participants visited six stands in a fixed order: (1) an old-growth Douglas-fir stand (Stand # 050904), (2) a non-CFIRP clearcut with no green tree or snag retention (Stand # 050907), (3) a 40-yr-old thinned stand (Stand # 051105), (4) a small patch cut (Saddle 3 and 4), (5) a snag retention clearcut (Saddle 5), and (6) a two-story stand (Saddle 6). Subjects rated each stand on a Likert-type scale (e.g., highly favorable rating, moderately favorable rating, unfavorable rating) (Babbie 2001) in terms of 20 attributes, including descriptors such as natural, quiet, colorful, and pleasant smelling. Next, they judged the acceptability of each stand for three qualities: as a scenic landscape, a place to hike, and a place to camp. At the end of the forest visit, subjects rated the importance they had placed on each attribute in making their acceptability judgments.

In the off-site phase of the public perceptions study, comparative judgments of recreation and scenic quality were obtained from 117 Oregon State University students enrolled in lower- and upper-division recreation, education, and anthropology classes during April 1991. Off-site participants were shown slides of three randomly selected views of 12 forest stands subjected to different silvicultural treatments (see Chapter 6, Table 6-1). Respondents rated all 36 scenes for one quality before re-judging the same slides in a different order for the next of 3 qualities.

Respondents were divided into three groups to examine the influence of forest knowledge on acceptability judgments. The first group was read an informational message that described how animals use snags in natural forests. The second group was informed of the rationale behind changing silvicultural practices. The third group was not read a message and began rating the scenes as soon as instructions were given; this group functioned as the control. Each group viewed slides during different sessions that were identical in all respects expect for the informational message.

Adjacent Landowners Study

Scenery is most often viewed from a place other than the scene itself. Consequently, the possibility of scenic views may increase the value of neighboring property. This study was designed to determine homeowner willingness to pay for the maintenance of scenic forest views.

Survey individuals identified for this study were landowners living adjacent to McDonald-Dunn Forest or abutting privately owned mature Douglas-fir forests. From a pool of 50 households, 41 adults in 29 households were interviewed at their homes. The interview focus was to gather scenic quality estimates and insight into the willingness of survey participants to pay for a scenic easement. Other questions explored landowner knowledge about McDonald-Dunn Forest, contact with harvest operations, and perceived change in property values due to harvests. Because individuals surveyed were not randomly selected, these study results may not be applicable to non-respondents, the larger population, or other near-urban forests.

Participating individuals were presented with slides of various silvicultural treatments under two situations and asked to rate the scenery. In the first situation, two slides representing different views were shown for each of the following four silvicultural treatments and viewed in fixed order: (1) patch cut, (2) thinning, (3) clearcut, and (4) two-story. In the second situation, slides of the same silvicultural treatments were altered by computer image capture technology to appear as if they were taken from the backyard of each survey participant. Image capture technology has the potential to communicate visual harvest impact information prior to the event and help mitigate near urban forest conflicts with adjacent landowners.

During the interview, residents were asked if they would be willing to pay for a scenic easement that would protect the forest in their backyard view from clearcutting. Four types of easements were considered, corresponding to the four clearcutting alternatives presented to the participants: original backyard scene, patch cut, two-story stand, and thinned stand. This survey did not seek to find the maximum willingness to pay; instead it used the contingent valuation method (Mitchell and Carson 1989) which assessed whether respondents were willing to pay the annualized value of forgone timber harvest from using practices other than clearcutting. Prices were calculated from the loss of timber value on a 62- by 31-m (200- by 100-ft) buffer, resulting in calculated easement costs of $110/yr to maintain the patch cut, $130/yr for a two-story stand, $190/yr for a thinned stand, and $350/yr for the original backyard scene.

Recreation Study

This study was conducted on the Peavy tract of the McDonald-Dunn Forest prior to and immediately following CFIRP harvest (June through September 1990 and 1991, respectively). This area of the Forest has many residential neighbors, high levels of recreational use, and high visibility from Hwy 99 located in the Willamette Valley below. The CFIRP Peavy harvest covered 11.6% of the Peavy tract land base. Greater than half of the harvest units were visible from Hwy 99. The visual proportion impacted within sight of recreational routes was close to a third of the area; however, only 12.3% of the recreation route lengths were adjacent to a harvest.

Four interview data sets were collected during this study. (1) Visitors were interviewed as they left McDonald-Dunn Forest via one of the Peavy tract exits. (2) These same visitors were mailed a follow-up questionnaire. (3/4) This two-step interview process was repeated with Peavy visitors immediately following harvest. In all, 842 individuals were encountered during the pre-harvest on-site survey in 1990 resulting in a 73.6% response rate (222 non-respondents), and 1244 individuals were encountered post-harvest with an identical response rate (329 non-respondents).

For the on-site survey, respondents were asked to identify their travel pattern on a map of the area. In addition, they were questioned about their recreational activity, visit duration, group composition, and about which scenic features contributed and detracted from their forest experience. The mailback questionnaire asked more in-depth questions concerning patterns of use, preferences for site attributes, management actions, public input, attitudes toward management techniques and performance, and demographics. In 1990, 384 people out of 504 returned their mailback survey (76.2% response rate). In 1991, 467 visitors out of 649 participated (71.9% response rate). No particular activity group (e.g., hiker, biker, equestrian) represented in the on-site surveys disproportionately responded to the mailback questionnaire.

Data Management

CFIRP is a complex long-term project involving many investigators from diverse fields collecting both qualitative and quantitative data. Vegetation and wildlife quantitative data collected on permanent plots during the studies presented in this volume are archived in the Oregon State University College of Forestry Databank using standard metadata to document data sets. Data have been proofed and documented, and they are accessible to future researchers upon request to the databank manager.

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Chapter 3. Harvest and Economics Research

Loren D. Kellogg and Ginger V. Milota

Research Strategy

The task of physically implementing selection harvest systems in a safe and productive manner has raised many questions concerning their viability. Currently, there is limited information regarding actual logging planning, felling, and yarding costs for these approaches. Clearcutting has been compared to alternative silvicultural treatments including group selection in research studies in California (Atkinson and Hall 1963, 1966; McDonald 1965), the Pacific Northwest (Dykstra 1976; Kellogg et al. 1991; Bennett 1993), the Intermountain region of the United States (Gardner 1980), and North Carolina (Campbell and Sherar 1991). However, an important limitation of many of these studies is that accurate comparisons between treatments are not possible because of varied data collection methods as well as different site, stand, and logging conditions among treatments.

We compared cost differences between clearcutting and alternative silvicultural treatments on the Peavy and Dunn CFIRP replications. In our studies, site, stand, and logging conditions were either similar or normalized in the analysis, and the data collection methods were identical among treatments for each replication.

Objectives of the first harvest study were to

(1) Identify logging planning and field layout requirements plus costs for ground skidding and cable logging systems on the three basic silvicultural treatments (clearcut, two-story, small patch) on the Peavy replication.

(2) Determine the logging production and costs of ground skidding and cable logging systems for each of the three silvicultural treatments.

Objectives of the second harvest study were to

(1) Identify logging planning and field layout requirements of a cable logging system in the Dunn replication for five silvicultural treatments (modified clearcut, small patch, large patch, wedge, strip) and two skyline road patterns (parallel and fan) representing six treatment combinations (see Chapter 2).

(2) Compare the following for a cable logging system on the six treatment combinations: planning time and costs; felling production and costs; yarding production and costs; road and/or landing change time and costs; total costs for planning, felling, yarding, and road changes.

Objectives of the snag economics study were to

(1) Determine costs associated with snag creation in the basic CFIRP silvicultural treatments.

(2) Determine timber revenue foregone from the creation of snags from green trees.

Harvesting equipment

Ground skidding was conducted on terrain that was primarily less than 30% slope. Designated skid trails, spaced approximately 46 m (150 ft) apart, were laid out prior to felling and used for skidding in the two-story and group-selection treatments. In the clearcut treatment, designated skid trails were not utilized and skidding was completed primarily with a John Deere 648 grapple skidder. The grapple skidder was also used in the group-selection treatment, and for skidding logs located on designated trails in the two-story stand treatment. An FMC 220 and FMC 210 with a winch were used for pulling logs to the skid trails and skidding into the landing for other felled trees in the two-story stand. The FMCs were also used occasionally on steep portions of other units.

Uphill cable yarding was completed on units where a significant portion of the terrain was greater than 30% slope. Skyline roads (spaced approximately 60–76 m [200–250 ft]) were laid out prior to felling and used for cable yarding in the two-story stand and group-selection treatments. In the clearcut treatment, the logger selected skyline roads during the logging operation.

In the Peavy replication, cable yarding was completed with a Thunderbird (TTY-50) mobile yarder in all three silviculture treatments. Four operating lines were used for the standing skyline system with a mechanical slackpulling carriage (MSP). The MSP skyline carriage allowed for lateral yarding distances up to approximately 38 m (125 ft) on each side of the skyline. A haulback line was used for outhaul. All skyline roads were logged as a single span; some required tail trees to obtain necessary log lift and skyline deflection.

In the Dunn replication, cable yarding was completed with a similar system as the Peavy replication. A slightly larger mobile yarder (Thunderbird TTY-70) was rigged in a standing skyline system with a haulback line for outhaul. The skyline carriage used was a Danebo S-35 drum-lock mechanical slackpulling carriage with slack for the dropline in the carriage being pulled from the yarder. Single span skylines were rigged; many required tailtrees for needed log lift and skyline deflection.

The harvest planning and field layout for all treatments will allow for the use of similar ground skidding and cable yarding equipment and logging methods with future harvest entries.

Research Findings

Silvicultural Treatment

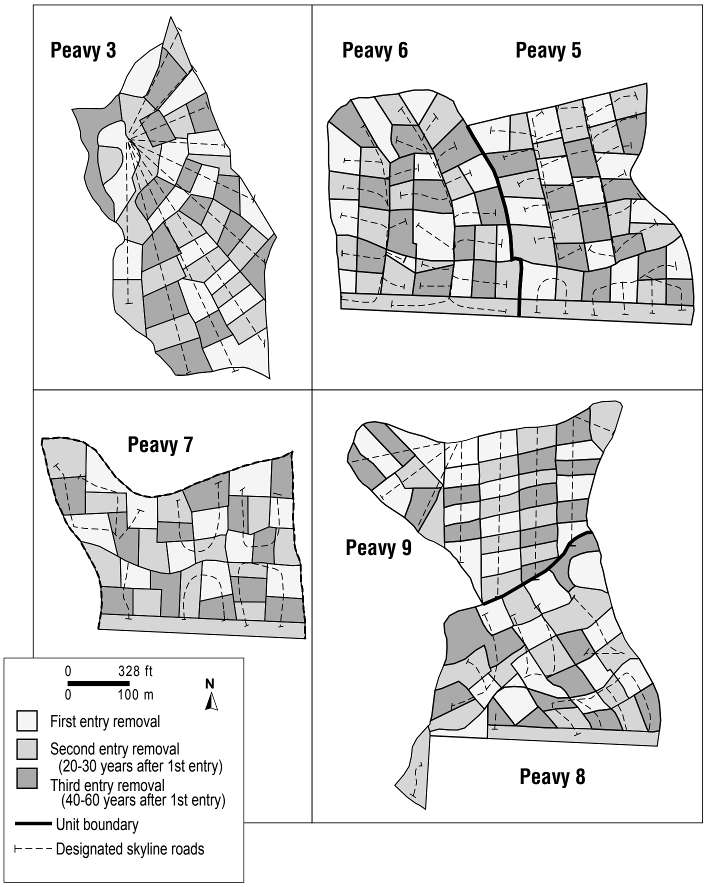

Figure 3-1. Logging layout and landing locations for the six small patch cuts in the Peavy replication. (Modified from Kellogg et al. 1996).

For both Peavy and Dunn replications, initial harvest planning and field layout activities were two to seven times higher (in hours per hectare or acre) for the various selection systems compared with clearcutting (Figures 3-1 and 3-2). However, the cost of planning activities was relatively low, ranging from 1.9 to 8.4% of total harvesting costs (in $/Mbf). The intensive engineering efforts during planning contributed to keeping felling and skidding/yarding costs down in selection systems compared with clearcutting.

Total harvesting costs for both harvest studies are presented in Figure 3-3. Group selection treatments cost 2.5% more and two-story harvest cost 16% more than clearcutting on terrain that allowed for ground skidding (Kellogg et al. 1991). On steeper cable ground, two-story harvest cost 25% more than clearcutting. Cost increases for cable logging the various group selection treatments ranged from 7 to 32%: 7% higher on wedge cuts, 16% higher on strip cuts, 18% higher in small patch cuts with parallel skyline roads, 22% higher in large patch cuts with fan skyline roads, and 32% higher in small patch cuts with fan skyline roads (Kellogg et al. 1991; Edwards 1992; Kellogg et al. 1996).

On the Dunn replication, felling and yarding costs differed little among clearcutting and the five group-selection treatment combinations. However, the cost of skyline road and landing changes varied greatly. Three aspects involved with changing skyline roads or landings were important: (1) the time required to make the change, (2) the number of changes required for a harvest unit, and (3) the volume harvested between changes (Kellogg et al. 1996). Road/landing change time was greater in the parallel road settings because with each road change there was also a landing change. Units with smaller harvest patch sizes generally showed increased time due to corridor obstructions and yarder-to-tailhold/tailtree alignment problems during road changes.

The harvest cost for the small patch stand with parallel skyline roads (Dunn 7) was approximately 50% lower than that of the small patch stand with fan roads (Dunn 11), even though road/landing change time was longer in the former unit. This was because the parallel unit required only two roads compared to the six roads in the fan. Approximately the same volume was removed from both stands. The wedge unit was the least costly treatment because it

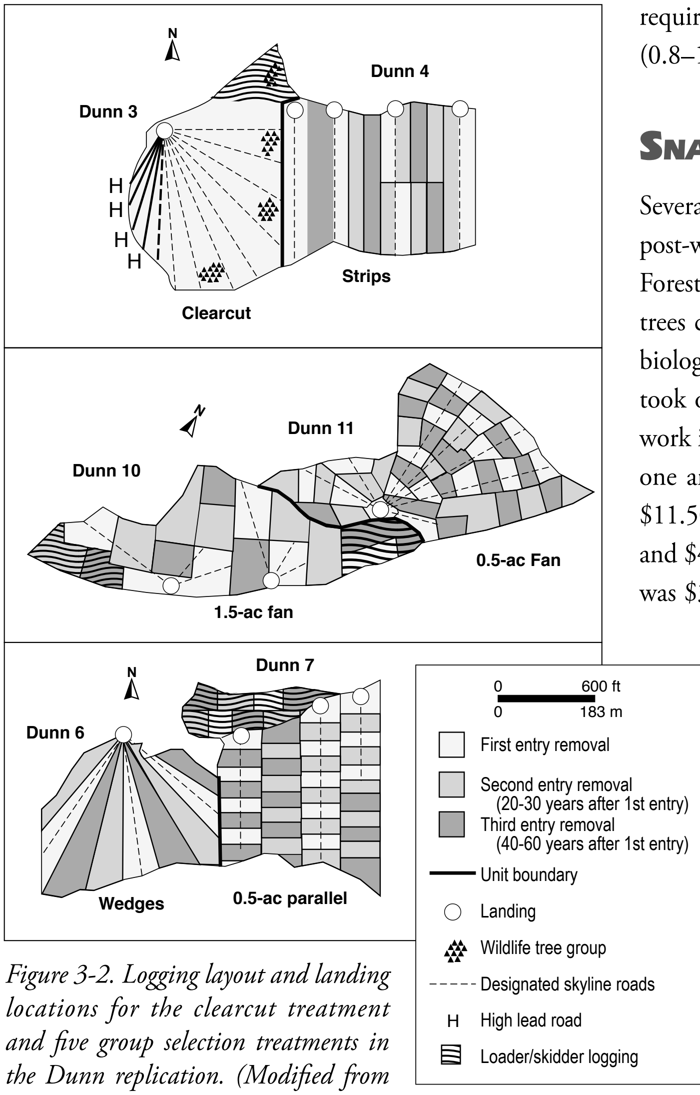

Figure 3-2. Logging layout and landing locations for the clearcut treatment and five group selection treatments in the Dunn replication. (Modified from Kellogg et al. 1996).

required only two road changes and had a relatively large patch size (0.8–1.2 ha or 2–3 ac).

Snag Treatments

Several components went into the cost of snag creation: (1) pre- and post-work by wildlife biologists, (2) contract administration by College Forests staff, (3) the contract price to top trees, and (4) the value of trees converted to snags instead of sold timber. Pre-work by wildlife biologists included the selection, marking, and mapping of snags; this took one person per day per unit regardless of treatment type. Post-work included baseline monitoring of snag characteristics, which took one and a half person-days per unit. These costs were calculated at $11.50 per person per hour and amounted to $2760 for the pre-work and $4140 for the post-work. The total contract cost for topping trees was $33,101. The cost per tree averaged $35, with a range of $27 to $45 per tree. The total volume of trees converted to snags was 1530 Mbf (Table 3-1). At a conservative stumpage of $300/Mbf, the value of timber revenue foregone from the snags was $459,000. Adding the cost of all these components together, the total cost for snag creation was approximately $500,000 or $1730 per hectare ($700 per acre). The value of the wood left on site as snags was 92% of the total cost, and the cost for selection and topping was 8%.

Management Implications

Compared to clearcutting, there was a range of increased harvesting costs for two-story and the variety of group-selec-

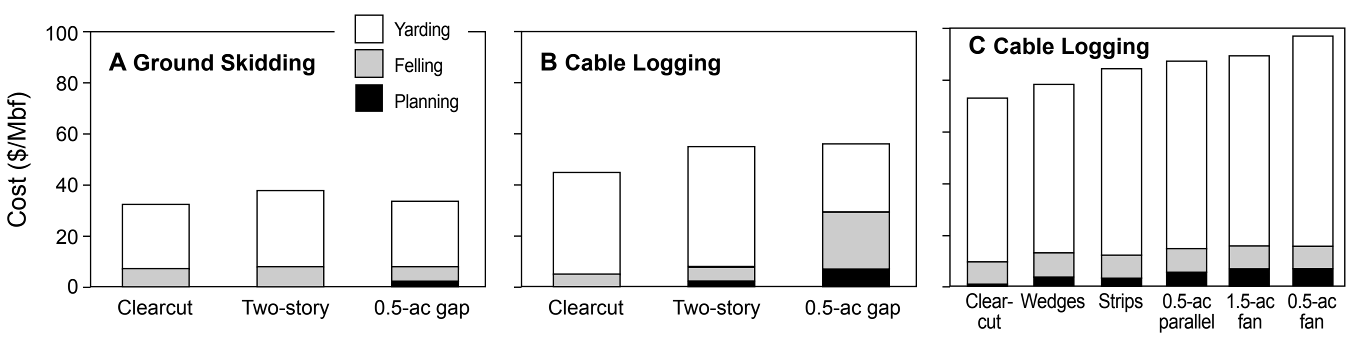

Figure 3-3. Total harvesting costs for CFIRP treatments: (A) ground skidding at Peavy replication; (B) cable logging at Peavy replication; and (C) cable logging at Dunn replication. Yarding costs at Dunn include logging equipment move in, move out, set up, and tear down; these costs were not included at Peavy. A larger yarder was used at Dunn than Peavy. Harvesting costs for both replications do not include profit and risk allowances, or hauling costs. (Modified from Kellogg et al. 1996.)

Table 3-1. Snag characteristics by CFIRP replication.

	Replication					
	Saddle		Peavy		Dunn	
Total number of snags	317		285		350	
Acreage of replication in ha (ac)	100	(248)	79	(194)	104	(258)
Snags per ha (ac)	3.2	(1.3)	3.6	(1.5)	3.4	(1.4)
Average dbh in cm (in.)	115.6	(45.5)	107.4	(42.3)	90.2	(35.5)
Average height in m (ft) before topping	52	(171)	51	(168)	46	(150)
Estimated volume per replication (Mbf)	511	421	598			

tion treatments examined in CFIRP. On mild terrain that allowed ground skidding, costs of group-selection treatments were 2.5% higher while two-story was 16% higher than clearcutting. On steeper cable ground, 0.8- to 1.2-ha (2- to 3-ac) wedges with a centralized landing and fan skyline roads were the least expensive to harvest (7% more than clearcutting); group-selection patches with fan skyline roads were the most expensive to harvest (32% more than clearcutting). This range reflects the increasing complexity of yarding various types of group-selection treatments, depending on the size and arrangement of patches and how quickly skyline road and landing changes can be made.

Several special considerations are required for harvesting the various selection systems compared to clearcutting. First, logging planning, including designated skid trails and skyline roads, needs to be done not only for the initial harvesting entry, but for future entries as well, so that future openings can be harvested without destroying previously planted openings. Second, the location of wildlife snags needs to be considered relative to future felling, skidding, and yarding activities. Snags can potentially be hazardous to workers during future harvesting activities. Third, future felling entries will most likely require more directional felling and limited options for tree lays in order to avoid felling large trees into patches of small trees. In the small patch treatment, some damage to small trees in replanted patches will occur because tall trees felled in the second and third entries cannot be contained therein. Fourth, it is important in cable yarding to leave trees in appropriate locations for future guyline and tailhold anchors. In some situations, tailtrees can be protected during the first logging entry by using rigging gear such as tree plates or nylon straps. Even with this level of planning, future entries may involve more costly alternative anchors such as buried logs or substitute earth anchors (Prellwitz 1978; Copstead and Studier 1990).

Future Research Needs

As demonstrated by the CFIRP harvest results, a number of different topics must be addressed to fully evaluate the feasibility of employing alternative silvicultural treatments. From a timber harvesting perspective, harvest planning and logging operations must be sound in several areas including environmental impacts, economics, logging system feasibility, and worker safety. Successful harvesting in CFIRP resulted from interactions between different forest resource management specialists and detailed harvest planning. An example of harvesting topic interactions included the design of group-selection openings and snag recruitment locations. These interactions provided for a more complete evaluation of the many factors that forest resource managers must consider when deciding among alternative silvicultural treatments.

A key ingredient for the success of CFIRP was that individual research leaders were open-minded and flexible with regard to other ideas and constraints outside of their main area of expertise. The research undertaken in CFIRP required collaboration and compromise among all disciplines involved in the project.

Results from CFIRP research demonstrates that there is a need to expand our knowledge about the effectiveness of alternative group-selection treatments covering a range of opening sizes and a variety of patch designs (shape and spatial location on the landscape). In CFIRP, we found that relatively small openings (0.2 ha [0.5 ac] or less) require a considerable amount of detailed harvest planning to be accomplished effectively, especially when the first entry planning effort includes considerations for future harvesting entries. It may be difficult, if not impossible, to carry out these efforts outside of a controlled research setting and to duplicate procedures on relatively large operational scales. There are harvest planning and logging efficiencies associated with relatively larger group openings. A group-selection system with larger openings effectively designed on the landscape may still meet certain forest resource management objectives for wildlife and visual quality.

Our research and other experiences with alternative silvicultural treatments involving various forms of partial harvesting have shown that the first entry harvesting can be effectively accomplished. However, future multi-story forest structures will present the most challenging harvesting conditions with questions regarding forest resource protection (e.g., residual tree damage), harvesting economics, logging feasibility, and worker safety. Research is needed now to begin answering questions regarding future harvesting entries in stands with complex forest structure characteristics. The size and pattern of openings in the group-selection system should be included as part of these research efforts.

Acknowledgments

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Chapter 4. Early Douglas-fir, Grand fir, and Plant Community Responses to Modified Clearcut, Two-story, and Small Patch Cut Silvicultural Treatments

J. Scott Ketchum and John C. Tappeiner

In the coastal forests of Oregon, the traditional method of timber management is clearcutting and subsequent regeneration of conifers. After harvest, typically the site undergoes herbicide application, mechanical scarification or burning, or a combination of these treatments to ensure a favorable environment for planted seedlings. These harvest and regeneration procedures are quite efficient, but there is growing concern over their effects on biodiversity and other non-timber management objectives.

Common coastal forest disturbances include fire, plant competition, disease, insects, slope failures, and windthrow. Disturbance occurs at a variety of frequencies, intensities, and spatial scales, but generally only fire is a stand-replacing event. It is hypothesized that plants and animals in coastal forests have adapted tolerances to these disturbances. These adaptations ultimately ensure the continual presence of a diversity of species in Oregon coastal forests.

Plant Community Response to Harvesting

If a forest management goal is to maintain biodiversity, an understanding of how plant species respond to stand treatments and to post-harvest vegetation control is fundamental. Most shrub species found in coastal forests of Oregon, such as vine maple (*Acer circinatum*), hazel (*Corylus cornuta*), salal (*Gaultheria shallon*), thimble berry (*Rubus parviflorus*), snowberry (*Symphoricarpos albus*), and bracken fern (*Pteridium aquilinium*), all sprout, persist, or expand after harvest or other disturbance.

There is evidence that many native herbaceous forest species survive clearcutting and burning and remain part of the post-harvest plant community (Dyrness 1973; Halpern and Spies 1995; Bailey et al. 1998). Some species can withstand these severe disturbances because of below-ground buds (Antos and Zobel 1984). However, the effects of alternative silvicultural treatments and vegetation control on these native species are unknown (Loucks and Harrington 1991). Similarly, although exotic species are playing an increasingly important role in early succession of disturbed sites, there is little documentation of their response to the range of silvicultural options available for coastal Oregon forests.

Conifer Regeneration

Tree regeneration is a major goal of most silvicultural operations. Federal and state laws require that trees be replaced promptly after clearcutting. Even in partially cut stands, regeneration is important for the development of multi-story structures if stands are managed to produce old-growth characteristics (Tappeiner et al. 1992). In these situations, foresters must adapt regeneration techniques used in clearcuts for regeneration in small openings or in understory conditions. This probably will involve use of shade-tolerant species such as grand fir (*Abies grandis*) coupled with the less shade-tolerant Douglas-fir (*Pseudotsuga menziesii*) (Brandeis 1999). In addition, successful regeneration, as in clearcuts, may be dependent on the control of competing herbs, shrubs, and hardwoods (Walstad and Kurch 1987; Hobbs et al. 1992). At the time of the CFIRP vegetation studies, no direct comparison of the regeneration potential of these two species on alternatively harvested sites had been made, nor was it known to what extent vegetation control would impact conifer establishment.

Similar to artificial regeneration, whether natural regeneration in the relatively shady environments created by partial cutting will occur at desirable levels is subject to debate. Isaac (1956) found that establishment of naturally seeded Douglas-fir in partially cut stands was highly unpredictable; this and other concerns led him to recommend clearcutting and even-aged management. However, Williamson (1973) found that the shelterwood method could be used to regenerate Douglas-fir stands provided that there was adequate site preparation and control of herbs and shrubs. Others have found that conifer regeneration often occurs naturally following stand thinning (Bailey and Tappeiner 1998). These varied findings suggest that further research is needed to determine under what stand conditions natural regeneration will be a feasible restocking option.

Research Strategy

Objectives of the CFIRP vegetation studies were as follows:

(1) To examine (from an operational perspective) the effects of modified clearcut, two-story, and small patch cut silvicultural treatments (see Chapter 2) on plant species composition.

(2) To evaluate the success of artificial and natural regeneration of Douglas-fir and grand fir under the three silvicultural treatments.

(3) To compare the combined effects of four vegetation management treatments (see Chapter 2) and the three silvicultural treatments on plant community composition and conifer regeneration.

All plant species encountered during this study are listed in Appendix C.

Research Findings

Plant Community Responses

Silvicultural Treatments

Silvicultural treatment had little influence on the summed cover (the sum of all individual plant cover values; can equal >100%) of understory vegetation cover across study sites; however, the bare-ground percentage was slightly greater in the two-story and control stands versus modified clearcut and small patch stands (Table 4-1). Percent cover up to 2 yr following harvest was similar to pre-harvest conditions estimated from control stands; yet, the relative contribution of some species groups to percent cover changed dramatically following harvest. Annual herbs, both native and exotic, increased across all silvicultural treatments; conversely, native perennial herbs decreased. Exotic perennial herbs increased significantly, but only in small patch stands. Neither native nor exotic grasses responded to harvest. Exotics accounted for half of the most common herbaceous and grass species following harvest.

Table 4-1. Percent cover of plants by physiographic and native versus exotic groupings.[1]

Vegetation management				Silvicultural treatment[2]		
Plant group	No treatment	Herbicide	Control	Clearcut	Two-story	Small patch
Native grasses	17a	6b	14a	18a	17a	17a
Exotic grasses	8a	4a	3a	9a	7a	3a
Total grass cover	26a	10b	16a	27a	24a	27a
Native annual herbs	32a	23b*	6a	31b	30b	36b
Exotic annual herbs	20a	12b*	1a	29b	21bc	9c
Total annual herb cover	52a	36b	6a	60b	51b	45b
Native perennial herbs	16a	9b	27a	19b	16b	13b
Exotic perennial herbs	4a	4a	0a	3ab	3ab	5b
Total perennial herb cover	20a	12b	27a	21a	19a	18a
Native shrubs	71a	70a	89a	62a	73a	76a
Exotic shrubs	1a	1a	0a	1a	1a	1a
Total shrub cover	72a	71a	89a	63a	74a	77a
Total native species cover	137a	107b	135a	130a	136a	142a
Total exotic species cover	33a	21b*	3a	41b	31b	25b
Bare ground percent	7a	14b	13a	6b	11a	5b
Summed cover[3]	185a	144b	171a	183a	190a	182a

[1] Means associated with similar letters within a row by vegetation management or silvicultural treatment are not significantly different at $P \leq 0.05$; * denotes a difference at $P \leq 0.1$.

[2] Silvicultural treatment comparisons are among sample plots (n = 9) not subject to vegetation management.

[3] Summed cover is the sum of all individual plant covers and can be greater than 100% due to overlapping of foliage from one species to another.

Three native herb species found in control stands were not found in any of the harvest units; these included: Menzies' larkspur (*Delphinium menziesii*), western rattlesnake-plantain (*Goodyera oblongifolia*), and Oregon bigroot (*Marah oreganus*). In contrast, several species found in harvested units were not found in control stands. Some of the most prevalent were: wood groundsel (*Senicio sylvaticus*), small-flowered nemophilia (*Nemophilia parviflora*), prickly lettuce (*Lactuca serriola*), common St. Johns' wort (*Hypericum perforatum*), tall annual willow-herb (*Epilobium paniculatum*), wild carrot (*Dacus carrota*), and pearly everlasting (*Anaphalis margaritacea*). No differences were found in silvicultural treatment response of herbaceous species associated with mature forests. Inside-out-flower (*Vancouveria hexandra*), vanilla leaf (*Achlys triphylla*), western starflower (*Trientalis latifolia),* pathfinder (*Adenocaulon bicolor*), star-flowered Solomon's seal (*Smilacina stellata*), trillium (*Trillium ovatum*), and stream violet (*Viola glabella*) are all herbs associated with mature forest (Spies 1991; Thomas et al. 1993). Each of these species occurred in control stands in all three CFIRP location replicates, and each persisted following harvest regardless of treatment. However, pathfinder, vanilla leaf, inside-out-flower, star-flowered Solomon's seal, and stream violet accounted for less cover (0.06%–1.7%) in harvested sites than in control stands (2.2%–5.4%). Starflower and trillium cover were unaffected by harvest.

Exotic annual herbs was the only physiognomic grouping that showed strong ties to silvicultural treatment. Exotic annuals were poorly represented in control stands, their cover increased to over 20% in clearcut and two-story stands, and to about 10% in small patch stands. The less intense invasion of exotic annuals into the cut patches may be the result of a lower degree of soil disturbance associated with the small patch treatment versus clearcut and two-story treatments. Additionally, the matrix of mature trees surrounding cut patches may function as a barrier to the spread of weedy exotic seeds from off-site sources.

Of the three general physiognomic groupings examined (grass, herbs, shrubs), shrubs were least impacted by silvicultural treatment. The predominant shrub species (all native) in control stands were trailing blackberry (*Rubus ursinus*), hazel, and western swordfern (*Polysticum munitum*); these same species were common in harvested stands. In addition, identical shrub species were found in both unharvested and harvested stands suggesting that silvicultural treatment had little influence on the composition of the shrub community.

Results Overview

Although understory vegetation cover returned to pre-harvest levels or greater within the first year after harvest, species composition changed markedly. Regardless of silvicultural treatment (clearcut, patch cut, two-story stand), exotic species increased while native herbs and shrubs decreased. Among the physiognomic groupings, annual herbs demonstrated the greatest increase in cover between unharvested and harvested stands, representing a four- to five-fold increase depending on silvicultural treatment. Annual herbaceous species tend towards weediness and they often require ground disturbance for establishment and moderate levels of light for seed production. Timber harvest provides these conditions. Contrary to annuals, perennial herbs in general are more tolerant of a range of environmental conditions (Grimes 1979), and many can withstand low light situations. Others rely on vegetative reproduction to increase their relative importance. However, perennial herbs do not reestablish as quickly as weedy annuals following disturbance. This observation was supported in the CFIRP study, as perennial herb cover was lower in harvested areas compared with controls.

If only species native to the study region are examined, their combined cover was unaffected by silvicultural treatments; conversely, cover of exotic species was greatly enhanced. Most of the exotic species in this study tend to be weedy in nature and are capable of taking immediate advantage of resources provided by harvest disturbance. Of the exotics, annual herbs increase the most in response to harvest, followed by invasive grasses. Exotic shrubs and perennial herbs play a minor role either pre- or post-harvest.

Herbicide Treatment

Herbicide treatment decreased summed cover and increased the bare-ground percentage (Table 4-1). Decreases were evident in all physiognomic groups examined except shrubs. This finding was not surprising, as herbs and grasses were the targets of the herbicide treatments. In general, herbicides reduced cover of the various physiognomic groups by 30 to 50% compared to untreated plots. Conversely, in addition to new germinants, shrubs tended to resprout from buds at the stem base or to increase in number via stolon growth, as in trailing blackberry.

Despite a reduction in cover overall, it is important to note that herbicide treatment did not impact the presence of native herbaceous species associated with mature forests; inside-out-flower, vanilla leaf, western starflower, pathfinder, star-flowered Solomon's seal, trillium, and stream violet all were present in both herbicide and non-herbicide treated plots.

Table 4-2. Mean characteristics of 2- to 3-yr-old Douglas-fir and grand fir seedlings (sampled fall 1993) across CFIRP vegetation control treatments.

	Vegetation management treatment			
	Herbicide	Manual	Intensive	None
Mortality (%)				
Douglas-fir	15.5ab	8.3a	10.5a	21.0b
Grand fir	19.0ab	12.8a	14.9ab	23.0b
Browse (%)				
Douglas-fir	47.5c	33.0b	5.2a	36.2b
Grand fir	3.3b	3.2b	0.6a	1.7ab
Stem volume (cm^3 / in^3)				
Douglas-fir	79.0 / 4.8a	86.5 / 5.3a	102.5 / 6.3b	74.4 / 4.6a
Grand fir	75.2 / 4.6b	86.5 / 5.3b	71.5 / 4.4b	45.6 / 2.8a
Height/diameter ratio				
Douglas-fir	52.5a	55.7b	60.3c	64.1d
Grand fir	54.7a	54.4a	57.0a	65.6b

Note: Data were pooled across three silvicultural treatments: modified clearcut, two-story, small patch cut. Means associated with similar letters within a row are not significantly different at $P \leq 0.05$.

Artificial Regeneration

No interactions were found between silvicultural and vegetation management treatments, thus, data were pooled across vegetation treatments for silvicultural treatment analysis. The following is an overview of seedling attributes for both the 1993 and 1995 measurement periods, and it should be noted that seedling characteristics had a large range in variability within all treatments relative to sample size.

Seedling mortality

Douglas-fir and grand fir mortality averaged 14% and 16%, respectively, across vegetation management treatments 2–3 yr after planting (Table 4-2). Mortality was highest for both species in non-treated plots and lowest in manual-treated plots.

Browse

Douglas-fir seedlings were browsed most heavily in herbicide-treated plots and considerably less in intensive-treated plots when sampled in 1993. One of the main attributes of the intensive treatment was the use of vexar tubing to prevent early deer browse damage. Grand fir was not often selected as forage, and overall it was browsed 93% less than Douglas-fir. The greatest levels of grand fir browse were only 3% in both manual and herbicide treatments.

Stem Volume

Two to three years after planting, only the intensive vegetation treatment yielded a stem volume increase (38%) over controls in Douglas-fir; for grand fir, growth increased beyond controls under all vegetation management treatments, although there were no differences among treatments (Table 4-2). Four to five years post-harvest, there were no significant differences in stem volume among silvicultural treatments or between herbicide and intensive vegetation management treatments (Table 4-3).

Table 4-3. Mean characteristics of resampled (Fall 1995) Douglas-fir and grand fir seedlings in response to three silvicultural and two vegetation management treatments.

	Seedling characteristics [1]			
	Height (cm/in)	Diameter (cm/in.) [2]	Height/diameter ratio	Stem volume ($cm^3/in.^3$)
Douglas-fir (*Pseudotsuga menziesii*)				
Silvicultural treatment				
Clearcut	139 / 56.3a	2.52 / 1.02a	58.2a	463 / 28.2a
Two-story	156 / 63.2a	2.50 / 1.02a	64.0ab	450 / 27.4a
Small patch	126 / 51.0a	1.87 / 0.76b*	68.3b	176 / 10.7a
Vegetation management treatment				
Herbicide	135 / 54.7a	2.23 / 0.90a	63.8a	339 / 20.7a
Intensive	145 / 58.7b*	2.37 / 0.96b*	63.2a	387 / 23.6a
Grand fir (*Abies grandis*)				
Harvest treatment				
Clearcut	109 / 44.1a	2.12 / 0.86a	54.5a	196 / 12.0a
Two-story	130 / 52.6a	2.23 / 0.90a	61.3b	268 / 16.3a
Small patch	125 / 50.6a	2.04 / 0.83a	63.7b	204 / 12.4a
Silvicultural management treatment				
Herbicide	120 / 48.6a	2.11 / 0.85a	59.9a	216 / 13.2a
Intensive	123 / 49.8a	2.15 / 0.87a	59.5a	230 / 14.0a

[1] Data are from 4- and 5-yr-old artificially regenerated seedlings. Means followed by the same letter within species by treatment groupings are not significantly different at $P \leq 0.05$; * denotes a difference at $P \leq 0.01$.

[2] Measured at 10 cm (4 in.).

Height and Diameter

Four to five years post-harvest, the ratio of height to diameter (H/D) for both Douglas-fir and grand fir progressively increased from clearcuts through two-story and small patch stands, although no height or diameter differences were observed (Table 4-3).

The H/D of Douglas-fir differed across all four vegetation management treatments 2–3 yr after planting. H/D was greatest under the no-herbicide treatment situation and decreased incrementally from intensive, through manual, and finally herbicide treatments (Table 4-2). Grand fir H/D also was highest in control plots, but H/D among the remaining treatments did not differ (Table 4-2).

Results Overview

Conifers were successfully regenerated under all three of the CFIRP silvicultural treatments. In general, Douglas-fir regeneration in modified clearcut and two-story stands was greater than in the small patch cuts. This trend is likely to continue, because as mature trees bordering the 0.2-ha (0.5-ac) patches continue to grow, they will increase the level of competition felt by regenerating trees. This will result in reduced growth of regenerating trees relative to trees in the other treatments. In contrast, trees regenerating in clearcuts will eventually be the tallest competitors on site, and they will compete principally with each other. Operational considerations also may influence regeneration growth across treatments. For example, herbicide treatments in small patch and two-story stands were administered as 0.9-m (3-ft) radius spot applications instead of broadcast applications as in clearcuts. Spot application is not as effective at promoting seedling growth (Rose et al. 1999), and it may have contributed to some of the growth differences noted among silvicultural treatments.

The 20 to 30 mature trees left per hectare (8 to 12 trees/acre) in two-story stands following harvest, are not expected to offer appreciable competition to regenerating seedlings. In fact, several of the original leave trees have died since harvest, either from Douglas-fir bark beetle (*Dendroctonous pseudotsugae*) attack or wind-throw, and these mortalities have reduced overstory impacts on regeneration even more. Douglas-fir H/D in the two-story stands was higher than for clearcuts. H/D is a reasonably good predictor of future growth and past competition for light and other resources (Cole and Newton 1986; Hughes and Tappeiner 1990; Rose et al. 1999; Opio et al. 2000). The long-term implications of an elevated H/D in two-story stands is not fully understood, but suggests that future growth may be less than in clearcuts.

Grand fir regeneration was less affected by silvicultural treatment than Douglas-fir. Although growth across silvicultural treatments was similar, as with Douglas-fir, H/D was higher under the two-story versus other silvicultural treatments. The long-term implication of current H/D values is debatable, as little is known about how H/D reflects past and future growth of shade tolerant species such as grand fir. It is the shade tolerant nature of grand fir, however, that may partially explain its failure to respond differentially to the three types of silvicultural treatment. Additionally, because grand fir did not grow significantly better than Douglas-fir in the small patch cuts, it is difficult to make the argument for planting grand fir if maximizing volume gain is a management priority.

Loss of the no-vegetation-management controls in clearcuts in 1994 limits our ability to address more than immediate seedling response to vegetation management. The early results suggest that vegetation control enhanced both Douglas-fir and grand fir survival and growth regardless of silvicultural treatment. The limited difference in growth across the three vegetation control treatments suggests that all had roughly equal levels of vegetation control efficacy. The observed positive effect of weed control on seedling growth is not a novel finding (see Stewart et al. 1984; Loucks and Harrington 1991; Loucks et al. 1996).

Despite the significant reduction in browsing resulting from use of vexar tubing seedling protectors in the intensive treatment, reduced browse did not translate into reduced mortality (Table

4-2). However, for Douglas-fir, the significant reduction in browsing likely contributed to the significant stem-volume increase for seedlings receiving the intensive treatment, because non-browsed seedlings tend to be taller than browsed seedlings. The impact of taller non-browsed seedlings also is reflected in the higher H/D of intensively treated seedling. Although we expect the best growing trees to have the smallest H/D, smaller stature in manual and herbicide treated seedlings often was the result of browse of the terminal shoot. By the second measurement period in 1995, regenerated trees largely had grown above deer browse level, and the growth gap between intensive versus herbicide treated seedlings had narrowed.

Because grand fir faced little browse pressure, use of vexar tubing in conjunction with herbicides in the intensive treatment did not increase survival or growth beyond that realized under the vegetation or manual treatments. Thus vexar tubing was an unnecessary protection for grand fir seedlings.

It was somewhat surprising to document enhanced seedling growth in response to the vegetation control treatments given the small decrease in absolute and summed cover (a reduction of 8% and 22%, respectively) resulting from herbicide treatment (Table 4-1). Enhanced survivorship is often the most responsive factor when vegetation competition is slightly lowered, but enhanced growth generally is not observed until low levels of competition are reached (Wagner and Radosevich 1991).

Natural Regeneration

Seed Fall

From personal observations and comparisons to other seed collections (Williamson 1973) it was determined that 1991-92 was a moderate to good seed year. Seeds from three tree species were found in the seed traps: Douglas-fir, grand fir, and big leaf maple (*Acer macrophyllum*). Total seed fall per hectare (per acre) was extrapolated from the seed data (Table 4-4). As expected, Douglas-fir seed was least available in clearcut stands. Grand fir and big leaf maple seed abundance, however, did not differ among silvicultural treatments.

Table 4-4. Tree seed fall estimated across silvicultural treatments from seed trap data.

	Seeds/ha (ac) by silvicultural treatment [1]		
Species	Clearcut	Two-story	Small patch
Douglas-fir	76,000 (30,770)a	187,000 (75,710)b	250,000 (101,210)b
Grand fir	18,000 (7,290)a	33,000 (13,360)a	23,000 (9,310)a
Bigleaf maple	2000 (810)a	500 (200)a	4,000 (1,620)a

[1] Values associated with similar letters within a row are not significantly different at $P \leq 0.05$.

Natural Seedling Survey

Natural Douglas-fir seedlings were five times more abundant in two-story stands than in clearcuts or small patch cuts (Table 4-5). Douglas-fir stocking was low across all silvicultural treatments, with the lowest stocking in small patch cuts and the highest in two-story stands (Table 4-5). These results suggest that natural regeneration is not a reliable regeneration option for any of the silvicultural treatments examined. The 227 trees/ha (92/ac) found in the

Table 4-5. Natural Douglas-fir stocking and seedling density across CFIRP silvicultural treatments.[1]

Silvicultural treatment	Stocking % [2]	Seedlings per ha (ac) [3]
Clearcut	33a	227 (92)a
Two-story	60b	1045 (423)b
Small patch	16c	227 (92)a

[1] Numbers associated with similar letters within a column are not significantly different at $P \leq 0.05$.

[2] Stocking percentage was calculated as the percent of 22-m^2 (236.7-ft^2) plots (N = 10/treatment) in which naturally regenerated seedlings were found.

[3] Number of seedlings/ha (ac) was extrapolated from the mean number of seedlings located within strip plots.

clearcuts and small patches barely meet Oregon's reforestation stocking requirement. Additionally, these trees are not all free to grow and tend to be clumped in their distribution. The end result will be a poorly stocked stand at maturity that will not be as productive as a planted forest.

Results Overview

Seed fall measures imply that the potential for natural regeneration of Douglas-fir is highest in small patch cuts; however, natural seedling stocking was actually greatest in two-story stands. For Douglas-fir seedlings to successfully establish they need germination safe sites on bare mineral soil (Burns and Honkala 1990). Logging activities disturbed soils in abundance in two-story and clearcut stands, but soil disturbance in the cut patches of small patch cut stands was much less. Thus, although seed availability was high in the 0.2-ha (0.5-ac) patch cuts because of the close proximity of seed-bearing trees, seedling establishment was low. In clearcuts, seed availability was low, but there were abundant bare soil safe sites for establishment. High seed availability and abundant bare soil sites both were present in two-story stands.

Conclusions

It appears that successful regeneration of both Douglas-fir and grand fir can be accomplished in the three CFIRP silvicultural treatments examined: modified clearcut, two-story, and small patch cut. However, because the growth rate of regenerating Douglas-fir was less in patch cuts than in clearcut and two-story stands, land managers should recognize that it will be necessary to continually reduce overstory density to enhance seedling growth in small patch cuts. This will be especially important on shady sites. Conversely, if managers are willing to sacrifice short-term timber volume returns to increase stand level structural diversity, the small patch cut harvest may be a legitimate option. A different type of structural diversity may be achieved with the two-story harvest, and productivity losses will be less.

Neither Douglas-fir nor grand fir seedlings had an early growth advantage under the two-story or small patch cut treatments explored in CFIRP; shade intolerant Douglas-fir maintained an edge in clearcuts. These relationships may change as the stands continue to develop, especially as tree crowns expand in the forest matrix and cast increasing shade onto the small patch cuts.

In regards to the understory plant community, we were unable to demonstrate that any of the three silvicultural treatments enhanced conditions for native species. Conversely, cover of competing exotic species was amplified across all treatments; the single exception occurred in small patch cuts where the invasion of exotic annuals was about 60 to 70% less than in other treatments. It is important to note that our measurements of species cover were made on only a small portion of any one stand and so may not fully represent cover throughout an entire stand.

Vegetation sampling in the study discussed here was conducted soon after harvest and the long-term inferences we are able to make from the data are limited. The trajectory of plant community succession in each of the silvicultural treatments most likely will vary dramatically over time. For instance, some of the less shade tolerant species likely will disappear or have much reduced cover as the canopy of the regeneration closes. However, we were unable to demonstrate that the starting point for the successional trajectories differed significantly among the silvicultural treatments examined. Additionally, most pre-harvest understory species maintained a presence in the post-harvest vegetation community.

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Chapter 5. Wildlife Responses

Carol L. Chambers and Brenda C. McComb

Animals are adapted to specific geographic areas, defined by dominant vegetation and climate. However, the resources that each animal needs to survive and reproduce (food, water, cover) are not distributed equally across its geographic range. Resources vary not only spatially, but also temporally in their availability; they may be present only during certain seasons of the year or they may be more abundant in some years than in others (MacArthur and MacArthur 1961; Roth 1976; Johnson 1980; Block and Brennan 1993; Morrison et al. 1998).

Animals frequently are studied during their breeding season because successful reproduction often reflects high quality habitat (Van Horne 1983). However, winter also may be a period critical for survival because of limited food or cover resources. Given that habitat use varies among seasons for many animals (Cody 1985; Manuwal and Huff 1987), it is important for land managers to provide adequate wildlife resources throughout the year, but particularly during the crucial breeding and winter periods (Morrison et al. 1985).

The task of identifying appropriate habitat across seasons is complicated by changes in the forest ecosystem triggered by human-induced disturbances. A variety of forest management techniques, including but not limited to controlled burning, thinning, even-aged and uneven-aged management, may produce very different effects on vertical structure and the horizontal patchiness in vegetation. Animals respond differentially to these environmental changes depending on the scale, intensity, and type of change, and the adaptability of the species.

In CFIRP, we hypothesized that the degree of timber removal (= disturbance) would precipitate changes in wildlife abundance. We predicted some wildlife species would decline, others would increase, and still others would not respond to the various harvest treatments (Table 5-1). Changes in abundance might occur immediately after harvest or following a lag of several years. Wildlife use might differ among seasons. We proposed that species associated with mature or old-growth forests would most likely decline with timber removal, while early successional species would increase. Species also could respond in direct proportion to the amount of overstory removed, or they might experience density changes only after reaching some disturbance threshold.

Table 5-1. Predicted (when number of observations were < 50) or actual (when number of observations were n ≥ 50) changes in abundance of forest wildlife species captured across four CFIRP harvest treatments.[1]

Common name [2]	Harvest treatment: Control	Group-selection	Two-story	Clearcut	Number of observations
Birds					
Actual response to treatment					
Decrease in response to treatment					
Brown creeper	0	-	- -	- - -	665
Chestnut-backed chickadee	0	+	-	- -	132
Evening grosbeak	0	0	- -	- - -	363
Golden-crowned kinglet	0	0	- - -	- - -	716
Hermit warbler	0	0	- - -	- - -	1641
Pacific-slope flycatcher	0	0	- - -	- - -	852
Red-breasted nuthatch	0	0	- - -	- - -	740
Steller's jay	0	0	- - -	- - -	543
Swainson's thrush	0	-	- - -	- - -	747
Western tanager	0	0	-	- - -	687
Wilson's warbler	0	+	- - -	- - -	1287
Winter wren	0	-	- - -	- - -	1146
Increase in response to treatment					
American goldfinch	0	- -	++	+++	179
Brown-headed cowbird	0	-	+++	+	56
House wren	0	+	+++	+++	462
MacGillivray's warbler	0	+	+++	++	357
Olive-sided flycatcher	0	- -	+++	+++	75
Purple finch	0	+	+++	+	280
Spotted towhee	0	0	+++	+++	575
White-crowned sparrow	0	0	++	+++	645
No detectable response to treatment					
American robin	0	0	0	-	549
Black-headed grosbeak	0	0	0	-	199
Black-throated gray warbler	0	0	0	0	251
Dark-eyed junco	0	0	0	0	1354
Gray jay	0	0	-	-	94
Hairy woodpecker	0	0	0	0	124
Northern flicker	0	0	++	++	83
Orange-crowned warbler	0	0	0	0	550
Red-breasted sapsucker	0	0	0	0	194
Red crossbill	0	0	0	0	166
Predicted response to treatment [3]					
American crow	0	0	+	++	9
Band-tailed pigeon	0	0	+	-	12
Barn swallow	0	0	+	++	1

continued

Table 5-1 continued

Common name [2]	Harvest treatment				Number of observations
	Control	Group-selection	Two-story	Clearcut	
Bewick's wren	0	+	++	++	24
Black-capped chickadee	++	+	-	- -	3
Blue grouse	0	+	-	- -	6
Bushtit	0	0	+	0	34
Cassin's vireo	0	0	-	- -	16
Cedar waxwing	0	0	0	0	22
Chipping sparrow	0	0	+	++	3
Common yellowthroat	0	+	++	++	1
Common raven	0	+	- -	- - -	4
Downy woodpecker	0	+	+	+	14
European starling	0	0	+	++	3
Great-horned owl	0	0	-	- -	3
Hammond's flycatcher	0	+	-	- -	26
Hermit thrush	0	0	- -	- - -	16
Hutton's vireo	0	++	++	-	18
Lazuli bunting	0	0	++	+++	17
Mountain quail	0	+	+++	+++	2
Mourning dove	0	0	+++	+	15
Northern pygmy-owl	0	0	0	-	1
Pileated woodpecker	0	0	-	- - -	27
Pine siskin	0	0	-	- - -	12
Red-tailed hawk	0	+	+++	++	13
Ruffed grouse	0	+	++	+++	15
Rufous hummingbird	0	0	0	0	38
Sharp-shinned hawk	0	+	-	-	1
Song sparrow	0	0	++	++	10
Townsend's warbler	0	0	- -	- - -	25
Tree swallow	0	0	++	++	1
Varied thrush	0	0	- -	- - -	9
Violet-green swallow	0	0	++	+++	19
Warbling vireo	0	0	0	0	6
Western wood-pewee	0	0	++	+++	17
Western bluebird	0	0	++	+++	10
Wild turkey	0	+	++	++	1
Willow flycatcher	0	0	+++	++	30
Mammals					
Actual response to treatment					
Decrease in response to treatment					
Pacific shrew	0	+	-	-	51
Trowbridge's shrew	0	- -	- - -	- - -	334

continued

Table 5-1 continued

Common name [2]	Harvest treatment: Control	Group-selection	Two-story	Clearcut	Number of observations
Increase in response to treatment					
Oregon vole	0	+	+++	+++	180
No detectable response to treatment					
Deer mouse	0	0	0	0	504
Townsend's chipmunk	0	++	+	+	59
Predicted response to treatment					
Coast mole	0	0	- -	- - -	6
Dusky-footed woodrat	0	0	+	++	1
Northern flying squirrel	0	-	- -	- - -	1
Pacific water shrew	0	-	- -	- - -	1
Red tree vole	0	-	- -	- - -	1
Shrew-mole	0	+	- -	- -	10
Townsend's mole	0	0	- -	- -	2
Vagrant shrew	0	0	0	0	17
Western red-backed vole	0	0	- -	- - -	9
Reptiles					
Predicted response to treatment					
Northern alligator lizard	0	+	++	+++	1
Western fence lizard	0	+	++	+++	16
Amphibians					
Predicted response to treatment					
Ensatina salamander	0	0	- -	- - -	5
Pacific tree frog	0	0	++	+++	2
Rough-skinned newt	0	0	-	- -	10

[1] Abundance could increase (+), decrease (-), or remain unaffected (0); the number of symbols represents the intensity of response, with a range from 1 to 3 (most intense).

[2] Data for birds and mammals are from Chambers (1996); data for reptiles and amphibians are from the 1995 coarse woody debris study (see Chapter 2).

[3] Information on known habitat relationships was used to develop predicted changes.

Research Strategy

Abundance and Diversity

We focused on diurnal breeding birds (i.e., birds active during the day, generally excluding large species such as hawks and nocturnal species such as owls) and small mammals to study wildlife responses to the CFIRP silvicultural treatments (see Chapter 2). These animal groups are well suited for investigating stand scale impacts. Birds are conspicuous, well documented, and respond readily to structural changes in habitat (Hagar 1960; Mannan and Meslow 1984); small mammals are closely linked with understory structure and microhabitat features such as coarse woody debris (Dueser and Shugart 1978). Although amphibians, reptiles, and mule deer also were encountered during the study, they were excluded from analysis because of small sample sizes or because their home ranges were much larger than stand sizes used in CFIRP. Appendix D lists all of the animal species observed during the CFIRP wildlife studies.

Indices of abundance, species richness, and community similarity (Brower et al. 1990) were used to compare animal groups among CFIRP treatments. Avian use of the various treatments also was compared between breeding and winter seasons. Analyses were restricted to species with home ranges small enough to be included within the managed stands. For most species, home ranges were large enough to incorporate disturbances created by the small openings (0.2 ha [0.5 ac]) harvested in group-selection stands (Brown 1985).

Nest Predation

A better measure of habitat quality than animal abundance or density is reproductive effort and success (Van Horne 1983). For songbirds, nest predation can seriously influence reproductive outcomes. The susceptibility of avian nests to predation often depends on location and habitat type. Nests that are hidden in dense vegetation may be less susceptible to predation than conspicuous nests (Wray and Whitmore 1979; Yahner and Cypher 1987; Crabtree et al. 1989; Moller 1989) because of reduced predator foraging efficiency (Yahner and Cypher 1987; Yahner and Morrell 1991). Some silvicultural systems may be more likely to result in songbird nest predation than others, and managers should consider the trade-offs involved in using various systems.

Finding bird nests to monitor for predation is difficult in the dense forests of the Pacific Northwest. Therefore, in addition to conducting nest searches for natural nests, nest predation pressure across CFIRP treatments was assessed using artificial bird nests baited with quail (*Coturnix chinensis*) eggs. Although predation studies on artificial nests are not a direct measure of nestling survival and results should be used with caution (Yahner and Voytko 1989), they may provide an index to natural nest success. We compared artificial nest predation among CFIRP treatments immediately and 4 yr after harvest (1992 and 1996, respectively). Natural nests searches were conducted in 1996 only.

Response to Snag Creation

Snags are an essential habitat component for many species of primary and secondary cavity-nesting birds (Thomas et al. 1979; Brown 1985). Unfortunately, snag density frequently is lower in managed than unmanaged stands in the Pacific Northwest (Zarnowitz and Manuwal 1985; Bull and Partridge 1986; Ohmann et al. 1994) because snags classically were removed during harvest (Snellgrove and Fahey 1977). Although the positive relationships between cavity-nesting bird density and snags are well documented (Bull and Meslow 1977; McClelland

Table 5-2. Number of created and natural snags tagged and monitored in each CFIRP stand.

Replication			Number of snags		
Stand	Treatment[1]	Snag arrangement	Natural	Created[2]	Total
Dunn					
1	TS	Clumped	1	34	35
2	LP	Clumped	0	36	36
3	CC	Clumped	0	33	33
4	SC	Clumped	9	33	42
5	UC	N/A			
6	WD	Scattered	3	30	33
7	SP	Scattered	1	35	36
8	TS	Scattered	2	31	33
9	CC	Scattered	0	30	30
10	LP	Scattered	7	34	41
11	SP	Clumped	0	39	39
Dunn total			23	335	358
Peavy					
1	UC	N/A			
2	CC	Scattered	10	31	41
3	SP	Scattered	4	32	36
4	TS	Scattered	1	36	37
5	SP	Scattered	1	25	26
6	SP	Scattered	1	20	21
7	SP	Clumped	1	22	23
8	SP	Clumped	1	20	21
9	SP	Clumped	2	31	33
10	TS	Clumped	2	29	31
11	CC	Clumped	1	38	39
Peavy total			24	284	308
Saddle					
1	CC	Scattered	6	23	29
2	TS	Scattered	6	41	47
3	SP	Scattered	2	27	29
4	SP	Scattered	8	23	31
5	SP	Clumped	0	28	28
6	SP	Clumped	2	26	28
7	TS	Clumped	8	50	58
8	CC	Clumped	2	44	46
9	SP	Clumped	0	31	31
10	SP	Scattered	7	38	45
11	UC				
Saddle total		N/A	41	331	372
Total			88	950	1038

[1] Silvicultural treatments: clearcut = CC; two-story = TS; small patch = SP; large patch = LP; wedge cut = WD; strip cut =ST; and uncut control = UC.

[2] Most snags (> 98%) were created by topping Douglas-fir trees. Some grand fir trees were topped in Dunn 1, 6, and 9.

et al. 1979; Thomas et al. 1979; Zarnowitz and Manuwal 1985; Schreiber and deCalesta 1992; Deal and Gilmore 1998), there is little information on the density of snags required to provide adequate habitat (Schreiber and deCalesta 1992).

Over the past 30 yr on McDonald-Dunn Forest, most snags and damaged trees that could deteriorate into snags have been salvaged, resulting in low snag densities at the initiation of CFIRP (snags ≥ 30 cm [11.8 in.] dbh were ≤ 1.9 snags/ha [0.8 snags/ac]). To supplement the low numbers, 3.8 snags/ha (1.5 snags/ac) were created from live conifers (see Chapter 2). Because snags are predicted to fall within 50 to 80 yr (Neitro et al. 1985), 1.3 green trees/ha (0.5 trees/ac) also were left to replace snags in the future. In addition, as it is not known how cavity nesters respond to the pattern of snags within stands and across the landscape, created snags either were clumped or scattered in each of the stands (Table 5-2), and avian use of snags in these two distributions was compared. Although leaving clumps of snags is often more economical, uniformly distributed snags may provide nesting and dispersal habitat for more species because territoriality and/or intraspecific competition may restrict use of adjacent snags.

Coarse Woody Debris Relationships

Research evidence suggests that logs are important habitat components in unmanaged stands for a variety of wildlife, particularly terrestrial small mammals (Aubry et al. 1991; Corn and Bury 1991a; Gilbert and Allwine 1991a; West 1991) and salamanders (Aubry and Hall 1991; Bury et al. 1991; Corn and Bury 1991b; Gilbert and Allwine 1991b). Although private, state, and federal land agencies in Oregon have policies that address retention of dead wood, when CFIRP was initiated, there had been relatively few studies conducted in western Oregon that specifically described relationships between dead wood amount and animal abundance in managed stands. CFIRP offered an opportunity to investigate down wood/wildlife relationships in recently harvested stands including clearcuts with high (936 m^3/ha [13,525 ft^3/ac]), moderate (546 m^3/ha [7890 ft^3/ha]), and low (44 m^3/ha [635 ft^3/ac]) densities of down wood.

Study Objectives

Diurnal Birds

To compare the following:

(1 Habitat characteristics and relative abundance during the breeding season among uncut, group-selection, two-story, and clearcut stands both pre- and post-harvest.

(2) Habitat characteristics and relative abundance among treatments during winter.

(3) Nest predation among treatments.

(4) Nesting use of clumped and scattered snags.

(5 Relative abundance during the breeding season among unreplicated treatments (large patch, strip cut, wedge, single-tree selection).

Small Mammals

To compare the following:

(1) Habitat characteristics and relative abundance during summer among treatments pre- and post-harvest.

(2) Relative abundance among post-harvest treatments during winter.

(3) Relative abundance in post-harvest clearcuts with low, medium, and high densities of down logs.

Research Findings

All wildlife species encountered during this study are listed in Appendix D.

Diurnal Birds

Breeding Season—Community Responses to Harvest Treatments

We observed fewer birds in two-story and clearcut stands than in uncut or group-selection stands the first year following harvest. Bird abundance in small patch cut stands decreased the second year after treatment (Table 5-3, Chambers et al. 1999). A significant difference in species richness was not observed pre- or either year post-harvest across treatments. In general, the bird community in group-selection stands was most similar to control stands, and two-story and clearcut stands were most similar to each other following harvest (Table 5-3).

Table 5-3. Means (± standard error in parentheses) for CFIRP silvicultural treatments for measures of bird abundance, species richness, and percentage community similarity (Brower et al. 1990) by treatment and year for the breeding season (15 May to 15 July, 1989-1992) and winter season (December to March 1994 to1995).[1]

Community	Control (n = 3)			Small patch (n = 14)			Two-story (n = 6)			Clearcut (n = 6)		
measure	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Breeding season[2]												
Abundance[3]	192 (12)	192a (3)	198a (32)	212 (7)	202a (6)	199b (9)	230 (11)	167b (19)	180b (13)	211 (11)	140b (19)	157b (14)
Richness[4]	22 (1)	21 (2)	21 (2)	24 (1)	23 (1)	23 (1)	24 (1)	27 (2)	27 (1)	23 (2)	22 (2)	21 (2)
Similarity (%)[5]		74a (1)	75a (4)		73a (1)	67b (2)		42b (4)	32b (3)		29c (3)	23b (5)
Winter season[6]												
Abundance			53ab (6)			65a (7)			39ab (6)			28b (5)
Richness			8b (0)			12a (1)			9ab (2)			7b (2)

[1] Year 1 = pre-treatment year; Year 2 = 1-yr post-treatment; Year 3 = 2-yr post-treatment.

[2] Means that differed significantly ($P < 0.1$) from controls using repeated measures analysis orthogonal contrasts were designated with different letters. Comparisons should only be made between control and treatments from the same year.

[3] Number of observations per 5 ha (12.3 ac) over six visits during breeding season and over three visits during winter season. Results represent birds (n ≥ 30 individuals per species) observed ≤ 75 m (≤ 247 ft) from the point count station.

[4] Number of species.

[5] For percentage similarity, Year 2 is the pre-treatment vs. 1-yr post-treatment comparison; Year 3 is the pre-treatment vs. 2-yr post-treatment comparison.

[6] Means that differed significantly ($P < 0.1$) using Scheffe means separation tests were designated with different letters.

Table 5-4. Percentage of total observations of the six most abundant post-harvest bird species in each silvicultural treatment. [1]

	Silviculture treatment [2]			
Species	Control	Small patch cut	Two-story	Clearcut
Chestnut-backed chickadee	10	8	7	7
Dark-eyed junco	—	9	9	9
Hermit warbler	11	13	—	5
House wren	—	—	5	7
Pacific-slope flycatcher	11	5	—	—
Spotted towhee	—	—	5	5
Swainson’s thrush	6	—	—	—
White-crowned sparrow	—	—	7	13
Wilson’s warbler	7	9	7	—
Winter wren	14	7	—	—
Totals	59	51	40	46

[1] Combined data for 2 yr after harvest.

[2] Control and small patch-cut treatments were similar in bird species composition. Two-story and clearcut treatments were similar in species composition but differed from control and small patch cut treatments.

Five of the six most abundant bird species in control stands also were common in harvested group-selection stands; similarly, five of the most abundant species in two-story stands were also common in clearcuts (Table 5-4). There was little overlap in abundant species, however, between control/group-selection and two-story/clearcut stands (Table 5-4).

Breeding Season—Individual Species Responses to Harvest Treatments

We analyzed 30 bird species (≥50 observations per species) for changes in abundance in response to the silvicultural treatments. Eight species increased, 12 decreased, and 10 exhibited no change (Table 5-1). Species that increased in one or more treatments following harvest likely responded to the overall increase in shrub density (Chambers 1996). For species that declined, two general patterns of decreasing abundance were observed: a gradual population decline as wood volume removal increased (e.g., brown creepers [*Certhia americana*]), or a precipitous drop in the bird population in two-story and clearcut stands, but little change in small patch cut stands (e.g., red-breasted nuthatch [*Sitta canadensis*], Steller's jay [*Cyanocitta stellen*]). Most declines occurred within the first year after harvest.

Winter Season—Community Responses to Harvest Treatments

During winter, we observed a total of 594 birds representing 30 species. The most birds were located in uncut and group-selection stands, while the fewest were in clearcuts (Table 5-3). Species richness was highest in group-selection stands and lowest in clearcuts (Table 5-3; Chambers and McComb 1997). As in the breeding season, two story and clearcut stands were similar in species composition, but differed from control and group-selection stands, which were similar to each other.

Winter Season—Individual Species Responses to Harvest Treatments

Of seven abundant winter species, only four differed among treatments. Golden-crowned kinglet (*Regulus satrapa*) and Steller's jay were most abundant in control and group-selection stands. Dark-eyed junco (*Junco hyemalis*) was more frequent in harvested stands than in controls. Spotted towhees (*Pipilo maculatus*) were most abundant in two-story and clearcut stands and absent in controls (Chambers and McComb 1997). Winter wren (*Troglodytes troglodytes*), song sparrow (*Melospiza melodia*), and Hutton's vireo (*Vireo huttoni*) abundance did not differ among treatments.

Nest Predation

Artificial Ground Nests

In 1992, nine of 126 ground nests (7%) were disturbed; eggs had holes or were fragmented in five nests and eggs were absent in four nests. Predation across treatments was not significantly different ($P = 0.99$). Predation averaged 6% for clearcut and control stands, and 8% for two-story and group-selection stands.

In 1996, 23 of 126 ground nests (37%) were disturbed, but once again, predation across treatments was not significantly different ($P = 0.73$). Predation averaged 28% for clearcuts, 19% for two-story stands, 14% for group-selection stands, and 6% for controls.

Artificial Shrub Nests

In 1992, eight of 126 shrub nests (6%) were disturbed. Five nests had eggs missing and three nests had fragmented eggs or eggs with holes. Predation rates differed among treatments ($P \leq 0.10$), averaging 8% for clearcuts, 11% for two-story stands, 3% for group-selection stands, and 0% for controls.

Table 5-5. Number and fate (S = successful, F = failed, U = fate unknown) of natural nests located in CFIRP stands (May–July 1996) for each bird species.

	Silvicultural treatment				
Species	Control	Small patch	Two-story	Clearcut	Total
American goldfinch			1 (F)	2 (F)	3
American robin		1 (S)			1
Cedar waxwing			1 (S)		1
Dark-eyed junco	1 (F)	5 (S)			6
Flycatcher		1 (S)		1 (S)	2
MacGillivray's warbler			1 (S)	1 (S)	2
Mountain quail				1 (S)	1
Mourning dove		1 (S)	1 (S)	1 (F)	3
Orange-crowned warbler				1 (S)	1
Song sparrow			1 (S)	2 (1S, 1F)	3
Spotted towhee		2 (1S, 1F)			2
Swainson's thrush	1 (S)	2 (1S, 1F)			3
White-crowned sparrow			5 (4S, 1U)	8 (4S, 2F, 2U)	13
Wilson's warbler	1 (S)	1 (U)			2
Total	4	12	11	16	43
Nests that failed (%)	25	17	9	38	23

Table 5-6. Number of artificially created Douglas-fir and grand fir snags with and without excavated cavities 5 years after snags were created in CFIRP by topping green trees with a chainsaw in 1995.[1]

Treatment (no. of stands) Snag tree species	Snags without excavated cavities	Snags with excavated cavities	Total
Group-selection (14)			
Douglas-fir	270	150	420
Two-story (6)			
Grand fir	1	4	5
Douglas-fir	84	138	222
Clearcut (6)			
Grand fir	2	6	8
Douglas-fir	105	123	228
Large patch (2)			
Douglas-fir	50	27	77
Strip cut (1)			
Douglas-fir	18	23	41
Wedge cut (1)			
Grand fir	0	1	1
Douglas-fir	20	11	31

[1] Number of excavated cavities ranged from 1 to 44 per snag.

In 1996, 17 of 126 shrub nests (14%) were disturbed, but contrary to 1992 results, there was no detectable difference in predation among treatments ($P = 0.81$). Predation averaged 11% for clearcuts, 22% for two-story stands, 9% for group-selection stands, and 11% for controls.

Natural Nests

We located and monitored 43 nests of 14 bird species while conducting artificial nest predation trials in 1996 (Table 5.5). Although the sample size for natural nests was limited, nest failure rate appeared higher in clearcuts than in other treatments (Table 5.5).

Snag and Hardwood Use

Excavated Cavities

Few excavated cavities were found in newly created snags. Three months after topping, there were 0.01 cavities per snag in clearcuts, 0.02 cavities per snag in two-story stands, and no cavities in group-selection stands. Five years after topping, excavated cavities had increased in all silvicultural treatments ($P = 0.0001$) and were higher in two-story and clearcut stands than in group-selection stands ($P \leq 0.0004$; Tables 5-6 and 5-7). We did not find a relationship between number of excavated cavities and snag pattern (clumped vs. scattered) ($P > 0.6$) (Carrigan 1995; Chambers et al. 1997).

Five years after topping, snags across silvicultural treatments did not differ in snag height, decay, bark cover, scorch, number of dead limbs, or lean. Snags with the highest probability of containing excavated cavities were in two-story or clearcut stands, had no live branches, were of large diameter, and had at least one natural cavity present (i.e., bole decay).

Cavity Nests

We located 146 nests in natural and created hardwood and conifer snags; 126 of these nests occurred in cre-

Table 5-7. Means (± standard error) of characteristics of 1995 in 5-yr-old Douglas-fir snags created by topping. [1]

Treatment [2]	n	DBH cm	DBH in.	Cavities per snag (no.) Excavated	Natural	Foraging
Clearcut	205	94 (2)	37 (0.8)	1.8a (0.3)	0.6a (0.1)	3.7a (0.8)
Two-story	223	92 (3)	36 (1.2)	2.1a (0.3)	0.7a (0.1)	4.1a (0.8)
Small patch	393	75 (1)	30 (0.4)	0.6b (0.3)	0.6a (0.1)	2.3a (0.5)

[1] Measured in 1995.

[2] Differences were not detected ($P > 0.10$) among silvicultural treatments with the same letter. Differences were significant among treatment means, at $P = 0.0001$.

ated Douglas-fir (*Pseudotsuga menziesii*) or grand fir (*Abies grandis*) snags. Ten species of cavity-nesters used created snags, and their nests were most abundant in clearcut and two-story stands (Table 5-8). House wren (*Troglodytes aedon*) nests accounted for half of all cavity nests located.

No difference in use was detected between clumped or scattered snags for cavity-nesters analyzed as a group; 73 nests were found in each of the snag treatments (Table 5-8). We did not detect a difference in effects of snag treatment for species with ≥ 10 nests, although we did detect silvicultural treatment effects (Table 5.9).

Total nest density differed among silvicultural treatments ($P = 0.0009$). We found more nests in two-story and clearcut stands than small patch cut stands ($P \leq 0.005$). House wren nest abundance in particular differed among silvicultural treatments and was highest in clearcut stands (Table 5-9). Red-breasted

Table 5-8. Number of nests of cavity-nesting birds found in natural or created snags across four silvicultural treatments and scattered (SC) and clumped (CL) snag treatments. [1]

Bird species	Small patch [2] SC	Small patch [2] CL	Two story [3] SC	Two story [3] CL	Clearcut [3] SC	Clearcut [3] CL	Large patch [4] SC	Large patch [4] CL	Species total	Percent of total
House wren	1	—	13	17	22	17	—	1	71	49
Red-breasted sapsucker	4	4	4	9	2	1	1	2	27	19
Northern flicker	—	1	2	6	4	—	1	—	14	10
Chestnut-backed chickadee	1	4	1	2	—	1	1	—	10	7
Violet-green swallow	—	—	1	—	4	3	—	—	8	5
European starling	—	—	1	1	4	—	—	—	6	4
Red-breasted nuthatch	1	—	—	1	—	—	—	2	4	3
Black-capped chickadee	—	—	1	—	—	—	1	—	2	1
Hairy woodpecker	—	—	—	—	1	1	—	—	2	1
Western bluebird	—	—	—	—	2	—	—	—	2	1
Treatment total	7	9	23	26	39	23	4	5	146	
Nests/ha	0.1	0.1	0.7	0.6	1.7	0.7	0.4	0.4	0.4	

[1] Nests were located in 1995 and 1996.

[2] n = 7 stands per snag treatment.

[3] n = 3 stands per snag treatment.

[4] n = 1 stand per stag treatment.

Table 5-9. Mean (± standard error) number of cavity-nesting birds in created snags per stand per silvicultural treatment.

Bird species	n	Silvicultural treatments [1] Small patch	Two-story	Clearcut	P [2] Silvicultural	Snag	Silvicultural* snag
House wren	64	0.07a (0.61)	4.67b (0.78)	5.83b (0.78)	0.0001	0.8	0.2
Red-breasted sapsucker	28	0.83a (0.68)	2.17b (0.75)	0.50a (0.75)	0.01	0.7	0.6
Northern flicker	11	0.00a (0.14)	1.17b (0.21)	0.67b (0.21)	0.0002	0.7	0.2

[1] Differences among least-squares means ($P < 0.01$) for silvicultural treatments are indicated by different letters.

[2] P is the probability associated with differences among silvicultural treatments, snag treatments, or silvicultural and snag treatment interactions as determined by Analysis of Variance performed on transformed data ($\log_{10}$[nest abundance+1]).

sapsucker (*Sphyrapicus ruber*) nest abundance was greater in two-story stands than in small patch or clearcut stands (Table 5-9).

Hardwoods

While nest searching, we encountered cavity-nesting birds using five species of hardwoods: bigleaf maple (*Acer macrophyllum*), Oregon white oak (*Quercus garryana*), Pacific madrone (*Arbutus menziesii*), Oregon ash (*Fraxinus latifolia*), and bitter cherry (*Prunus emarginata*). Minimum diameter of hardwoods used as nest trees was 31.0 cm (12.4 in.); minimum height was 10.7 m (35 ft).

Mammals

Summer Season

We captured 1176 small mammals during 8676 trap nights over four summers (1989–1992). Five of 14 species represented 94% of captures (Table 5-1), and the most abundant small mammal, deer mouse (*Peromyscus maniculatus*), accounted for 42% of encounters. No difference in abundance among silvicultural treatments was found for mammals as a group, although species richness increased in group-selection stands the first year after harvest (Chambers 1996). Percent community similarity did not differ among treatments 1 yr after harvest, but the following year it dropped in treatment stands compared with controls (Chambers 1996).

Mammal community composition in group-selection stands was most similar to control stands, and two-story stands were most similar to clearcuts. Although many species in the uncut control stands also were present in harvested units, relative abundance changed. Deer mice and Oregon voles (*Microtus oregoni*) appeared to increase after harvest and to dominate in clearcut and two-story stands.

Table 5-10. Number of individual mammals captured per silvicultural treatment during the December 1991 trapping period.[1]

	Treatment				
Species	Control	Small patch	Two-story	Clearcut	Total
Oregon vole	4	3	8	8	23
Deer mouse	4	3	4	4	15
Trowbridge's shrew	4	1	2	1	8
Townsend's chipmunk	0	1	0	5	6
Northern flying squirrel	0	1	0	0	1
Ermine	0	0	1	0	1
Dusky-footed woodrat	0	1	0	0	1
Shrew-mole	1	0	0	0	1
Vagrant shrew	0	1	0	0	1
Total	13	11	15	18	57

[1] 240 trap nights per treatment.

Winter Season

We captured 57 individuals representing nine species during one winter trapping session (December 1991). Four species comprised 91% of all captures (Table 5-10). The most abundant winter species, Oregon vole, accounted for 40% of all encounters. Clearcuts yielded the most individuals, but species richness was highest in small patch stands (seven species).

Coarse Woody Debris and Habitat Variables

In addition to the slash and unmerchantable material remaining after harvest, tops of created snags were added to the sites. These factors resulted in different lengths of logs > 50 cm (20 in.) in diameter among the three treatments (Table 5-11). Shrub cover also was positively associated with log retention levels (Table 5-11). With few exceptions, small mammal captures did not correlate well with most habitat variables measured.

During the coarse woody debris study, we captured 448 forest floor mammals representing 14 species, plus 34 amphibians and reptiles of five species (Table 5-12). Mammal captures and species richness were highest in units with medium log volumes (Table 5-13). At the species level, this trend was significant only for the vagrant shrew (*Sorex vagrans*) (Table 5-13).

Oregon vole captures were associated with average log diameter (r = 0.67, P = 0.05) and cover by forbs and shrubs (r = 0.60, P = 0.08). Capture rates of deer mice were associated with length of logs < 20 cm (8 in.) in diameter during the spring but not during the fall. Capture rates for Trowbridge's shrew (*Sorex trowbridgii*) were positively associated with log length and slash cover, and negatively associated with grass cover. Capture rates for vagrant shrews were

Table 5-11. Means for habitat characteristics at 0.16-ha (0.4-ac) sampling grids among three log retention levels in 1995.

	Log retention level [1]			
Variable	Low (n = 3)	Medium (n = 3)	High (n = 3)	P [2]
Logs > 15-cm diameter				
Volume in m^3/ha (ft^3/ac)	44 (621)	546 (7803)	930 (13,377)	0.12
Total length in m/ha (ft/ac)	1275 (1658)	1196 (1555)	2309 (3002)	0.25
Logs 15- to 50-cm diameter				
Volume in m^3/ha (ft^3/ac)	35 (500)	471 (6731)	807 (11,533)	0.12
Diameter in cm (in.)	24.2 (9.7)	24.9 (10.0)	24.2 (9.7)	0.94
Total length in m/ha (ft/ac)	1212 (1576)	932 (1212)	1528 (1986)	0.64
Logs > 50-cm diameter				
Volume in m^3/ha (ft^3/ac)	6 (86)	75 (1072)	129 (1844)	0.12
Diameter in cm (in.)	30.5 (12.2)	48.5 (19.4)	35.3 (14.1)	0.17
Total length in m/ha (ft/ac)	63 (82)b	264 (343)b	781 (1015)a	0.0035
Cover (%)				
Slash < 15-cm diameter	24.7	13.8	33.2	0.31
Grasses	16.8	31.2	0.3	0.28
Forbs	45.5	40.7	43.0	0.95
Shrubs	7.5c	12.9b	19.7a	0.0009
Shrubs and forbs	53.0	53.6	62.7	0.75
Grasses, forbs, and shrubs	69.8	84.8	63.0	0.28
Area devoid of vegetation (%)	5.7	1.5	3.8	0.33

[1] Means within variables that differed significantly designated with different letters.

[2] P is the probability associated with differences among log retention treatments.

Table 5-12. Number of individuals captured for vertebrate species during the 1995 CFIRP coarse woody debris study.

Species	Fall	Spring	Total
Reptiles			
Northern alligator lizard	0	1	1
Western fence lizard	9	7	16
Amphibians			
Pacific treefrog	2	0	2
Ensatina salamander	5	0	5
Rough-skinned newt	10	0	10
Mammals			
Pacific water shrew	0	1	1
Pacific shrew	13	0	13
Trowbridge's shrew	25	20	45
Vagrant shrew	80	42	122
Shrew-mole	2	0	2
Western red-backed vole	1	0	1
Oregon vole	25	48	73
Townsend's vole	4	0	4
Dusky-footed woodrat	0	3	3
Deer mouse	52	81	133
Pacific jumping mouse	5	2	7
California ground squirrel	0	9	9
Townsend's chipmunk	0	34	34
Ermine	0	1	1
Total	234	248	482

Table 5-13. Small mammal mean captures (N) per 0.16-ha (0.4-ac) grid during spring (400 trap nights/grid) and fall (525 trap nights/grid) 1995, across three log volumes in clearcuts. [1]

Species	Season	N	Low (3)	Medium (3)	High (3)	P
Total amphibians	Fall	15	1.0 (1.0)	1.7 (1.5)	2.3 (1.5)	0.5305
Total reptiles	Spring	8	1.0 (1.7)	1.3 (2.3)	0.3 (0.6)	0.5743
	Fall	9	1.7 (1.5)	1.0 (1.7)	0.3 (0.6)	0.5305
	Total	17	2.7 (3.1)	2.3 (4.0)	0.7 (1.2)	0.6975
Insectivores						
Vagrant shrew	Spring	42	2.7 (1.5)	7.0 (3.6)	4.3 (5.8)	0.4610
	Fall	80	7.3 (2.1)b	16.7 (4.2)a	2.7 (1.2)c	0.0012 [2]
	Total	122	10.0 (3.5)b	23.7 (3.8)a	7.0 (5.3)b	0.0065
Trowbridge’s shrew	Spring	20	3.0 (3.6)	0.3 (0.6)	3.3 (3.1)	0.3994
	Fall	25	3.0 (4.4)	1.7 (0.6)	3.7 (1.2)	0.6566
	Total	45	6.0 (7.9)	2.0 (0.0)	7.0 (3.5)	0.4768
Total insectivores	Spring	62	5.7 (3.8)	7.3 (3.8)	7.6 (7.0)	0.8784
	Fall	121	12.3 (9.3)	20.0 (5.3)	8.0 (2.0)	0.1378
	Total	183	18.0 (13.1)	27.3 (4.9)	15.7 (6.4)	0.3065
Microtines						
Oregon vole	Spring	48	4.3 (4.5)	6.7 (9.0)	5.0 (4.4)	0.8988
	Fall	25	4.0 (4.0)	3.7 (3.5)	0.7 (0.6)	0.4044
	Total	73	8.3 (7.2)	10.3 (12.1)	5.7 (4.9)	0.8078
Total microtines	Spring	48	4.3 (4.5)	6.7 (9.0)	5.0 (4.4)	0.8988
	Fall	30	4.3 (3.5)	4.7 (3.5)	1.0 (0)	0.2963
	Total	78	8.7 (6.7)	11.3 (12.1)	6.0 (4.4)	0.8876
Cricetids						
Deer mouse	Spring	81	8.0 (3.6)	10.7 (11.6)	8.3 (3.8)	0.8911
	Fall	52	4.0 (1.0)	6.7 (7.2)	6.3 (4.0)	0.7315
	Total	132	12.0 (4.4)	17.3 (11.2)	14.7 (5.9)	0.7142
Total cricetids	Spring	126	5.7 (3.8)	7.3 (3.8)	7.7 (7.0)	0.8784
	Fall	57	12.3 (9.3)	20.0 (5.3)	8.0 (2.0)	0.1378
	Total	183	18.0 (13.1)	27.3 (1.4)	15.7 (6.4)	0.3065
Townsend’s chipmunk	Spring	34	1.0 (1.7)	3.3 (5.8)	7.0 (9.6)	0.5614
Total mammal captures	Spring	248	21.0 (7.5)	33.0 (15.6)	28.7 (12.7)	0.5256
	Fall	234	23.3 (11.0)ab	36.7 (6.8)a	18.0 (5.6)b	0.0721
	Total	482	44.3 (18.1)	69.7 (18.4)	46.7 (7.6)	0.1689
Amphibian species richness	Fall		1.0 (1.0)	2.0 (2.0)	1.7 (1.2)	0.7065
Mammal species richness	Spring		4.3 (1.2)	5.7 (1.1)	4.7 (0.6)	0.3075
	Fall		4.3 (1.1)	6.0 (1.0)	5.3 (0.6)	0.1739
	Total		5.3 (1.2)b	7.7 (0.6)a	6.7 (1.2)ab	0.0751
Total species richness	Spring		4.3 (1.2)	5.7 (1.1)	4.7 (0.6)	0.2963
	Fall		5.3 (0.6)	8.0 (1.7)	7.0 (1.7)	0.1555

[1] Means that differed significantly across log treatments are designated with different letters.

[2] Log transformation (log variable + 1) used to normalize data.

Table 5-14. Bird species detected in the single-tree selection stand during four visits to four sample points both pre- (1992) and post-harvest (1993).

Species	Pre-treatment	Post-treatment
Golden-crowned kinglet	21	13
Dark-eyed junco	18	14
Swainson's thrush	16	13
Wilson's warbler	14	17
Black-headed grosbeak	13	7
Hermit warbler	12	13
Ruffed grouse	11	0
Red-breasted nuthatch	11	14
Chestnut-backed chickadee	9	20
Evening grosbeak	9	0
Steller's jay	6	16
Orange-crowned warbler	5	7
Hammond's flycatcher	5	1
MacGillivray's warbler	4	2
Pacific-slope flycatcher	4	1
Black-throated gray warbler	3	1
Hutton's vireo	2	0
Western tanager	2	4
Pileated woodpecker	2	1
Red crossbill	2	0
Spotted towhee	1	0
Warbling vireo	1	1
Brown creeper	1	5
Olive-sided flycatcher	1	1
Bushtit	0	13
Northern flicker	0	4
Mountain quail	0	3
Red-breasted sapsucker	0	3
White-crowned sparrow	0	3
Rufous hummingbird	0	2
House wren	0	2
Purple finch	0	1
Winter wren	0	1
Total	173	183
Species richness	24	28

negatively associated with percent of exposed bare soil in the spring and with small log length in the fall. We did not detect associations with Townsend's chipmunk (*Tamias townsendii*) capture rates and any of the habitat characteristics measured.

Wildlife Observations in the Single-Tree Selection Stand

Twenty-four bird species were detected 1-yr pre-harvest (1992) and 28 species were detected 1-yr post-harvest in the single-tree selection stand (Table 5-14). The most abundant species prior to harvest were golden-crowned kinglet, dark-eyed junco, Swainson's thrush (*Catharus ustulatus*), Wilson's warbler (*Wilsonia pusilla*), and black-headed grosbeak (*Pheucticus melanocephalus*). After harvest, the most abundant species were chestnut-backed chickadee (*Poecile rufescens*), Wilson's warbler, Steller's jay, dark-eyed junco, and red-breasted nuthatch. Percent similarity between pre- and post-treatment bird communities was low (17%).

Wildlife Observations in Demonstration CFIRP Stands

Birds

Bird abundance decreased after harvest in the wedge cut (Dunn 6), the strip cut (Dunn 4), and the two large patch cut (Dunn 2 and 10) stands. In the wedge cut stand, bird observations after harvest fell from 201 to 152 per 5 ha (12.4 ac), in the strip-cut stand from 213 to 147, and in the large patch stands from 205 to 148. Alternatively, species richness appeared to increase following treatment (wedge: 19 to 25 species; strip: 19 to 24 species; large patch: 22 to 27 species). The percent similarity with pre-treatment bird community composition declined for the wedge cut stand from 70% to 59%, but remained about the same for stands with large patch or strip cuts (67% to 60% and 68% to 68%, respectively). The most abundant species in the demonstration stands both pre- and post-harvest are listed in Table 5-15, and the full species list is reported in Chambers (1996).

Mammals

We captured three mammalian species in the wedge cut stand, four in the strip cut stand, and five in the two large patch stands for a total of 79 individuals. Capture summaries for pre- and post-harvest are located in Table 5-16.

Table 5-15. Percentage of total observations of the six most abundant bird species in each of three demonstration silvicultural treatments 1-yr pre-harvest and 2-yr post-harvest.

	Large patch (n = 2)		Strip cut (n = 1)		Wedge cut (n = 1)	
Species	Pre-harvest	Post-harvest	Pre-harvest	Post-harvest	Pre-harvest	Post-harvest[1]
Brown creeper					5	10
Chestnut-backed chickadee	9		9	10	10	5
Dark-eyed junco		9	14	15		13
Golden-crowned kinglet			6			
Hermit warbler	12		14		10	
House wren				8		
MacGillivray's warbler				5		
Orange-crowned warbler		6				
Pacific-slope flycatcher	10		12	8	15	13
Red-breasted nuthatch				8		5
Red-breasted sapsucker		6 [2]				
Swainson's thrush	7	6				
White-crowned sparrow						5
Wilson's warbler	10	10	7		7	
Winter wren	8	9			20	9
Western tanager						7
Total of 6 most common species	56	46	62	54	67	67

[1] Three species were equally represented at 5%.

[2] Two nest trees with adults and young were recorded.

Table 5-16. The number of small mammals captured/1000 trap nights and the number of individuals captured (in parentheses) in three demonstration silvicultural treatments 1-yr pre-harvest and 2-yr post-harvest.

	Silvicultural treatments					
	Large patch (n = 2)		Strip cut (n = 1)		Wedge cut (n = 1)	
Species	Pre-harvest	Post harvest	Pre-harvest	Post harvest	Pre-harvest	Post harvest
Trowbridge's shrew	17 (4)	4 (1)	17 (2)	58 (7)	17 (2)	33 (4)
Pacific shrew	4 (1)	0 (0)	—	—	—	—
Shrew-mole	—	—	0 (0)	8 (1)	—	—
Deer mouse	38 (9)	100 (25)	8 (1)	67 (8)	8 (1)	58 (7)
Oregon vole	—	—	0 (0)	8 (1)	8 (1)	0 (0)
Townsend's chipmunk	4 (1)	9 (2)	—	—	—	—
Northern flying squirrel	0 (0)	4 (1)	—	—	—	—
Number of individuals	15	29	3	17	4	11
Number of species	4	4	2	4	3	2

Conclusions

If the habitat needs of all wildlife species are to be met, then forest management that more closely imitates natural stand disturbances should be considered. Our silvicultural treatments are alternatives to traditional clearcut regeneration systems, and provide for both timber extraction and retention of habitat features important for wildlife.

Wildlife Response to Harvest Treatments

For both breeding and winter seasons, the wildlife community in group-selection stands (less disturbance) was most similar to uncut control stands, whereas two-story stands were most similar to clearcuts. All treatments affected wildlife, although two-story and clearcut treatments had the most pronounced effects. Results of the CFIRP wildlife studies suggest that two-story stands provided the greatest range of habitat conditions among the treatments studied. They offered nesting and foraging habitat for early seral-associated species, but retained components of older forests that provided foraging, and in some cases nesting habitat, for several species associated with mature or old-growth forests. Although two-story stands had higher shrub nest predation rates immediately following harvest, no differences were found among treatments 5 yr later.

Some researchers (Morrison et al. 1986; DellaSala et al. 1996) have suggested that winter bird use may be associated with forests high in cover and food resources, such as is found in late-successional forests. We did find higher bird abundance in uncut and small patch cut stands compared with two-story and clearcut stands. Some of the CFIRP bird species (e.g., golden-crowned kinglet, Steller's jay) and mammals (e.g., Trowbridge's shrew) were most abundant in control and patch-cut stands with their dense vegetation cover and multilayered canopies. However, other species (e.g., dark-eyed junco, spotted towhee, Oregon vole) were more abundant in the more structurally simple two-story and clearcut stands. These latter species may be better adapted at finding shelter and food in areas with dense understories; alternatively, they may depend less on closed-canopy stands for suitable thermal conditions because winter conditions in the Oregon Coast Range are relatively mild.

The CFIRP wildlife studies indicated that silvicultural prescriptions based on natural disturbance regimes had limited impact on some bird and mammal species associated with late-successional or old-growth forests. Alternative silvicultural treatments provided foraging and nesting habitat that are not available in traditional clearcut stands. Our results suggest that if the management intent is to extract timber and simultaneously retain wildlife species associated with late-successional forests, then silvicultural treatments similar to our group-selection stands will be more effective than two-story or clearcut treatments. As our harvest treatments represent just a few of the range of silvicultural options available to resource managers, however, CFIRP treatments should not be used to the exclusion of other management possibilities.

Wildlife Use of Created Snags

Most of the snags created from live Douglas-fir trees in CFIRP had little or no decay prior to topping, but within 5 yr, 46% (472 of 1019) of these snags had excavated cavities. In contrast, 79% (11 of 14) of grand fir snags had excavated cavities after the same time period, but grand fir accounted for < 2% of all snags. In addition, we found excavated cavities and observed primary cavity-nesters in five species of hardwoods. Hardwoods appear to be an important resource for cavity-nesting birds in western Oregon.

These results highlight several snag management strategies:

(1) If resource managers need to quickly create suitable snag habitat, they should select tree species that decay relatively rapidly, such as grand fir.

(2) Unfortunately, because snags created from tree species that decay relatively rapidly also have shorter half lives, we recommend that managers consider using several tree species with varying decay rates to provide snags over a longer period of time.

(3) Both conifer and hardwood snags should be provided.

The snags we created were used by 10 species of primary and secondary cavity-nesting birds. More excavated cavities and nests were found in clearcut and two-story stands than in group-selection stands. Cavity-nesters as a group did not utilize one snag treatment over the other, although chestnut-backed chickadees used clumped snags more than scattered snags. Contrary to the CFIRP findings, Saab and Dudley (1998) observed many cavity-nesting species utilizing clumped snags in ponderosa pine (*Pinus ponderosa*) forests.

The CFIRP snag study was limited in that we created only one snag density using trees in the same diameter size class. Schreiber and deCalesta (1992) found that density of cavity-nesting birds was associated with snag density. Presumably, creating snags at higher densities would increase numbers of cavity nesters.

Small Mammals and Log Retention

Small mammal association with down wood varied with season, with most captures occurring during fall trapping on sites with moderate levels (264 m^3/ha [3773 ft^3/ac]) of down wood > 50 cm (20 in.) in diameter. Increasing log length was associated with higher species richness of mammals. High levels of down wood may not be beneficial to small mammals; however, the results are inconsistent with small mammal responses across similar down wood volumes in other studies (e.g., Butts and McComb 2000; Maguire 2002). The relationship between small mammals and down wood on CFIRP sites continues to be studied (see Hayes and Waldien 1999).

Demonstration Silvicultural Treatments

Species richness for birds increased after harvest in all demonstration treatments, particularly in the wedge cut stand. This change coincided with a substantial reduction in bird abundance in the same stands. The reduction was similar to that observed in two-story and clearcut stands.

Small mammal responses to the demonstration treatments were not consistent. Two notable examples are the deer mouse and Trowbridge's shrew. Deer mice increased in all treatments following harvest while Trowbridge's shrews appeared to decline in the large patch stands but to increase in the wedge and strip cut stands.

The demonstration treatments present additional options for managers beyond those explored in depth in CFIRP. As with the group-selection and two-story treatments, habitat was retained for some wildlife species associated with mature forests. In addition, removing larger forest patches may be more economical than removing smaller ones. However, it appears that spatial arrangement of leave trees may be as important to some wildlife species as the amount of timber volume removed, and should be considered when devising silvicultural strategies sensitive to wildlife needs.

Application

Because each animal species has its own set of resources and habitat elements necessary for survival, reproduction, and movement, manipulating forest structure and composition (e.g., overstory cover, shrub cover, snags, logs) can lead to changes in the occurrence or abundance of a suite of animals. Some species respond to changes in just one habitat element, but many respond to the combination of changes resulting from a disturbance. It is for this reason that no single stand management prescription, including the "no management" option, will produce conditions needed by all wildlife. This clearly was evident in the variable responses of wildlife to the CFIRP treatments.

The silvicultural and snag treatments described in this study, as well as a host of others not addressed in CFIRP, represent silvicultural tools that are available to manage forests. The management challenge, however, is to apply these techniques in a thoughtful manner that will address multiple-use concerns. As one approach to the problem, land managers may wish to consider the following questions when formulating management strategies, if wildlife are an important component of the land management goals:

- What species are favored in the future landscape?
- Are there species that likely would be eliminated from the area in the future under current patterns of land use?
- Are there species for which the property under management is or could be a key contributor to the welfare of local or regional populations?

Careful planning of stand treatments over space and time based on responses to these questions will move a forest toward a "desired future condition" that meets multiple-use goals.

Regional Diversity Considerations

Organisms that currently occur in Pacific Northwest forests have persisted through decades of natural- and human-induced disturbances. However, the age- and size-class distribution of managed forest stands in the present most likely do not represent the conditions that would have prevailed under natural disturbance regimes in the absence of management. Indeed, consider the following cover estimates simulated for forests in the northwest during the early 1800s (Wimberly and Spies 2000): early seral shrub/sapling pole (5%–15%), mid-seral pole, small sawtimber (40%–60%), late seral large sawtimber/old-growth (40%–60%). In the early 1990s, federal forested land in the Coast Range contained 11% old-growth and 5% late-successional forests (Wimberly and Spies 2000). If non-federal land has < 1% old-growth and < 5% late-successional forests (Ohmann et al. 1994), the entire Coast Range contains approximately 5% old-growth and 11% late-successional forests. Certainly, the percent of stands in each seral stage changes among years, decades, and centuries as fires, wind, floods, and other disturbances occur with varying levels of frequency and intensity. However, there is a small probability that the low levels of older forests noted above would have arisen under the historical fire regime (Wimberly and Spies 2000). It is important to think of the range of forest variability that once occurred not only within the context of seral stage, but also from the perspective of the represented plant communities (e.g., conifers, hardwoods, mixed stands, shrubby wetlands, and others). What would be a reasonable representation of seral stages and plant community types across the landscape if the goal is to reflect the natural disturbance conditions in which current species evolved?

While considering the proportional representation of seral stages and plant community types, it also is important to recognize the spatial scales of patch types across the landscape. It has been proposed that many patches should be of small size, fewer of medium size, and very few of large size to reflect the general size distributions of natural disturbance patterns (Hunter 1990).

Once one evaluates current forest conditions in comparison with the broad natural patterns of vegetation, conditions that are likely under-represented in the region become evident, and managers should consider incorporating them into their long-term plans when possible. Contributing to the regional representation of under-represented seral conditions, plant communities, and/or patch sizes can be a first effort at regional biodiversity protection. This process is a *coarse filter* approach to land management. The silvicultural tools described in this book provide a sub-set of a wide range of options to contribute to coarse filter goals while actively managing some or all of a forest land holding.

Species of Concern

Not all species in a region are likely to be accommodated simply by establishing the broad vegetation and patch size goals noted above. Sensitive, threatened, or endangered (STE) species often require a particular arrangement of habitat conditions across the landscape, and responsible management for them necessitates attention to forest pattern during the planning process. Other species require specific habitat elements that are not necessarily linked with particular seral stages or vegetation types, but are required to fulfill life requisites, such as down wood or snags. When broad forest goals characteristic of the *coarse filter* management approach are insufficient to accommodate particular species, than a more *fine filter* approach to management should be undertaken.

Species that may need special management consideration to ensure continued occurrence and viability include

- species at risk
- federal listed threatened or endangered species
- state listed sensitive species
- Natural Heritage Program species of concern
- species that have been declining regionally
- species restricted to specific seral stages
- species sensitive to environmental change/gradients
- species with critical ecological functions
- keystone species: species whose effects on one or more critical ecological processes or on biological diversity are much greater than would be predicted from their abundance or biomass
- umbrella species: species that encompass the habitat requirements of many other species because of their large area requirements or use of multiple habitats
- link species: species that play critical roles in the transfer of matter and energy across trophic levels or provide a critical link for energy transfer in complex food webs (e.g., insectivorous birds)
- game species
- species for which there are limited data or knowledge
- species with a public or regulatory interest

Some species in the groups noted above are common, but they have experienced population declines. Others have become uncommon and deserve immediate attention to halt or reverse population declines. All of these species would benefit from a management perspective that combines both coarse and fine filter approaches. The desired outcome of the process would be to develop a "desired future condition" focus for the target area, whereby some stands are allowed to develop under natural disturbance pressures devoid of human intervention, while others would be managed under a range of silvicultural options, including single-tree selection, group-selection, two-story treatment, and clearcuts, as appropriate to meet the multiple-use goals for the property. This suite of silvicultural tools provides flexibility and creativity in achieving desired future conditions.

Summary

Species of small vertebrates responded differently to the treatments tested in the CFIRP study. Because no single stand management strategy met the needs of all species, the results demonstrated that a range of silvicultural treatments should be utilized to achieve multiple-use goals, particularly when habitat for a broad range of species is an objective. Clearly not all silvicultural options will be acceptable or even possible on all sites. Nonetheless, the prevalent use of one dominant system (even-aged management) over a narrow range of spatial scales in the past has led to current concerns about the long-term sustainability of a number of resources, including several wildlife species.

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Chapter 6. Socioeconomic Responses to Silvicultural Alternatives

Rebecca L. Johnson, Bo Shelby, Mark Brunson, and Jessica Leahy

Placement of the CFIRP Peavy replication squarely in the middle of one of the most popular recreation areas of McDonald-Dunn Forest, adjacent to Corvallis, Oregon, set the stage for a potential conflict of values. CFIRP provided an opportunity to study social aspects of various silvicultural treatments in a near-urban forest setting. Specifically, three research projects related to the socioeconomic responses to silvicultural alternatives are discussed in this chapter: a public perceptions study, an adjacent landowner study, and a recreation study.

The urban-forest interface is defined as any location where forestry and urban development occur near or adjacent to one another. With expanding urban growth, forests that were once relatively removed from urban areas now share boundaries with residential developments, and they increasingly are pressured to provide recreation and other non-commodity values. Near-urban forests like McDonald-Dunn are distinguished from more remote forests by smaller acreage, fragmented ownership along the forest boundaries, and high concentrations of competing and overlapping social demands. Criticism of forest management practices such as clearcutting can come from recreationists as well as newly arrived adjacent property owners who see the forest not as a working asset, but as an extension of their own backyard. Changing natural resource values within society have become highly visible when near-urban forests are involved.

In the last 20 yr, recreational use of McDonald-Dunn Forest has skyrocketed. Between 5,000 and 10,000 recreational visits were estimated for the Forest in 1980. In 1993, up to 60,000 visits were made. In 1990, a random telephone survey of Corvallis residents revealed that 74% had visited the Peavy Tract of McDonald-Dunn Forest. Over half of those polled wanted clearcutting in the forest to stop, and 62% disagreed with the statement that the forest should be used primarily for timber production. With the implementation of CFIRP, we set forth to assess public acceptance of a variety of silvicultural treatments from scenic, economic, and recreational perspectives.

Public Perceptions Study

Research Strategy

The following questions guided the research design (Brunson 1991):

(1) How do public judgments of scenic and recreational quality differ among silvicultural treatments?

(2) Do judgments of scenic quality of a stand differ from judgments of recreational quality?

(3) What attributes of forest stands are most important when judging scenic and recreational quality?

(4) What physical stand features influence acceptability judgments, including features that can be manipulated silviculturally, such as the creation of snags?

(5) How do the scenic and recreation quality judgments compare between on-site and off-site viewing conditions?

(6) Does information affect judgments?

The research framework outlined above was selected for two main reasons. Foremost, this was one of the first stand-level scenic assessment studies conducted within the Pacific Northwest, requiring that the information gathered be of use to forest managers concerned about public sentiment surrounding specific silvicultural treatments. Additionally, this was the first research that would compare the perceived scenic quality of harvested stands with assessments of their suitability as places for specific recreational uses. Prior studies involving recreationists had only focused on scenic quality and not the suitability of sites for recreation (e.g., Rutherford and Shafer 1969).

Silvicultural Treatment Comparisons

Participant responses were compared across treatments to ascertain whether the alternative CFIRP silvicultural systems outlined in Chapter 2 would produce stands more or less acceptable for amenity uses than traditional clearcuts or thinned stands. Distrust of scientific solutions is one factor underlying the growing skepticism about forestry (Shepard 1990). Accordingly, any changes in forest practices, such as switching to patch cuts or a two-story silvicultural treatment, is unlikely to be viewed favorably unless it addresses social values as well as scientific ones (Clark and Stankey 1991). Public use of forests for scenic viewing and outdoor recreation is an important social value.

Land managers in North America have also had to modify their forest practices to reflect public demands for greater protection of ecological systems. Ecosystem management approaches often entail leaving behind ecological legacies: clumps of live trees, standing dead snags, down logs, and woody debris (Franklin 1989; McComb et al. 1993). Stands containing ecological legacies often produce landscapes unfamiliar or unattractive to some forest visitors, thereby reducing public acceptance (Brunson and Shelby 1992; Johnson et al. 1994). There is an important social aspect to ecosystem management as well (Gilmore 1997). Because public acceptance is crucial to the success of management strategies for publicly used lands, it is important for foresters to mitigate the amenity impacts of ecosystem management practices.

Comparison Between Scenic and Recreational Quality

Participant responses within silvicultural treatments were compared to determine whether the perceived scenic quality of a stand differed from its quality as a recreation setting. It has been suggested that identification of the relative importance of setting attributes is essential to integrated resource management (Clark and Stankey 1986). Treatments that produce stands that are scenic but unsuitable for some forms of recreation, or vice versa, can lead to disenfranchisement of users, irreversible loss of recreation opportunities, and increased inefficiency in service delivery (Clark and Stankey 1979).

Hypotheses

From previous studies, researchers have found that scenic ratings are affected by landscape attributes including tree size and distribution, down wood, and understory vegetation (Ribe 1990). Based on the published literature, we hypothesized that the scenic quality of the six stands we studied (see Chapter 2) would rate as follows: (1) old-growth = high; (2) recent traditional clearcut = low; (3) thinned mature stand = high; (4) small patch cut = high; (5) clearcut with snags and some green trees = low; (6) two-story stand = intermediate. We did not develop hypotheses to predict recreational quality of stands, as prior studies offered little basis for such predictions. However, we did hypothesize that quality ratings would differ between respondents who experienced stand conditions on- versus off-site (photos).

Research Findings

On-site Scenic and Recreational Acceptability Ratings

Survey respondents (n = 95) preferred mature forest stands over young ones. They also favored natural-looking stands over those with obvious human impact, and partially cut stands over clearcuts. Old-growth stands were judged most attractive, the traditional clearcut was least acceptable, and partial cut stands evoked intermediate ratings. Among partial cut stands, the small patch cut was most acceptable; it also had the most standing volume. Acceptability ratings were positively correlated with the percentage of mature timber found in a stand. For example, the two-story stand with its residual 100-yr-old trees was favored over the thinned 40-yr-old stand.

Preference for old-growth was consistent among recreationists partaking in the three major forest activities (scenic viewing, hiking, camping); however, acceptability ratings were not significantly

Table 6-1. Comparison of scenic and hiking and scenic and camping acceptability ratings for different silvicultural treatments.[1]

Survey location/ Silvicultural treatment	Scenic/hiking Difference	Hiking	Scenic	Camping	Scenic/camping Difference
On-site					
Old-growth	-0.3*	3.4	3.1	0.4	+2.7*
Small patch cut	-0.4*	1.8	1.4	-0.0	+1.4*
Two-story (S)	+0.1	0.5	0.6	-0.7	+1.3*
Snag retention clearcut	+0.5*	-0.1	0.4	-1.4	+1.8*
1990 40-yr-old thinning	-0.5*	0.1	-0.4	-1.5	+1.1*
1989 traditional clearcut	-0.1	-1.1	-1.2	-2.7	+1.5*
Off-site (photos)					
Old-growth	+1.0*	2.2	3.2	1.4	+1.8*
Small patch cut	+0.1	1.5	1.6	1.1	+0.5*
Patch cut 2 (J)	+0.3	1.8	2.1	0.8	+1.3*
Patch cut 2 (S)	-0.4*	1.5	1.1	0.4	+0.7*
Two-story (J)	-0.3*	0.2	-0.1	-0.0	-0.1
Two-story (S)	-0.5*	-0.6	-1.1	-1.5	+0.4*
Snag retention clearcut (J)	-0.3*	-0.5	-0.7	-1.3	+0.6*
Snag retention clearcut (S)	-0.4*	-1.1	-1.5	-1.9	+0.4*
1969-79 thinning	+0.2	2.7	2.9	2.3	+0.6*
1990 thinning	+0.4*	0.5	0.9	-0.7	+1.6*
1985 traditional clearcut	+0.5*	0.7	1.2	0.1	+1.1*
1990 traditional clearcut	-0.9*	-0.1	-1.0	-1.3	+0.3*

[1] A Likert-type rating scale was used, where -4 is unacceptable, 0 is neutral, and 4 is acceptable. An asterisk signifies significant different means at $P \leq 0.05$ using the Wilcoxon signed-rank test. (J) = July; (S) = September. (Modified from Brunson and Shelby 1992.)

different between old-growth and small patch cut stands (Table 6-1). For the most part, alternative harvest treatments retaining green trees and snags were judged more favorably than clearcut or traditionally thinned treatments. When all responses were collapsed into acceptable versus unacceptable categories, old-growth, small patch cut, two-story stand, and snag retention clearcuts were all rated "acceptable" by a majority of respondents. This is particularly noteworthy because scenic quality of stands is typically lowest immediately after harvest (Hull and Buhyoff 1986), and these harvests were less than 1-yr-old.

Off-site Scenic and Recreational Acceptability Ratings

Off-site acceptability ratings of the six harvest treatments studied were not consistent with on-site ratings. Slides of snag and green-tree retention treatments were rated lower than their on-site counterparts. Conversely, slides of the commercially thinned stand were rated higher. Follow-up debriefings of participants suggested that several factors influenced scenic quality ratings, most notably the unnatural character of down wood generated from trees topped to create snags. Additional complaints were voiced about the appearance of chain-sawed topped snags, suggesting that other snag creation methods may help mitigate the negative visual effect.

The difference in quality ratings between the on- and off-site phases of this study may be explained in two ways. (1) Photo-based ratings were more likely to be affected by personal characteristics of participants. For example, membership in an environmental organization significantly influenced acceptability judgments of respondents off-site, but not on-site. (2) Photo-based ratings of scenic and recreational quality were influenced by the viewer's familiarity with the forest. Because slides do not provide environmental information equivalent to an on-site visit, people may substitute missing information with knowledge from prior experiences. Without prior experience, slide viewers reacted more negatively to harvest treatments. These findings have important policy and management implications, because the public experiences the forest both on-site when recreating and off-site when viewing photographs or driving by.

Table 6-2. Scenic quality ratings (refer to Table 6-1) for different silvicultural treatments given by participants who accepted or rejected scenic protection payments.[1]

	Scenic quality ratings		
Silvicultural treatment	Accepted (n = 27)	Rejected (n = 14)	Z-score
Clearcut [2]	-3.26	-2.36	1.11
Clearcut no. 1	-2.59	-0.71	2.69*
Clearcut no. 2	-2.85	-0.64	3.11*
Patch cut [2]	-0.82	0.29	1.51
Patch cut no. 1	-0.26	1.36	2.65*
Patch cut no. 2	0.44	0.92	0.97
Two-story [2]	-1.19	-0.29	1.39
Two-story no. 1	-0.15	0.50	0.96
Two-story no. 2	1.00	1.64	1.10
Thinning [2]	1.59	1.71	0.29
Thinning no. 1	2.59	2.64	0.14
Thinning no. 2	2.63	2.50	0.48

[1] Modified from Kimura 1992. An asterisk (*) denotes a significant difference at $P \leq 0.05$ using the Mann-Whitney U Test.

[2] Denotes a backyard scene.

Differences between Scenic and Recreational Quality Ratings

On-site ratings of scenic and hiking quality were significantly higher than those of the same stands for camping quality; even the old-growth stand was rated unacceptable for camping by a majority of respondents (Table 6-2). Scenic and camping quality differed in a statistically significant way in 17 of 18 comparisons, and scenic and hiking quality differed in 13 of 18. Old-growth, thinned, and patch cut stands were rated more acceptable as places to hike than as places for scenic viewing, while the reverse was true for the snag-retention clearcut.

Off-site ratings of hiking and scenic acceptability differed for all stands but the thinning and two patch cuts. Two-story stands and recent clearcuts were rated higher for hiking than scenic views, while the opposite was true for old-growth, thinned, and older clearcut stands. Scenic acceptability judgments were similar to ratings for hiking but not for camping.

Ratings for recreation depended upon a greater number of site attributes than did ratings for scenic acceptability. For example, the quality of hiking and camping was associated more with the traversability of the stand and the presence of attractive views rather than to aspects of biodiversity. This suggests that location of a silvicultural treatment and the presence of trails may influence acceptability as much as treatment type. For example, a small clearcut may enhance recreational quality if it reveals a previously hidden scenic vista. Scenic quality appears to be an important component of recreational quality, but the latter hinges on whether elements of a setting facilitate recreational goals rather than attractiveness alone.

The order of preference for different stands varied only slightly between uses; however, there was a significant difference in mean acceptability depending on whether scenic or recreation quality was being considered. Of the sites judged more acceptable for hiking than scenic viewing, all had trails crossing them. In the off-site phase of the study, hiking ratings were higher than scenic ratings in 17 of the 18 slides that showed a portion of a trail, and lower than scenic ratings for 16 of the 18 slides that showed no trail or road. In general, findings suggest that managers should not regard scenic value as a surrogate for recreation value; rather they should consider silvicultural options that protect or enhance the recreation activities for which a site is most used or best suited.

Attributes Important in Judgments

Influential attributes were identified in two ways. First, respondents were asked directly which descriptors were most influential when they made their judgments. Second, multivariate statistical analysis was used to reduce the matrix of descriptor scale responses to a series of subscales. Scores for each subscale were calculated, then regressed on acceptability ratings to determine which attribute most influenced judgments. The following attribute categories were used:

- Attraction places: has distant vistas, good places to stop and rest.
- Biodiversity: abundant bird life, abundant wildflowers, colorful.
- Canopy closure: bright, closed in.
- Lack of human influence: foot traffic only, natural, pleasant smelling, quiet.
- Microclimate: cool, damp.
- Topography: has flat places, steep.
- Death: dead or dying trees.

Separate regressions were run for each stand and for each use. No subscale was significant for all six stands within any single use. For *scenic* quality, attributes of biodiversity and lack of human influence were most often significant (83% of stands). The presence of dead or dying trees was a detraction within stands that experienced heavy removal of trees, but not within old-growth or patch cut stands. For *hiking* quality, lack of human influence, attraction places, and biodiversity were significant in several stands. Attraction places and lack of human influence also were most influential attributes for *camping* quality.

Stand Features Important in Judgments

Silvicultural treatment acceptability was influenced by several factors that can be physically manipulated (e.g., diversity of overstory trees) as well as others that are independent of stand conditions (e.g., quiet, trail-use regulations). A noteworthy finding was that when snags were visible in photos, their presence was associated with lower scenic quality. This suggests that previously acceptable two-story stands may easily become unacceptable with the addition of snags, despite their benefit to wildlife.

Informational Influence

Information about the purpose of non-traditional forestry practices was associated with more favorable scenic ratings for the two-story stand but not for patch cut or snag-retention clearcut stands.

Role of Respondent Characteristics

Many individuals in the survey visited McDonald-Dunn Forest frequently (73%, n = 69), and others spent the majority of their lives near forests intensively managed for timber (18.2 yr on average). Because survey participants did not represent a cross-section of society, they had demographic characteristics that might significantly affect their value judgments. For instance, individuals with prior employment within the field of forestry (45%, n = 43) were inclined to rate the scenic and recreational quality of harvested stands higher than other participants.

Changes over Time

Since 1990, on-site ratings of the original six stands have been obtained annually from natural resource students enrolled in a lower-division forest recreation course at Oregon State University. Across years, no significant differences in responses have been found for either old-growth or traditional clearcut stands. Old-growth continues to be rated highly acceptable for scenery and hiking, and less acceptable for camping. The large traditional clearcut is consistently rated unacceptable for all three visitor uses. Over time, the thinned stand has become more acceptable for camping, and it now rates higher than the two-story stand. Both scenic and hiking acceptability are deteriorating for the two-story and snag-retention clearcut treatments. Finally, the snag-retention clearcut, which initially was rated more acceptable than the traditional clearcut, is now seen as equally unacceptable. Many of the changes in ratings appear to be tied to vegetation successional changes in the stands as they continue to develop.

Adjacent Landowner Study

Research Strategy

In this study, the following questions guided the research design (Kimura 1992):

(1) Do scenic quality ratings made by adjacent landowners differ by silvicultural treatment?

(2) Are respondents willing to pay for an easement to protect their backyard scenic views?

(3) Are certain silvicultural treatments more palatable to neighboring landowners?

(4) Are scenic ratings of similar silvicultural treatments different between backyards versus unspecified locations?

(5) Is there a quantifiable link between scenic quality ratings and willingness to pay for an easement?

To reduce conflicts and promote compromise, forest managers should seek to understand the values and attitudes of adjacent residents. Urban expansion to the edge of forestlands is creating new forest management problems as homeowners protest effects of timber management on their scenic views. The CFIRP harvests were the focal point of a brief “Not-In-My-Back-Yard” (NIMBY) protest in the fall of 1990 and the scenic protection issue was still salient to many neighbors when they were contacted a year later and asked to participate in this study.

Cortner (1991) identified three types of strategies to resolve urban/forest interface conflicts: information and education, co-operative action, and land acquisition and protection. All strategies require that participants are informed about impacts that forest management can have on local residents and about impacts that residential development can have on forest land owners. Image-capture technology (Bishop and Hull 1991) was used to demonstrate harvest impacts on scenic views, and contingent valuation (Mitchell and Carson 1989) was used to assess scenic value.

Hypotheses

Previous studies suggest that reactions toward forested landscapes depend on attributes of the visual scene (Ribe 1990). This led us to hypothesize that most landowners would be willing to pay for scenic protection measures restricting timber harvest options on adjacent properties, and that scenic quality would be positively correlated with economic value.

Research Findings

Adjacent Landowner Characteristics

Participants in the landowner study had lived at their property an average of 8.4 yr and they intended to remain at their present residence indefinitely. The average property size was 1.9 ha (4.8 ac) and the average length of boundary with the adjacent forest was 149 m (488 ft). Respondents were closely divided between female (57%, n = 23) and male (44%, n = 18).

Scenic Quality Ratings

Of the four harvest methods, landowners preferred thinnings over small patch cut and two-story stands; clearcuts were rated most poorly (Table 6-2). Differences were significant in all cases except between two-story and patch cut stands.

Acceptability ratings of the silvicultural treatments viewed from the backyard setting fell by 11% to 25% from the unspecified setting view. This suggests that individuals willing to accept visual impacts of silvicultural treatments in a general sense may be less willing to accept them in specific valued places. Of the four silvicultural treatments studied as backyard views, only thinning was acceptable for more than half (78%) of the respondents. In addition to silvicultural treatment, certain stand attributes (e.g., stumps, bare ground) affect scenery ratings. Therefore, consideration of the silvicultural treatment in isolation of visual stand characteristics will be insufficient to predict scenic impacts or conflicts with adjacent landowners.

Willingness to Pay for Scenic Easements

A majority of respondents were willing to pay for at least one silvicultural alternative to clearcutting in their backyards. When asked about four hypothetical scenic easements (thinning, patch cut, two-story, original backyard), 14 respondents (34%) refused all payments, 14

(34%) indicated they would make all type of easement payments, and 13 (32%) would only pay for particular easements.

Respondents who refused all payments usually cited expense as the reason, and they differed in several attributes from those willing to pay. Individuals unwilling to pay were less likely to have a buffer on their property, less likely to have considered the adjacent forest as important when they purchased their property, less likely to expect compensation for altered scenic views, and less likely to give clearcuts negative acceptability ratings.

Among landowners willing to pay for an alternative silvicultural treatment, most chose thinning over patch cut and two-story treatments. However, this finding should be viewed with caution because the two thinnings used in this study do not represent the entire range of thinning possibilities or the different successional stages of stand development. In addition, the range of scenes presented may affect ratings of the scenes. For example, if an old-growth stand was included in the evaluation, thinned stands may not have rated as high.

Scenic Acceptability and Willingness to Pay

In general, the 27 respondents who rated scenic quality of the silvicultural treatments lower were more likely to agree to some or all scenic easement payments than the 14 respondents who refused all payments. However, differences were significant only for clearcut and patch cut scenarios in unspecified settings (Table 6-2). These results were surprising given that backyard scenic quality was clearly valuable to the forest-adjacent homeowners in this study. The lack of a clear correlation suggests that scenic quality ratings are complex, and a market-oriented policy may not be the most useful approach for resolving scenic easement disputes between forest owners and neighbors. However, the small sample size of this study prevents definitive conclusions.

Recreation Study

Research Strategy

In this study of recreational users of the Peavy Tract of McDonald-Dunn Forest, the following questions guided the research design (Balfour 1996) :

(1) What are the characteristics of near-urban forest recreationists?

(2) What forest attributes make up the recreational experience and recreational setting for the user?

(3) How are forest management actions perceived by recreationists to influence their experience and setting?

(4) How do recreation quality ratings compare before and after timber harvest?

Before harvest, the prevalence of 120-yr-old trees and small pockets of very large trees made the Peavy Tract reminiscent of an old-growth forest. The visual changes precipitated by the harvest of these stands could cause a change in use patterns and opinions of recreationists. Although a change in visitation intensity between before and after conditions may suggest harvest impacts on recreationists, this information does not provide much guidance for future forest management decisions. Thus, our recreation study attempted to translate visitation numbers into preferences for specific physical components of the forest, for it is physical characteristics of the forest and their associated recreational attributes that can be either protected or modified by management actions.

Hypotheses

Based on previous polls (Finley 1990; Shindler et al. 1993), we hypothesized that the CFIRP harvest would cause negative reactions in after-harvest recreationists. Although recreationists may continue to use a site even after unacceptable changes take place (Clark and Downing 1984), we posed no hypotheses about behavioral changes. Considerable research has already been done indicating that changes in recreation settings can lead to user dissatisfaction, displacement, product shift, and substitution (Shelby et al. 1988; Kuentzel and Heberlein 1992; Brunson and Shelby 1993).

Research Findings

General conclusions of the recreation study are that more frequent users, longer-term residents, and trail users showed the greatest sensitivity to changes in the landscape. Newcomers to McDonald-Dunn Forest were more tolerant of timber harvest and less impacted by harvest scenery than were frequent visitors. These results are consistent with previous studies showing that visitors who fill the void created by earlier users displaced by crowding are more tolerant of existing conditions (Vaske et al. 1980).

Characteristics of Forest Recreationists

McDonald-Dunn Forest recreation visits increased from nearly 38,000 visits per year before the CFIRP harvest to 52,000 visits per year after harvest, but there were few changes in the demographic character of forest visitors. The average age of respondents was 36, and genders were equally represented across sample years. The reported education level did not differ between years, and 65% of respondents had a Bachelor's degree or higher. The average income for both years was between $30,000 and $39,000, and most recreationists worked full-time in education, management, or service occupations. More than half of the forest users had been residents of Corvallis for more than 5 yr, giving them ample time to discover and experience recreation opportunities in the area. In comparison to Corvallis residents as a whole, McDonald-Dunn Forest users tended to be more educated, to have a higher income level, and to be employed in a professional occupation.

Several behavioral changes were noted in the forest users after harvest of the CFIRP stands in the Peavy Tract. First, the main entrance to the Peavy Tract received less use, while auxiliary entrances, especially those near residential areas, received more use. After harvest, repeat users were more likely to make trips shorter (by about 30 minutes) than repeat users contacted before harvest. Sixteen percent of the people contacted pre-harvest were on their first visit to McDonald-Dunn Forest; post-harvest, 27% of the visitors were new. Almost half of all recreationists surveyed before and after harvest had made their first visit within the last 2 yr. This finding is evidence that the boost in use levels post-harvest includes a large group of newcomers not familiar with the forest.

There were three significant differences in user characteristics before and after harvest. First, although the majority of local resident users continued their use after harvest, use by recreationists from out-of-state rose from 6 to 12%. Second, after harvest there was a general shift toward group visitation and fewer people frequented the forest alone. Third, before harvest, 84% said they were members of a conservation organization; this dropped to 52% after harvest. This suggests that a loss or displacement of conservation group members may have occurred after harvest.

Table 6-3. Features and characteristics of McDonald-Dunn Forest rated for importance to enjoyment by recreational visitors. [1]

Forest features and characteristics	1990 Mean (SE)	1991 Mean (SE)
Scenery within the forest area	4.83 (0.02)	4.71 (0.03)**
Peace and quiet	4.78 (0.03)	4.67 (0.03)**
Natural conditions	4.65 (0.03)	4.53 (0.03)*
Hiking trails	4.63 (0.04)	4.54 (0.04)
Solitude	4.46 (0.04)	4.23 (0.04)**
Roads without public traffic	4.36 (0.05)	4.34 (0.04)
Wildlife	4.33 (0.05)	4.23 (0.04)
Close to home	4.13 (0.06)	3.95 (0.06)*
Views of surrounding countryside	4.10 (0.05)	3.96 (0.05)
Easy access	4.04 (0.05)	3.96 (0.05)
Seeing no clearcuts	3.99 (0.07)	3.78 (0.06)*
Signs and trail markers	3.98 (0.05)	3.97 (0.05)
Separate horse and bike trails	3.80 (0.07)	3.78 (0.06)
Challenging terrain	3.76 (0.06)	3.61 (0.05)
Shade and shelter	3.70 (0.06)	3.54 (0.05)*
Drinking water	3.07 (0.07)	2.87 (0.06)*
Public bathrooms	2.92 (0.07)	3.15 (0.06)**
Well-maintained roads	2.83 (0.06)	2.86 (0.06)
Facilities (trash cans, BBQs)	2.31 (0.06)	2.58 (0.06)*
Meeting others	2.23 (0.06)	2.32 (0.05)

[1] Surveys were conducted before (1990) and after (1991) harvest of the CFIRP Peavy stands. Items were rated on a scale of 1 (not important) to 5 (high importance). The total number of responses equaled 384. Means were compared by t-tests where a single asterisk (*) denotes a between-years significant difference at $P < 0.05$ and double asterisks (**) denote differences at $P < 0.01$. Modified from Balfour 1996.

Prior to the CFIRP harvest, most individuals learned about the McDonald-Dunn Forest through word of mouth. After harvest, more people learned of the forest from media sources. CFIRP resulted in an increase in public meetings, announcements, and media coverage that may help to explain the increase in general use levels after harvest and the increase in visits by newcomers. There also was rapid growth in nearby residential areas, so more people in general lived close to the forest after harvest. Finally, the logging activity itself attracted attention because of noise, visual impact, and trail closures.

Importance of Site and Management Actions to the Recreational Experience and Setting

In the recreation survey, visitors were asked to rate McDonald-Dunn Forest as a suitable place for their recreation activity using ordinal rating categories. Before harvest, 93% of respondents provided “best” or “very good” ratings, while after harvest there was a statistically significant downward shift. An open-ended follow-up question asked about the reason behind selected ratings. Good ratings were often associated with statements noting the proximity, access, and good trails of the forest (Table 6-3). Poor ratings were linked to statements noting better scenery elsewhere or trail conflicts, traffic, and noise. There were no changes pre- and post-harvest in the proportion of individuals that identified logging or other forestry activities as the reason for poor recreation ratings.

Before and after harvest, respondents overwhelmingly reported that scenery was important to their recreation experience. When forest setting attributes were rated, strong preferences were shown for scenery, solitude, natural conditions, and wildlife. Yet, visitors felt that multiple-use of the forest was appropriate, and they rated "seeing no clearcuts" of moderate importance. However, this did not prevent recreation on the forest from being rated more poorly by post-harvest users.

As for public involvement, pre- and post-harvest respondents favored joint decision-making. The favored modes of public input were citizen advisory boards, small workshops, public meetings, written submissions, and voting. Approximately 45% of visitors said they were willing to volunteer time to be involved in decision-making processes.

Perceived Influence of Management Actions on the Recreation Experience and Setting

Scenic features that impacted visitor enjoyment were gathered through open-ended questioning. Flowers/ferns, old-growth, and forest atmosphere were positive features noted in 50% of responses before harvest. Detracting features were identified by barely 50% of the respondents; but 48% of these individuals cited forest management activities such as logging/clearcuts, road building, and traffic as impediments (Table 6-4). The biggest change was that after harvest, 16% more people listed logging/clearcutting as a detraction to recreation. This suggests that harvest operations produce negative impacts on recreation pursuits.

Table 6-4. Primary scenic features that detracted from visitor enjoyment of McDonald-Dunn Forest before (1990) and after (1991) harvest of the CFIRP Peavy stands.[1]

	Percent of responses	
Detracting forest features	1990[2]	1991[3]
Logging, clearcuts	29	45
Poor trails/maintenance	13	4
Lack of amenities, maps, signs	12	8
Forestry operations	8	7
Poison oak, nettles	8	5
Other people/their dogs	6	6
Road building	5	8
Heavy traffic/log trucks	5	2
Mountain bikes	4	2
Restrictions	3	2
Horses	3	3
Noise	1	1
Other	4	8

[1] Survey responses were significantly different between years as determined by chi-square analysis ($\chi^2 = 15.15$; $P < 0.01$). Modified from Balfour 1996.

[2] 431 responses.

[3] 392 responses.

During the study, users were questioned about their attitudes towards forest management in relation to their recreational use. Before harvest, 16% said that forest management enhances their use, 52% said that it conflicts with their use, 32% said there was no impact (Table 6-5). Overall, there was no significant difference in user responses after CFIRP harvest. Recreation enhancement was based on improved access and educational opportunities. Recreation conflict resulted from degraded scenery and increased roads, traffic, and noise. References to destroyed scenery increased from 74% to 83% post-harvest. Hikers, bikers, and joggers were more likely to report management/recreation conflicts than equestrians. First time visitors to the forest were more inclined than repeat users to rate management actions neutrally.

Because of the non-random sample of individuals surveyed in this study, the scope of inference for the results may not extend beyond McDonald-Dunn

Table 6-5. Results of the survey to determine effects of forest management on recreational use in McDonald-Dunn Forest.[1]

	Percent of responses	
Questions (Q) and answers	1990	1991
Q1: Forest management directly ... recreational use.[2]		
Answer options:		
A) enhances	16	16
B) conflicts	52	53
C) neither	32	31
Number of responses	378	460
Q2: Forest management "enhances" recreational use because it ...[3]		
Open-ended answers provided:		
A) improves access	40	26
B) is good management	27	32
C) is educational	23	23
D) creates better views	10	19
Number of responses	62	78
Q3: Forest management "conflicts" with recreational use because it ...[4]		
Open-ended answers provided:		
A) destroys scenery	74	83
B) generates roads/traffic	16	11
C) generates noise	10	6
Number of responses	190	240

[1] Participants were questioned before (1990) and after (1991) harvest of the CFIRP Peavy stands. Response differences between years for each question were analyzed by chi-square. (Modified from Balfour 1996.)

[2] $\chi^2 = 0.03$, $P < 0.99$

[3] $\chi^2 = 4.85$, $P < 0.50$

[4] $\chi^2 = 11.9$, $P < 0.02$

Forest. In addition, only summer users of the forest were represented, possibly excluding students who use the forest while classes at Oregon State University are in session. Furthermore, recreationists who filled out surveys before harvest were only re-contacted if they happened to be encountered after harvest.

Management Implications

Non-federal forest managers do not operate under the same stringent multiple-use mandates and legal environmental guidelines as their federal counterparts. They do, however, remain accountable to the public. There are three key characteristics of near-urban forests that promote keen public interest: urban proximity, high level of recreation use, and interest in forest planning/management among users.

Forest neighbors and city residents who use the forest regularly are concerned with scenic issues related to livability. Concern typically percolates out of perceived threats to property values, visual quality, and management activities in places of personal attachment. The public is interested in how decisions are made, and how their interests can be incorporated into forest policy. The convergence of rapid urban outgrowth and an increase in the sense of public ownership in small near-urban forests makes it particularly important for forest managers to include public concerns in management decisions.

It is not a new concept that forest management activities influence interactions between the public and forest managers. Compared to remote federal forests, though, less is known about influences and impacts of management decisions on the public using near-urban forests. Research presented in this chapter provides insight into the complexity of near-urban forest interface issues, and presents social values information that would benefit forest managers in their decision-making.

The forestry profession faces a difficult task in trying to seek better ways to integrate social values with biological and economic objectives of forest management. Research results presented here suggest that the challenge can be better met if social values receive as much attention in research and planning as biological and economic objectives. This integration is particularly important in near-urban forests because they are inextricably linked to the quality of life of local residents, adjacent neighbors, and recreation users alike. Utilizing the information obtained in this study, we provide suggestions for integration below.

Public Consideration in Forest Management Decisions

The three research studies presented in this chapter demonstrate that near-urban forest constituencies (general public, adjacent neighbors, recreationists) are highly sensitive to impacts of silvicultural treatments. It also is evident that alternative silvicultural treatments are capable of producing stands with higher scenic and recreational quality than traditional clearcutting, which is strongly opposed by recreationists.

Respondents in the three studies reported higher amenity values for sites and photos with limited evidence of human manipulation. Managing for naturalness in high use areas or visually sensitive places will require creative silvicultural and non-silvicultural strategies. Small patch cuts may be a viable silvicultural option; they were judged natural by most respondents in the public perceptions study. Furthermore, objectionable woody debris may be removed or concealed by the addition of low ground-cover plants that provide forage for wildlife. Non-silvicultural strategies for maintaining or improving forest naturalness might include, closing roads in and/or around stands with recreation potential, timing harvests for the recreation off-season if there is one, and removing evidence of harvest activities such as landings or flagging.

During follow-up discussions in the public perceptions study, some participants reported rating the snag-retention clearcut higher because of the attractive hillside behind it. This serves as a reminder that just as biological considerations at the stand level cannot be completely separated from the landscape level context (Probst and Crow 1991), neither can scenic judgments be made entirely independent of the surrounding landscape, nor of the broader social context in which they occur. On the other hand, results of the study suggest that scenic and recreational quality should be considered separately when making management decisions, because they are not synonymous. Scenic judgments are based on the aesthetically pleasing arrangement of visual elements, while recreational judgments also include the usefulness of the arrangement for particular activities. It is unfortunate that the distinction between scenic and recreational values of forests largely has been ignored in traditional forest management.

Our results also demonstrate that forest managers should not consider recreational visitation levels alone as the measure of scenic or recreational quality impacts of harvest; it is important to carefully consider all possible explanations for use. Recreation use in the Peavy Tract of McDonald-Dunn Forest increased dramatically 1 yr after the CFIRP harvest, yet there was an overall negative shift in ratings of recreation quality. In deciding to revisit, forest users focused on pragmatic issues associated with proximity and access, overriding dissatisfaction with aesthetics and scenery.

Communication between the Public and Forest Managers

Increase in forest recreational use, continued residential growth, and demographic characteristics of forest users and neighbors all point to increasing pressure on near-urban forests to deliver more recreation and other amenity values. Lessons from other forests suggest that the keys to avoiding the stalemate of conflict and litigation are to integrate all forest values across all levels of the landscape, gather information from local constituents, and use effective public involvement.

Three specific approaches may help to minimize conflict between the public and forest managers without derailing management goals set by planners. The first is to use public notification to take advantage of local public interest. Second, public surveys like the one used in the recreation study help highlight public concerns. Finally, image-capture technology can be used to communicate the visual impacts of different management activities, elicit public comments, and prepare the public for changes in their visual landscape. These various approaches to public communication can help develop and implement silvicultural treatments that mitigate public concerns and earn public support.

Acknowledgments

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Chapter 7. Additional Studies Using CFIRP Treatments: Douglas-fir Genetics and Ambrosia Beetle Log Colonization

Chris C. Maguire, W. Thomas Adams, and Rick G. Kelsey

As highlighted in previous chapters, the primary biological objectives of CFIRP were to assess impacts of diverse silvicultural treatments on vegetation structure and growth and on the abundance and diversity of wildlife. Stand conditions resulting from implementation of the CFIRP research design, however, provided for the overlay of additional research projects that utilized subsets of CFIRP units. Described below are studies focused on genetic ramifications of the CFIRP silvicultural treatments, and chemical and biological interactions between ambrosia beetles (family Scolytidae) and aging Douglas-fir (*Pseudotsuga menziesii*) logs.

Silvicultural Treatments and the Genetics of Douglas-fir

Genetic Diversity

The potential genetic impacts of silvicultural manipulation are numerous and they may precipitate biodiversity changes not only at the stand scale but also at population and landscape scales. Although silvicultural practices can have positive or negative consequences on the genetic composition of managed forests, the research described here focused on potential negative effects.

Dysgenic selection within a stand may occur with silvicultural practices, and managed stands allowed to regenerate naturally may experience reduced genetic variability if only a few parent trees contribute seed to the next generation. Increased inbreeding is also a possibility if wide spacing of leave trees enhances self-fertilization or if mating occurs between neighboring leave trees that are close relatives (Adams and Birkes 1991; Mitton 1992). Dysgenic selection, reduced genetic variability, and increased inbreeding also may occur with artificial regeneration if seeds are collected from limited parents, from isolated trees with restricted outcrossing, from inferior phenotypes, or from trees with genotypes maladapted to the planting site. Although all of these undesirable genetic situations are possible in managed forests, careful attention to the genetic consequences of management practices can ameliorate or prevent them from occurring.

Reduction of genetic variation within tree populations is meaningful because it may lead to increased vulnerability to pest attack and climatic extremes, and to reduced ability of species to evolve in response to changing environments (Ledig 1986; Millar and Libby 1991). Despite the obvious importance of genetic variability for healthy and resilient tree populations, and the concerns expressed among forestry professionals regarding possible negative genetic impacts of forest management (Society of American Foresters 1991), little data are available to objectively assess the potential implications of diverse silvicultural practices on levels of genetic diversity (Savolainen and Kärkkäinen 1992). The research summarized below (Adams et al. 1998) helps fill this information void and adds stand genetic diversity to the varied list of topics tackled under CFIRP. The overall objective of the research was to assess the impact of the three silvicultural treatments (small patch cut, two-story, and clearcut) on the genetic composition of the overstory Douglas-fir left unharvested and of both natural- and artificial-regenerated seedlings.

Research Strategy

Allozymes are various forms of an enzyme that have the same activity but which differ slightly in amino acid sequence; they are produced by different alleles at a single genetic locus. Alleles are genes governing variations of the same trait. Because allozymes are relatively inexpensive to assay, are readily interpretable, provide genetic information at the level of individual genes, and are largely unassociated with patterns of environmental variation, they are widely applicable in genetic studies of forest trees (Adams et al. 1992b). For these reasons, allozymes were chosen to assess the impact of silvicultural treatments on the genetic diversity of seedlings and overstory trees.

Table 7-1. CFIRP stands used to assess genetic diversity of mature and naturally regenerated Douglas-fir among silvicultural treatments.

		Stand number[1]	
Replication (block)	Treatment	Mature trees	Natural regeneration
Saddle	Control	11	—
	Small patch cut	9 & 10[2]	—
	Two-story	2	2
	Clearcut	—	1
Peavy	Control	1	—
	Small patch cut	5	—
	Two-story	4	4
Dunn	Control	5	—
	Small patch cut	7	—
	Two-story	8	8

[1] See Appendix A for stand locations.

[2] Stands were combined and treated as one sample unit.

Eleven stands across all the CFIRP location replicates were chosen for allozyme analysis; Saddle 9 and 10 were combined and treated as a single stand (Table 7-1). Near the center of each of the 10 functional stands, a rectangular sampling plot averaging 6.5 ha (16 ac) was established. In all plots except the clearcut, twigs containing dormant buds were collected in winter 1992-93 from 120 mature trees within each plot (n = 1080). The same winter, dormant buds also were collected from 120 seedlings of each of the seven planting stocks (n = 840; see Chapter 2). Because natural regeneration was poor in the three small patch cuts sampled and in the Peavy and Dunn clearcuts (Ketchum 1995), dormant buds from 120 natural seedlings per plot were collected only from the three two-story replicates and from the Saddle 1 clearcut (n = 480; Table 7-1). Seedling buds were collected during the winters of 1994-95 and 1995-96. Allozyme analyses were performed on bud tissues according to the procedures described by Adams et al. (1990). Twelve enzyme systems (ACO, PGM, PGI, SDH, GDH, GOT, G-6PD, F-EST, 6-PGD, IDH, DIA, and MDH) and 17 loci coding allele variants of these enzymes were assayed.

Three parameters were used to estimate genetic diversity: number of alleles per locus, percentage of polymorphic loci, and expected heterozygosity (the probability that two alleles sampled at random from two individuals in the same population are different). Number of alleles per locus and expected heterozygosity were calculated separately for each locus, then averaged over all 17 loci. Contingency χ^2 statistics were used to test the significance of allele-frequency differences between population samples ($\alpha < 0.01$). The degree of inbreeding was estimated with the fixation index (Nei 1987, p. 155) which equals 0 when there is no inbreeding and is > 0 and ≤ 1 when inbreeding is present. Differences between treatments in gene diversity and inbreeding were tested using t-tests ($\alpha < 0.10$; Steele and Torrie 1980), and the extent of genetic differentiation among populations was evaluated by calculating Nei's (1978) unbiased genetic distance (d). Most calculations were performed using the computer program BIOSYS-1 (Swofford and Selander 1989).

Research Findings

Control Stands

Consistent with earlier reports (Shaw and Allard 1982a; Neale 1985; Moran and Adams 1989), mature Douglas-fir in untreated (i.e., control) stands manifest considerable variation at allozyme loci (Figure 7-1). All loci with the exception of *Gdh* were polymorphic, and up to four alleles were detected per locus. Expected heterozygosity was high, no inbreeding was detected, and genetic differentiation among control populations was small (mean d = 0.0033), with allele frequency heterogeneity significant (*P* < 0.01) at only five loci.

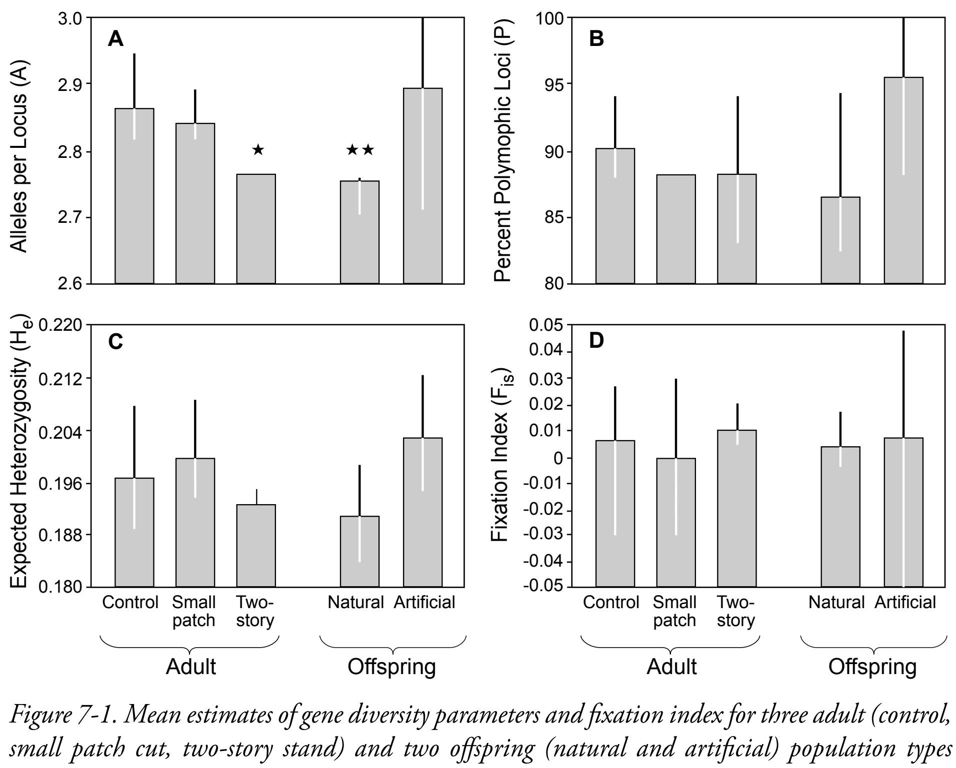

*Figure 7-1. Mean estimates of gene diversity parameters and fixation index for three adult (control, small patch cut, two-story stand) and two offspring (natural and artificial) population types of coastal Douglas-fir growing in the same vicinity. Brackets with each bar give the range over replicates (3 for each adult population type, 4 for natural offspring, 7 for artificial offspring). Based on 17 allozyme loci for gene diversity statistics and 9-11 loci for fixation index (n = 120 for each population replicate). * and ** represent significant differences from the control at P < 0.10 and P < 0.5, respectively). Modified from Adams et al. 1998.*

Post-harvest Overstory Trees

Percent polymorphic loci, expected heterozygosity, and the fixation index were comparable between control trees and residual overstory trees in small patch cut and two-story stands. Cutting the smallest trees in the two-story treatment, however, precipitated the removal of rare alleles such that significantly fewer alleles per locus were observed among residual trees (mean = 2.76) compared with control trees (mean = 2.86). Residual small patch cut and two-story trees differed in allele frequencies from control stands in the same block at an average of only two loci. In addition, genetic distances between control stands and residual trees in the two partial-harvest treatments were very small, averaging 0.0020 for both comparisons. The results suggest that partial harvesting had minimal influence on the genetic composition of mature trees in the treated stands.

Natural Regeneration

Naturally regenerated seedlings had significantly fewer alleles per locus (mean = 2.75) than found in the overstory of the control stands (mean = 2.86), but were similar to the controls in percent polymorphic loci and expected heterozygosity. Apparently, the reduced number of alleles in natural regeneration is simply a reflection of losses in rare alleles due to harvesting, because the number of alleles per locus in naturally regenerated seedlings was nearly the same as observed in their putative parents (remaining overstory trees in the two-story plots, including the one clearcut sampled). Fixation indices were close to zero indicating that inbreeding was insignificant or that inbreds were lost prior to sampling because of poor germination or survival of inbred individuals (Sorensen and Miles 1982). Genetic distances between naturally regenerated seedlings and controls were small (mean d = 0.0028).

Artificial Regeneration

Number of alleles per locus, percentage of polymorphic loci, and expected heterozygosity all were significantly greater in artificially regenerated seedlings than in seedlings regenerated naturally. In comparison with control trees, artificial regeneration had similar numbers of alleles per locus and expected heterozygosity, but larger percentages of loci were polymorphic. Since artificial stocks generally include seeds from multiple and widely scattered stands, it was not unexpected to find greater gene diversity in artificial regeneration than in natural regeneration of individual populations. Fixation indices in artificial regeneration were not significantly different from zero, indicating again that inbreds are rare or non-existent. Genetic distances (mean d = 0.0020) between control trees and artificial regeneration were no greater than observed between controls and naturally-regenerated seedlings.

Conclusions

With the exception of some rare alleles lost in the two-story treatment, harvesting followed by natural regeneration had little impact on the allozyme composition of Douglas-fir stands in this study. Although rare alleles may be deleterious under current environmental conditions (Bongarten et al. 1985; Strauss and Libby 1987; Bush and Smouse 1992), their importance for adaptation in future environments is unknown. Thus, in stands designated as gene conservation reserves and managed under a two-story regime, trees chosen to be left as parents of the next generation should include a range of sizes in order to maximize retention of alleles. The lack of significant changes in all measured levels of genetic diversity, with the exception of rare alleles, suggests that overstory trees would have to be harvested more intensively than in the partially harvested stands in this study before losses in allelic diversity due to genetic drift are detectable. Previous studies reached similar conclusions (Neale 1985; Savolainen and Kärkkäinen 1992).

This study also revealed that artificial regeneration had greater levels of genetic diversity than natural regeneration. Because seeds used in artificial seedling stocks come from a variety of wild stands each with somewhat different allele frequencies, they reflect a genetic range that is greater than that found in any single stand (Adams et al. 1992a). If large numbers of parents consistently are involved in the production of planting stock, regenerated stands will likely possess considerable genetic diversity, and thus, a range of genotypes, including individuals adapted to the extreme conditions that might be experienced during the life of a stand.

Gene Dispersal

Gene dispersal via pollen and seeds has a major influence on the amount and distribution of genetic variation within populations. In addition, the extent of gene dispersal within stands has important practical implications for forest management. The degree of cross-pollination among trees influences the validity of open-pollinated seed lots used for genetic testing of parent trees and the choice of sampling strategies employed in collecting seed for reforestation and gene conservation. The extent of seed dispersal influences the spatial distribution of offspring in natural regeneration. In particular, limited seed dispersal may result in clustering of relatives and subsequent inbreeding in the next generation.

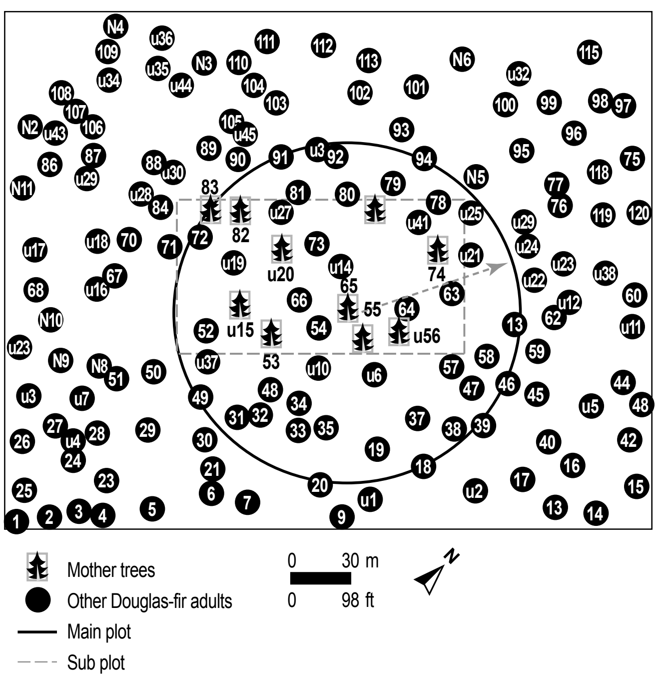

Figure 7-2. Map of the study plot in the Peavy 4 two-story stand showing the location of adult trees. Also shown is an example of a 70-m (230-ft) radius neighborhood for mother tree 65.

Research Strategy

Materials

Effective gene dispersal of Douglas-fir was investigated by applying mating models that account for the composition of allozyme genotypes observed in the offspring of individual mother trees (i.e., pollen dispersal) and seed dispersal models that account for the spatial distribution of offspring genotypes on the ground. The study focused on gene dispersal in the two-story CFIRP stands Saddle 2 and Peavy 4.

All adult trees within large rectangular plots in the two-story stands (n = 99 and 163 trees in Saddle and Peavy, respectively) were mapped according to position using surveying methods (Figure 7-2) and diameters at breast height (DBH) recorded. Density of leave trees in Peavy (29 trees/ha [12 trees/ac], 19 m [62 ft] spacing) was nearly twice that in Saddle (15 trees/ha [6 trees/ac], 26 m [85 ft] spacing). A rectangular subplot was designated within each plot (dashed-line box in Figure 7-2), such that distances from the edge of the subplot to the boundaries of the main plot were always at least 70 m (230 ft). Cones (seeds) were collected in August 1993 from the upper crowns of eight mother trees in the Saddle subplot and 10 trees in the Peavy subplot. These seeds subsequently were used for the pollen dispersal analysis. Seed traps (0.6 m^2 [6.5 ft^2]) were placed on the ground in a grid pattern within each subplot and seed collected throughout the summer, fall, and winter of 1993. These seeds were used for the seed dispersal analysis.

To evaluate pollen and seed dispersal, a subset of seven of the 17 allozyme loci used in the genetic diversity analysis that were highly variable and could be readily scored in both dormant buds (adult trees) and in seeds were utilized. Genotypes of most of the adult trees at these seven loci were available from the genetic diversity analysis, although some additional adults (~60) not sampled previously also were scored. In total, the 7-locus genotypes of 408 seeds from mother trees at Saddle (50–54 seeds per tree), 378 seeds from the mother trees at Peavy (23–55 seeds per tree), and 130 and 157 seeds, respectively, from the Saddle and Peavy seed traps, were determined. The female gametophyte and embryo tissues of the seeds were assayed separately. The female gametophyte is haploid and has the same genetic constitution as the egg cell contributing to the embryo (i.e., female gamete). The diploid embryo has genes from both parents, and by accounting for the mother's contribution with the female gametophyte, the haploid genotype of the pollen grain contributed by the father (i.e., pollen gamete) can be inferred.

Estimation Methods

Gene dispersal models were fitted to the observed frequencies of 7-locus genotypes in the pollen gametes of seeds collected from mother trees in order to estimate levels of self-fertilization and patterns of outcrossing, including distance and direction of effective pollen dispersal. Similar models were applied to genotypic arrays of female gametes in seeds sampled on the ground to estimate effective seed dispersal. The basic model, described for pollen dispersal, is shown in Figure 7-3 (Burczyk et al. 1996). In this model, a circular area around a mother tree (M) is called a neighborhood. The probability of observing 7-locus genotype g_i in the pollen gamete of a seed from this tree is

$$p(g_i) = s\ p(g_i|M) + (1\text{-}m\text{-}s)\ \Sigma\ \phi_j\ p(g_i\ F_j) + m\ p(g_i\ |B),$$

where

s is the proportion of self-fertilized seeds,

m is the proportion of pollen gametes from sources outside the neighborhood,

1-m-s is the proportion of pollen gametes from males within the neighborhood,

ϕ_j is the relative mating success of the j^{th} male within the neighborhood,

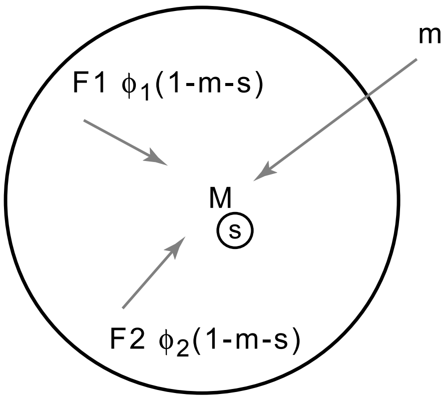

Figure 7-3. Pictorial depiction of the neighborhood model, where the male parentage of the offspring on an individual mother tree (M) is ascribed to three sources: self-fertilization (with probability s), mating with males outside the neighborhood (with probability m), and mating with specific males (F_j) within the neighborhood [with probability (1-s-m)ϕ_j]. Modified from Burczyk et al. 1996.

$p(g_i|M)$ is the probability that the mother tree produces gametes with genotype g_i,

$p(g_i|F_j)$ is the probability that the j^{th} male within the neighborhood produces this gamete, and

$p(g_i|B)$ is the probability that pollen grains produced by sources outside the neighborhood have genotype g_i.

Mating success of males within the neighborhood was assumed to be a function of one or more of the following factors: distance of the male from the mother tree, size (DBH) of the male, and the cardinal direction of the male to the mother tree. An exponential function was used to relate mating success to these factors, with one parameter for each factor (Burczyk et al. 1996). Thus, the largest model we tested for effective pollen dispersal included five parameters: s, m, and β, γ, δ. The latter three parameters related ϕ_j to distance to the mother tree (β), DBH of the male (γ), and cardinal direction of the male to the mother tree (δ). Maximum likelihood methods were used to evaluate the fit of the models (Burczyk et al. 1996). When individual parameter estimates significantly ($P <$ 0.05) increased the likelihood of the model, they were retained in the model and their values reported. Otherwise, the estimated parameters were assumed to equal zero.

For seed dispersal, the center of the neighborhood is the seed trap and the model is modified such that s is deleted, m is the proportion of seeds dispersed into the trap from mother trees outside the neighborhood, and ϕ_j is the relative contribution of the j^{th} mother tree in the neighborhood to seeds in the trap. We chose a distance of 70 m (230 ft) for the radius of the neighborhoods. This radius included an average of 18 trees in the Saddle two-story stand and 45 trees in Peavy. At 70 m (230 ft), the neighborhood radius is only 1.5 to 2 times the height of the adult trees. In retrospect, we wish we had chosen somewhat larger neighborhoods (say 100 m [328 ft]), but the larger the neighborhood radius, the larger the plot size required and the more adult trees that have to be mapped and genotyped. Because the main interest in this study was to evaluate the extent to which mating in natural stands is restricted to near neighbors and the degree to which seed dispersal may be restricted, the size of the neighborhoods was adequate for this purpose.

Research Findings

Effective Pollen Dispersal

In both the Saddle and Peavy two-story stands, the great majority of effective pollen came from sources outside the 70 m (230 ft) neighborhoods (m = 0.89 and 0.74, respectively; Figure 7-4). As expected, m is smaller at Peavy ($P < 0.05$) where tree density is greater and neighborhoods included more males. In both stands, the proportion of selfed (s) offspring was estimated to be zero, which is consistent with the low levels of selfing observed previously in Douglas-fir (El-Kassaby et al. 1981; Shaw and Allard 1982b; Neale and Adams 1985). Mating success of males within neighborhoods was not significantly related to either distance from the mother

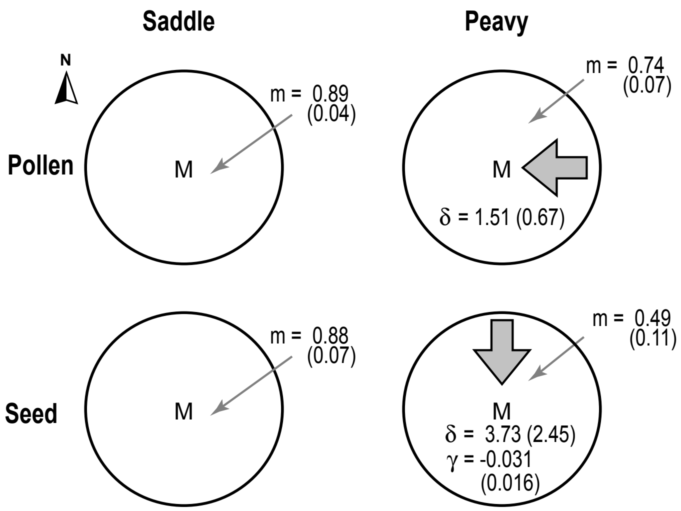

Figure 7-4. Neighborhood model parameter estimates (standard errors in parentheses) for effective pollen and seed dispersal in the Saddle (15 trees/ha; 6 trees/ac) and Peavy (29 trees/ha; 12 trees/ac) two-story stands. m = proportion of pollen gametes in the offspring of mother trees (or seeds in a seed trap) from sources outside the 70-m (230-ft) radius neighborhood. γ and δ are parameters that relate the relative contributions of males (or females) within neighborhoods to pollen gametes (or seeds) depending on their size (DBH) and the cardinal direction to mother trees (or seed traps).

tree or DBH of males (i.e., $\beta = \gamma = 0$). The only deviation from random mating detected within neighborhoods was a tendency at Peavy for males in an easterly direction from mother trees to be more successful in mating than those from other directions (estimated $\sigma = 1.51$). A σ of 1.51 indicates that neighborhood males east of mother trees are 20 times more successful in mating than those west of mother trees. Perhaps this is due to wind direction within the stand during pollen shed, but the standard error on the estimate is large.

Effective Seed Dispersal

Most seed also appears to have come from trees outside the neighborhoods in the Saddle two-story stand (m = 0.88), while about one-half of the seeds sampled at any one location at Peavy came from trees more than 70 m (230 ft) away. The greater density and smaller size of trees at Peavy (mean height = 38 m [125 ft], versus 46 m [151 ft] in Saddle) probably resulted in more limited seed dispersal in this stand. Topography of the two sites may also be a factor. Saddle is on a north-facing slope, while Peavy is on flat terrain. Interestingly, both directionality and size of mother trees significantly influenced seed dispersal at Peavy (i.e., estimates of both γ and σ are significantly different from zero). More seed came from trees north of traps than elsewhere, and from smaller trees than larger trees (because estimated γ is negative). The latter finding is the reverse of expectation because fecundity is expected to be positively associated with tree size. Perhaps smaller trees are more vigorous and responded more readily to release following harvesting.

Conclusions

It is evident that individual mother trees mate with large numbers of males in the two-story stands that were studied. This is consistent with the large genetic diversity and low levels of inbreeding observed in the natural regeneration of these stands (Figure 7-1). Seeds from relatively few females capture much of the genetic diversity in a local population. This means that seed from a relatively small number of trees is adequate to characterize the genetic makeup of a stand in provenance studies or in collections made for gene conservation purposes. In addition, the large number of males mating with each female means that open-pollinated seed lots are adequate for evaluating the breeding value of individual mother trees in progeny tests (i.e., breeding values are not biased because only a few, perhaps unrepresentative, male parents are involved in mating). Broad seed distribution within the two-story stands indicates that natural regeneration under this system does not lead to tight spatial clustering of close relatives and potentially increased inbreeding in the next generation.

Acknowledgments

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Interactions between Ethanol and Ambrosia Beetles in Aging Douglas-fir Logs

Ambrosia beetles (family Scolytidae) help initiate log decomposition by boring into the sapwood where they rear young in excavated egg galleries and cultivate fungi (ambrosia) for food (Dowding 1984; Carpenter et al. 1988; Schowalter et al. 1992). Their pin-hole-size tunnels stained by fungus can cause considerable damage to the wood and decrease economic values of commercial logs and lumber (McLean 1985). Conifer logs in the Pacific Northwest are attacked most heavily by ambrosia beetles in spring, with Douglas-fir and western hemlock (*Tsuga heterophylla*) their preferred hosts (Johnson 1958; Chapman 1961; Zhong and Schowalter 1989).

Ethanol is synthesized in plant tissues by anaerobic respiration when the O_2 supply is inhibited (Kimmerer and MacDonald 1987; Kimmerer and Stringer 1988; Harry and Kimmerer 1991; MacDonald and Kimmerer 1991). Ethanol was found in tissues of aging conifer logs under attack by ambrosia beetles (Cade et al. 1970; Moeck 1970), and subsequent experiments demonstrated ethanol would attract ambrosia beetles to artificial traps (Moeck 1970; Nijholt and Shönherr 1976; Klimetzek et al. 1986; Liu and McLean 1989; Schroeder and Lindelöw 1989). In addition, these beetles may respond synergistically to traps releasing their pheromones in combination with ethanol, or ethanol plus α-pinene, one of the monoterpenes found in most conifer tissues (Vité and Bakke 1979; Borden et al. 1980; Shore and McLean 1983).

Temporal Variability in Ethanol Concentrations and Densities of Ambrosia Beetle Galleries

Despite the economic and ecological impacts of ambrosia beetles and their known response to ethanol, the process of ethanol synthesis and accumulation in logs under field conditions was poorly understood when CFIRP was initiated. Thus, research consistent with the CFIRP design was implemented to determine relative concentrations of ethanol in Douglas-fir logs felled during fall, winter, and spring, and to confirm a relationship between log ethanol concentrations and subsequent densities of ambrosia beetle gallery holes.

Research Strategy

This study was conducted in the Dunn 4 strip cut stand harvested in August 1991. Eighteen Douglas-fir trees destined for snag creation (see Chapter 2) were topped at 15–18 m (50–60 ft) above ground; six trees were topped in November 1991, six in January, and six in March 1992. A 2.4-m (8.0-ft) log was cut and delimbed from the base of each crown the day after felling. Phloem and sapwood samples were then collected with an increment borer along the top, sides, and bottom of each log. These samples were analyzed by gas chromatography to determine ethanol concentrations (see Kelsey 1994a for detailed methodologies). November-felled logs were resampled in January and March, and January-felled logs were resampled in March for ethanol analysis. Densities of *Trypodendron lineatum* and *Gnathotrichus retusus* gallery holes in the sapwood were determined for each log in August 1992. Their entrance holes were separated based on size (Kinghorn 1957).

Research Findings

Ethanol concentrations in tissues from freshly felled logs were similar among dates, but concentrations in the phloem were consistently higher than in sapwood (Figure 7-5; Kelsey 1994a). By January, sapwood ethanol concentrations had increased significantly in November-felled logs with quantities similar to the phloem. After four months on the ground, ethanol concentrations had increased four times in the phloem and 83 times in the sapwood. In contrast, ethanol concentrations in January-felled logs during their first two months on the ground remained unchanged on the tops, and decreased on the bottoms and sides.

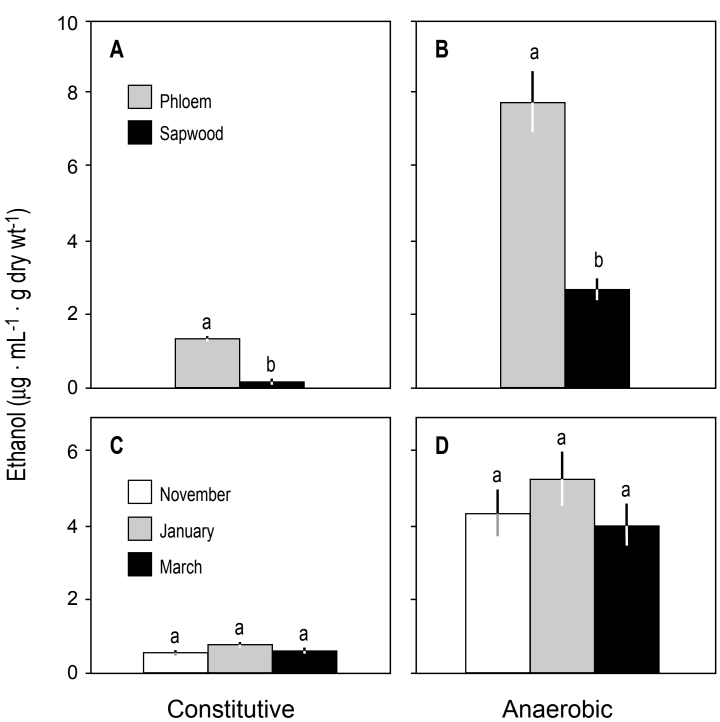

Figure 7-5. Constitutive and anaerobic ethanol concentrations (mean ± standard error) among tissues (A and B, n = 18) and felling dates (C and D, n = 6) from freshly felled logs. Anaerobic concentrations were measured after inducing the tissues to synthesize ethanol by incubating in a N_2 atmosphere for 24 hours at 30°C (86° F). Within each graph, bars with the same lowercase letter are not significantly different (P < 0.5). Modified from Kelsey 1994a.

Ethanol accumulation in November-felled logs indicates their tissues were or had been respiring anaerobically. Because January-felled logs did not accumulate ethanol, but had the potential to do so as indicated by laboratory experiments (Figure 7-5B and C; Kelsey 1994a), something in the environment caused these logs to respond differently. A review of the timing and quantity of rainfall from November to March revealed that November-felled logs received rainfall sooner, more consistently, and in greater quantities than January-felled logs. This most likely contributed to the generation of hypoxic conditions and prolonged periods of anaerobic respiration in November-felled logs. Hypoxic conditions probably were never established in January-felled logs; consequently, they had much lower ethanol concentrations.

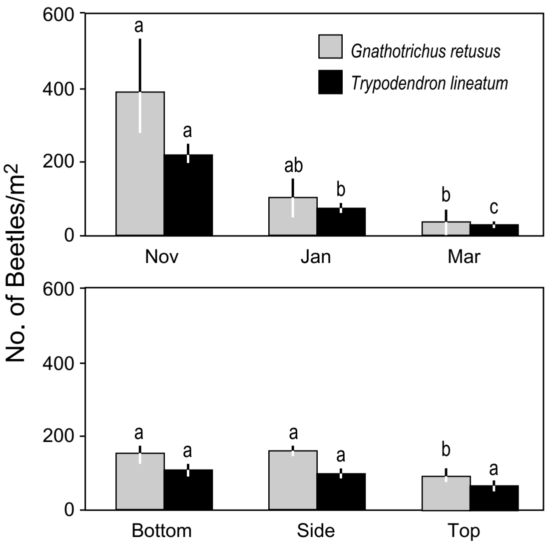

Figure 7-6. August densities of ambrosia beetles (mean ± standard error) in Douglas-fir logs felled the previous November, January, or March (n = 6) and at various positions on the logs (n = 18). Within each graph, bars with the same lowercase letters within species are not significantly different (P < 0.05). Modified from Kelsey 1994a.

When α-pinene is released simultaneously with ethanol, there can be a synergistic attraction of *T. lineatum*, provided α-pinene release rates are not too high (Schroeder and Lindelöw 1989). In March when beetles began to attack, the three age groups of logs differed in their ratio of ethanol/α-pinene concentrations. Phloem and sapwood ratios were 6.5 and 6.1, respectively, for November-felled logs; 0.4 and 0.2 for January-felled logs; and 0.9 and 0.02 for March-felled logs. Thus, November logs had ethanol/α-pinene ratios more attractive to ambrosia beetles.

In August 1992, densities of *T. lineatum* and *G. retusus* were highest in November-felled logs and progressively lower in January- and March-felled logs (Figure 7-6; Kelsey 1994a). Densities of *G. retusus* gallery holes were correlated with ethanol concentrations in the phloem (r^2 = 0.6735) and sapwood (r^2 = 0.731). Densities of *T. lineatum* gallery holes increased with increasing ethanol concentrations up to a maximum and then decreased, suggesting repellency at high ethanol concentrations.

Conclusions

The relationships between log ethanol concentrations and densities of ambrosia beetle galleries are consistent with ethanol functioning as an attack stimulant (McLean and Borden 1977) and as a key factor in ambrosia beetle preference for aging logs. Post-harvest log treatments that minimize ethanol accumulation could reduce attack densities of ambrosia beetles.

Ethanol Accumulation and Densities of Ambrosia Beetle Galleries in Logs with and Without Branches

Observations during the study summarized above, and with logs similarly cut in a second stand nearby, indicated that branched crowns of November-felled logs were only lightly attacked by ambrosia beetles compared to delimbed logs. It was hypothesized that branch retention restricts ethanol accumulation in logs and reduces their attraction of ambrosia beetles. This hypothesis was tested by measuring ethanol concentrations in branched and delimbed logs while they were being attacked and colonized by beetles in May.

Research Strategy

This study was conducted in the Dunn 2 (large patch cut) and Dunn 4 (strip cut) CFIRP stands. In November 1991, the fall after harvest, six Douglas-fir trees within the residual portions of each stand were selected to become wildlife snags, and their crowns felled at 15–18 m (50–60 ft) above ground. The day after felling, a 2.4-m (8.0-ft) log was cut from the base of each crown and delimbed. The remaining portion of crown was left as one long piece with branches attached [mean crown length ± SE was 15.6 ± 1.5 m (51.2 ± 4.9 ft)]. Diameters of delimbed [53.8 ± 3.8 cm (21.2 ± 1.5 in.)] and branched [49.3 ± 3.6 cm (19.4 ± 1.4 in.)] logs were not significantly different. Tissues from all logs were sampled in May to ascertain ethanol, acetaldehyde (the metabolic precursor to ethanol during anaerobic respiration), α-pinene, and water concentrations (see Kelsey 1994b for detailed methodologies). Densities of ambrosia beetle gallery holes in the sapwood were determined for each log in August 1992.

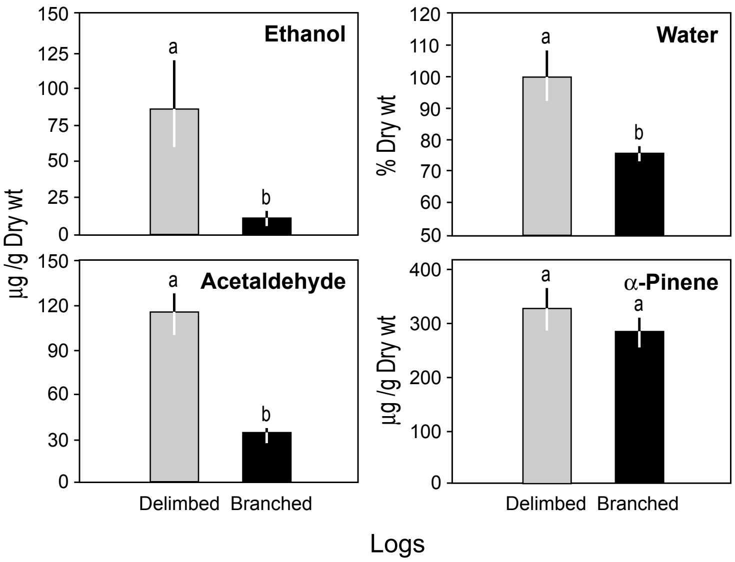

Figure 7-7. Ethanol, acetaldehyde, water, and α-pinene concentrations (mean ± standard error, n = 10) in delimbed and branched logs when sampled in May. Modified from Kelsey 1994b.

Research Findings

Ethanol, acetaldehyde, and water concentrations in delimbed logs were significantly higher than in branched logs, but α-pinene was not (Figure 7-7; Kelsey 1994b). Delimbed logs were attacked by ambrosia beetles in March, whereas attacks on branched logs did not occur until much later. Densities of *T. lineatum* and *G. retusus* galleries in August were 16 and nine times greater, respectively, in delimbed logs than in branched logs (Figure 7-8; Kelsey 1994b). *Trypodendron lineatum* showed no preference for log positions, whereas *G. retusus* attacked the sides more heavily than tops, despite greater quantities of ethanol in log tops than sides. These position preferences are not always consistent across studies (Prebble and Graham 1957; Dyer 1963; Lindgren et al. 1982) and may be related to levels of sunlight logs receive. Multiple regression analyses revealed that densities of *T. lineatum* galleries were best explained by the interaction between ethanol concentrations and log type (branched or unbranched), while densities of *G. retusus* galleries were explained by an interaction between acetaldehyde concentrations and position on the log.

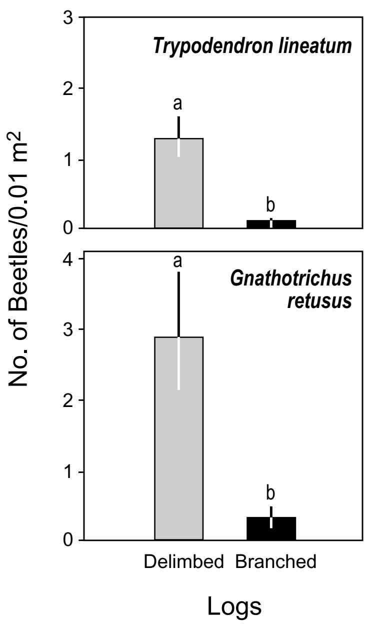

Figure 7-8. August densities of ambrosia beetles (mean ± standard error, n = 10) in delimbed and branched logs felled the previous November. From Kelsey 1994b.

As determined in the temporal variability study described above, rainfall seemed to play an important role in creation and maintenance of hypoxic conditions necessary for ethanol synthesis. Evaporation from needles and twigs probably caused absorbed rain to move through log tissues by capillary action, similar to transpirational water movement in live trees. This lowered the tissue water content in branched logs and apparently interfered with establishment or duration of hypoxic conditions. This limited ethanol accumulation and reduced the densities of ambrosia beetle galleries, in contrast to delimbed logs with higher tissue water and ethanol contents.

A relationship between *G. retusus* attack densities and acetaldehyde concentrations is notable because acetaldehyde has received only minor attention relative to many studies with ethanol. Thus, the response of ambrosia beetles to acetaldehyde released alone, or in combination with ethanol and α-pinene warrants further study.

Conclusions

Differences in log chemistry measured during the initial attack and early colonization of delimbed and branched logs influenced subsequent levels of ambrosia beetle attack. Ethanol appears to be the most important compound, but acetaldehyde also may be involved, particularly for *G. retusus*. In branched logs, a lower tissue water content probably results from translocation and evaporation of absorbed rainwater through the foliage, which apparently limits hypoxia and restricts synthesis of acetaldehyde and ethanol. Branch retention on logs can decrease subsequent ethanol concentrations and densities of ambrosia beetle galleries.

Related Studies on Ethanol Synthesis and Accumulation in Logs and Stumps

The CFIRP studies described above initiated a series of closely related experiments examining ethanol synthesis and accumulation in fall cut logs and stumps, but the more recent studies were not conducted on CFIRP sites. Key results from these experiments are briefly described below because of their relevance to the initial CFIRP work and their implications to forest health, ecology, and management.

Ambrosia beetles prefer to attack and colonize logs of aging Douglas-fir and western hemlock over logs of western redcedar (*Thuja plicata*) and Pacific silver fir (*Abies amabilis*) (Prebble and Graham 1957; Johnson 1958; Chapman 1961, 1963; Zhong and Schowalter 1989), but an explanation for this preference has never been provided. To determine whether ethanol was influencing host species selection by ambrosia beetles, fall cut logs of Douglas-fir, western hemlock, and western redcedar were left in the forest through winter. By early June, logs of Douglas-fir contained 2.1 times more ethanol than western hemlock, and 3.3 to 4.0 times more ethanol than western redcedar (Kelsey and Joseph 1997). Also, densities of ambrosia beetle (*T. lineatum*, *Gnathotrichus retusus*, and *G. sulcatus*) gallery holes were significantly higher in logs of Douglas-fir and western hemlock than in western redcedar. Douglas-fir and western hemlock had similar numbers of beetle galleries even though Douglas-fir tissues contained significantly more ethanol. Beetles seemed unable to discriminate between logs with different ethanol concentrations when ethanol exceeded some threshold concentration. Ethanol and α-pinene accounted for 61% of the variation in gallery densities for *T. lineatum* and 52% of the variation in *Gnathotrichus* species. Ethanol was positively related to densities of beetle galleries, while α-pinene was negatively related. None of the variation in ambrosia beetle attack densities was explained by acetaldehyde concentrations (Kelsey and Joseph 1997).

Various forest insects colonize stumps or roots of stumps following harvest. Some of these insects vector root diseases to healthy trees or stands, and others may damage seedling and sapling regeneration. Stumps of Douglas-fir in western Oregon and ponderosa pine (*Pinus ponderosa*) in central Oregon were created in the fall by various forest management practices (Kelsey and Joseph 1999a). The trees cut varied in age and size, and their stumps were exposed to different environmental conditions through winter and spring. Regardless of these differences, all stumps showed similarities in their synthesis and accumulation of ethanol. By spring, tissues remaining above ground produced three to 116 times more ethanol than tissues in their roots. Above-ground tissues were probably more hypoxic and produced greater quantities of ethanol than roots because of their direct exposure to precipitation and warmer temperature. Ponderosa pine stumps contained two to six times more ethanol than Douglas-fir. Insects that colonize stumps very likely use ethanol as a primary host attractant.

Although precipitation was suspected as an environmental parameter strongly influencing ethanol accumulation in logs and stumps during winter, as discussed above, its function had never been tested directly. To evaluate the role of precipitation in ethanol synthesis, an experiment was initiated with one group of fall cut, delimbed Douglas-fir logs protected from rain (dry logs), and another group of similar logs exposed to rain (wet logs). The following spring, ethanol concentrations in tissues of wet logs were significantly higher than in dry logs (Kelsey and Joseph 1999b). A third group of logs with branches was also exposed to rain. They contained low ethanol concentrations in the spring, similar to dry logs. Again, water evaporating from foliage reduced tissue water content and ethanol concentrations in branched logs. Densities of *Gnathothrichus* species gallery holes in late summer were highest in wet logs where ethanol concentrations had been greatest during spring. These findings confirm that rain is an important environmental factor influencing ethanol accumulation in logs, and further shows that attacks from ambrosia beetles can be manipulated by controlling ethanol production in aging log tissues.

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Chapter 8. CFIRP Management and Research Overview

Chris C. Maguire and Ann Bennett-Rogers

When the College of Forestry Integrated Research Project (CFIRP) was initiated, it was envisioned that the study be long term (100 yr). Detailed harvest planning, however, was restricted to the initial cut, and research projections focused on the immediate years post-harvest. This short-term research strategy provided leeway for future project scientists to consider results of previous studies and to assess impacts of succession and natural disturbance on stand development prior to committing to stand re-entry treatments and accompanying research objectives within the general framework of the original study. Accordingly, the goals of this chapter are to (1) outline results of the first decade of CFIRP research, (2) present an overview of subsequent studies utilizing CFIRP stands, (3) review proposed harvest recommendations for the next phase of CFIRP research, and (4) provide the general management structure of CFIRP, highlighting particular activities that have affected the sites since the initial harvest.

Summary of CFIRP Research: The First Decade

CFIRP was initiated in 1989 to create and/or retain mature forest structure while simultaneously accommodating timber harvest in uneven-aged silvicultural systems designed to reflect natural disturbance patterns. Major research goals were to compare harvest costs and to assess biological and human responses to mature Douglas-fir (*Pseudotsuga menziesii*) control stands versus stands subjected to three structure-retaining silvicultural treatments: clearcuts with reserved green trees (1.2 trees/ha [0.5 trees/ac]), selection cuts promoting two-story stand conditions (75% volume removed), and group-selection cuts of various sizes and shapes (33% volume removed). Economic, biological, and sociological impacts of clumped versus randomly distributed manmade snags (3.8 snags/ha [1.5 snags/ac]) within the treatments also were evaluated. The following is a synopsis of the research objectives for the various studies conducted under CFIRP during its first decade and a recapitulation of the major research findings reviewed in this publication.

Harvest Research

One objective of the harvest study was to compare costs and operational challenges of ground skidding versus cable logging of trees felled by manual chainsaw across three silvicultural treatments (clearcut, two-story, small patch cut). A second objective was to compare costs and operational challenges of cable logging with manual chainsaw felling for five silvicultural treatments (modified clearcut and four types of group selection) and two skyline placement patterns (fan and parallel). Research results revealed that group-selection treatments cost 2.5% more and the two-story treatments cost 16% more to plan and harvest than clearcutting when ground skidding was possible. Cost increases for cable logging group-selection patches ranged from 7% to 32% more than clearcutting, with the highest costs sustained in small patch cut units employing fan skyline roads. A third objective of the harvest research was to quantify the cost of creating and leaving snags. The average cost to create a snag by manually topping a live tree was $35. When the value of the wood left on site as snags was added to snag creation costs, revenue reduction attributed to snags (3.8 snags/ha [1.5 snags/ac]) was $1730/ha ($700/ac).

Vegetation Research

Primary objectives of the vegetation study were to assess tree regeneration and plant community responses to three silvicultural treatments (modified clearcut, two-story, small patch cut) and four vegetation management treatments, and to compare these results with conditions in untreated control stands. Vegetation treatments included herbicide application, manual scalping, and a combination of herbicides and manual scalping plus the installation of vexar tubing to protect seedlings from browse; or vegetation was left untreated. It was shown that understory plant cover returned to pre-harvest levels or greater within the first year following harvest, but species composition changed markedly. An increase in exotic annual herbs dominated the change. Although exotic plants were poorly represented in control stands, they increased to 10% in small patch cuts and to 20% in clearcuts. Additionally, conifer regeneration was successful under all silvicultural treatments, but small patch cuts had the least regrowth. Natural Douglas-fir stocking was prevalent but low, suggesting that natural regeneration is not a reliable regeneration option for the silvicultural treatments examined. Seedlings had similar growth patterns across the vegetation management treatments.

Wildlife Research

The wildlife study compared relative abundances of birds, small mammals, and amphibians across harvested and control stands both pre- and post-treatment. Cavity-nesting bird use of clumped or scattered manmade snags also was quantified under all silvicultural treatments. In general, the wildlife community in group-selection stands was most similar to uncut control stands, and two-story stands were most similar to clearcuts. Although species composition showed a clinal change from least to most disturbed stands (uncut, patch cut, two-story, and clearcut, respectively), two-story stands provided the greatest range of habitat conditions among the treatments studied. Within 5 yr after creation, approximately half of the manmade snags contained excavated cavities. Douglas-fir contained fewer cavities than grand fir (*Abies grandis*), and group-selection stands had fewer cavities than other silvicultural treatments. Snag arrangement did not impact snag use. Large down logs and hardwood trees and snags were identified as important wildlife habitat components.

Social/Recreation Research

Objectives of the research focusing on human responses to CFIRP activities were threefold: (1) determine silvicultural treatment impacts on scenic and recreational quality, (2) assess adjacent landowners' perceptions of the treatments, and (3) examine harvest consequences on forest recreational use. Surveyed individuals preferred mature forest stands over young ones, partially cut stands over clearcuts, and natural-looking stands over those obviously impacted by harvest. However, scenic value was not a surrogate for recreation value. Scenic judgments were based on the aesthetically pleasing arrangement of visual elements, while recreational judgments included the usefulness of the arrangement for particular activities. It also was found that individuals willing to accept visual impacts of silvicultural treatments in a general sense were less willing to accept them when viewed from their backyard in a simulated photo. Additionally, frequent forest visitors were less tolerant of harvest activities than incidental visitors.

Additional CFIRP Studies

In addition to the main CFIRP research projects reviewed above, two additional studies were conducted on CFIRP sites during the first decade. The first study focused on the genetic ramifications of three CFIRP silvicultural treatments (clearcut, two-story, small patch cut); the second study examined chemical and biological interactions between ambrosia beetles (family Scolotidae) and aging Douglas-fir logs. In the genetics study, it was found that harvesting followed by natural regeneration had little impact on the allozyme composition of Douglas-fir stands except for the loss of some rare alleles in the two-story treatment. However, the natural regeneration of two-story stands had large genetic diversity and low levels of inbreeding, suggesting that seeds from relatively few females captured much of the genetic diversity in the local population. When natural regeneration was compared with artificial regeneration, planted trees had greater levels of genetic diversity than naturally-seeded trees.

Results from the log study demonstrated that down wood ethanol concentrations and densities of ambrosia beetle galleries were consistent with ethanol functioning as an attack stimulant. Ambrosia beetles helped initiate log decomposition by boring into the sapwood, and ethanol was synthesized in down logs by anaerobic respiration during decomposition. To decrease ethanol concentrations and parallel densities of destructive ambrosia beetle galleries in logs destined for the mill, this research suggests that branches should be retained on logs until just prior to their removal offsite.

CFIRP Stands: The Second Decade

Procedures to Implement CFIRP Research or Projects

Individuals wishing to utilize CFIRP stands to build upon the initial CFIRP purpose or to implement new activities must first submit their research or project proposal to the CFIRP

Oversight Committee for approval. Information about the Oversight Committee can be obtained from the Academic Coordinator for forest lands under the jurisdiction of the OSU College of Forestry. The Academic Coordinator is located in the College Forests main office, situated in McDonald-Dunn Forest. Following proposal review by the Oversight Committee to ensure that the intended activity does not compromise the long-term nature of CFIRP, the Committee then forwards its recommendation to the OSU College Forests Director for final approval. It is the duty of the Director to insure that the proposed work does not conflict with goals of the McDonald-Dunn Forest.

Research in Progress

(1) Research Title: Linkages among Birds, Arthropods, and Habitat Structure in Western Oregon Douglas-fir Forests

Researchers: Joan C. Hagar[1], Edward Starkey[2], and John C. Tappeiner[1,2,3]. [1]Oregon State University, Department of Forest Science; [2]Oregon State University, Department of Forest Resources; [3]USGS Forest and Rangeland Ecosystem Science Center, Corvallis, Oregon.

Initiation Date: 1998

The objective of this research was to compare patterns of bird abundance and distribution with patterns displayed by their arthropod prey. The study specifically focused on the contribution of understory vegetation to arthropod and bird diversity in conifer-dominated forests. Forest practices influence cover, density, and frequency of understory shrubs; shrub characteristics, in turn, impact shrub-dwelling arthropods. Changes in the abundance and species composition of arthropod communities were hypothesized to influence the distribution and abundance of avian insectivores. Results of this research will further our understanding of trophic relationships among shrubs, insects, and birds in managed forests. This research was conducted on federally managed land in western Oregon in addition to seven CFIRP stands.

Acknowledgments: This research was supported through the Cooperative Forest Ecosystem Research Program with funding provided by the USGS Forest and Rangeland Ecosystem Science Center.

(2) Research Title: Mechanisms of Invasive Plant Success in the Pacific Northwest.

Researchers: Susan C. McDowell and Steven R. Radosevich. Oregon State University, Department of Forest Science.

Initiation Date: 1999

This research was designed to identify the physiological mechanisms by which exotic invasive plants achieve greater competitive success over native species. Two hypotheses were tested. Hypothesis 1: Invasive species have more efficient rates of resource capture than native species (e.g., invasive species may have higher rates of photosynthesis for a given amount of carbon or nitrogen invested in leaf tissue). Hypothesis 2: Invasive species have more efficient allocation of resources among physiological functions, such as growth and reproduction. Native and exotic blackberry (*Rubus*) species growing on four CFIRP stands were the focal plants of the study. Results of this research will further our understanding of the mechanisms involved in successful species invasions, and this information should assist with the more effective management of forest understory species.

(3) Research Title: Influence of Down Wood and Stand Condition on Populations of Small Mammals in Coniferous Forests of the Oregon Coast Range

Researchers: David L. Waldien[1] and John P. Hayes[1,2]. Oregon State University, [1]Department of Fisheries and Wildlife and [2]Department of Forest Science.

Initiation Date: 1999

This research was designed to explore relationships among coarse down wood and stand condition on small mammal population demographics (abundance, survival, age and sex ratios, reproductive condition). The researchers studied small mammals on 21 CFIRP stands representing the four basic CFIRP silvicultural treatments: control (3), small patch cut (6), two-story (6), and clearcut (6). After preliminary estimates of small mammal populations were established, approximately 42 m^3/ha (600 ft^3/ac) of large-diameter down wood was placed by helicopter (during winter 2000–2001) on three clearcut stands and created by falling trees in three small patch cut stands. The volume of wood added reflected recommendations in the Northwest Forest Plan proposed by the Oregon Department of Forestry in 2000. The response of small mammals to this level of down wood was examined through November 2002. Additional studies to examine longer-term effects of the treatments will be conducted in future years. Results from this research will further our understanding of interactions between small mammals and forest structure.

Acknowledgments: This research was supported through the Cooperative Forest Ecosystem Research Program with funding provided by the USGS Forest and Rangeland Ecosystem Science Center, the Oregon State University College of Forestry (COF) Fish and Wildlife Habitat in Managed Forests Research Program, and the discretionary research account of the COF Director of the Forest Research Laboratory.

(4) Research Title: Snag Longevity, Bird Use of Cavities, and Conifer Response across Three Silvicultural Treatments in the Oregon Coast Range

Researchers: Scott T. Walter and Chris C. Maguire. Oregon State University, Department of Forest Science.

Initiation Date: 2001

In managed forests, considerable emphasis is placed on retaining and creating snags for cavity-nester use and in placing green trees in reserve for future snag replacement. This research utilized the 30 harvested CFIRP stands and was designed to assess (1) bird use of 10-yr-old manmade snags created during the initial CFIRP harvest, (2) the 10-yr fall rate of created snags, and (3) post-harvest growth and 10-yr mortality rates of retained green trees. This research will allow for the quantification of snag longevity and green tree mortality in westside Oregon forests subject to different harvest treatments. The data obtained will also increase our ability to effectively manage snags as wildlife habitat and to assess the consequences of partial harvests on the growth and structure of retained green trees.

Acknowledgments: This research was supported by the Oregon State University College of Forestry Fish and Wildlife Habitat in Managed Forests Research Program.

(5) Research Title: Influence of Alternative Silvicultural Practices on Songbirds

Researchers: John P. Hayes and Margo A. Stoddard. Oregon State University, Department of Forest Science.

Initiation Date: 2002

This study was conducted on 21 CFIRP stands to determine the relative influences of clearcutting and two uneven-aged management approaches (group-selection and two-story stands) on abundance and diversity of songbird populations in western Oregon. Response of bird populations to silvicultural treatment during the first 2 yr following harvest was studied by Chambers et al. (1999, *Ecological Applications* 9: 171–185). As structural development of these stands has progressed in the more than 10 yr after treatment, current habitat conditions at the sites differ considerably from those present at the initiation of CFIRP. This increased structural diversity may have important implications to songbirds that were not evident during the initial years following harvest. By examining songbird response one decade after harvest, this study will provide information on longer-term impacts of these management approaches on songbirds.

Acknowledgments: This research was supported by the Oregon State University College of Forestry Fish and Wildlife Habitat in Managed Forests Research Program.

(6) Project Title: College of Forestry Integrated Research Project: Interpretive Trail

Participants: Kristen Babbs and Ann Bennett-Rogers. Oregon State University, College of Forestry, College Forests.

Initiation Date: 1999

Motivation for this project grew out of public concern for the environmentally, economically, and socially sound management of forest resources. Phase one of this project emphasized the development of an interpretive trail through select CFIRP stands in the Peavy replication (Figure 8-1) representing the four silvicultural treatments, and the production of activities based

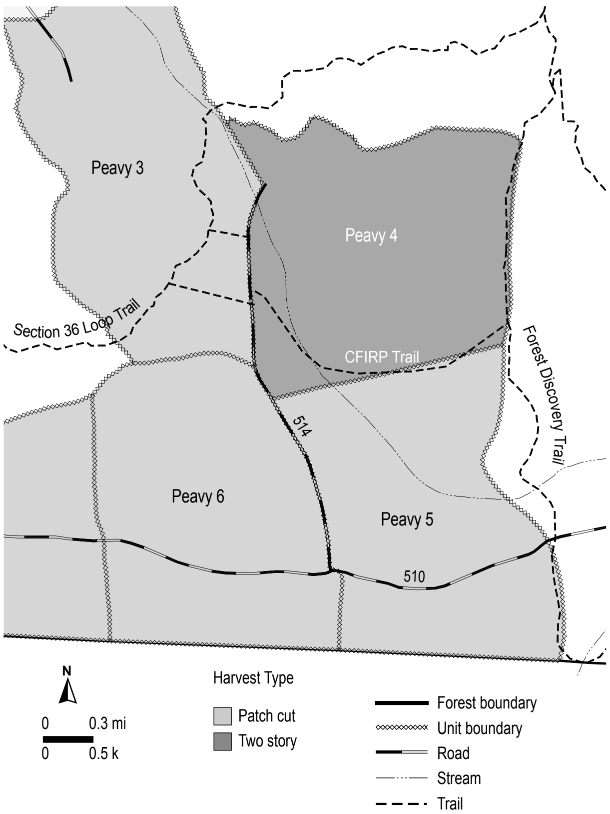


Figure 8-1. Map of the CFIRP trail located in the Peavy replication.

on the first decade of CFIRP research to be employed in educational outreach for grades K-12. A K-12 self-guided education kit was completed in 2000 that utilizes CFIRP as an educational model for better understanding the integration of forest management, environmental protection, and economic development; the education kit is available from the College Forests office. Phase two of the project focuses on the construction of self-guided interpretive kiosks and sign-boards along the CFIRP trail. Project completion is dependent on funding.

Future Research Recommendations

When CFIRP was implemented, there was general consensus among the researchers and College of Forestry administration that re-entry into the stands for additional harvest would not occur earlier than 10 yr following the initial cut. With the exception of this time-frame agreement, no future research plan nor implementation schedule was formally outlined until 2-yr post-harvest (in 1993) when a future treatments recommendation was forwarded to the College Administrative Committee by researchers associated with or interested in the long-term potential of CFIRP. Over the years, additional harvest scenarios have been suggested and they reflect a variety of research objectives. Following is a summary of proposed future harvest recommendations, an overview of general research goals that the CFIRP Committee has identified that should be met with each harvest, and a recommended monitoring plan.

Future Harvests

Initial CFIRP logging plans for the group-selection stands within Peavy and Dunn location replicates were devised for a three-entry cutting cycle, with one-third of the stand to be harvested during each entry (see Chapter 3). The researchers who initiated CFIRP envisioned that the second cutting entry would not occur for at least one decade following the first entry. It also was perceived that additional harvest of two-story and clearcut stands would be limited early on to selective thinning when appropriate, but that overstory trees retained during the first entry would remain unharvested indefinitely. The original intent of the two-story treatment was to produce a coarse-scale disturbance that would allow for development of a stand with old-growth features in a reduced time period. Retained trees in clearcuts were designed to provide a future source of snags and to add structure to the stands as they develop.

Since the initial CFIRP harvest, several second-entry harvest proposals have been put forth for group-selection stands. One proposal recommends that the forest matrix in group-selection stands be thinned in the near future, prior to or in conjunction with an entry to remove the second set of patches outlined in the initial logging plans. A second proposal advocates expanding current patches rather than creating new ones. Other proposals consider various combinations of thinning, new patches, and expanding patches within stands and across replicates. In addition, the need exists to pre-commercially thin regeneration in all 30 treated stands. The ideal is to have all CFIRP harvests occur in the context of a multi-disciplinary research framework. If it is not possible to couple research with harvest, sensible silvicultural approaches should continue to be initiated and properly maintained so as not to limit further research opportunities. There is, however, considerable flexibility in when silvicultural treatments are implemented.

As of this writing, procedures have been established to install permanent vegetation plots within all CFIRP units and to plan for a second harvest. The nature of the harvest will emerge from discussions between the CFIRP Harvest Planning Coordinator, the CFIRP Oversight Committee, and individuals interested in CFIRP research opportunities. Once a future research direction is agreed upon, a 5-yr management plan will be drafted and implemented.

General Research Goals

The CFIRP Oversight Committee has discussed basic research objectives that should be met each time CFIRP stands are harvested. Because one of the major objectives of CFIRP was to explore silvicultural options representing a range of disturbance conditions that were reflective of wildlife habitat requisites while maintaining forest productivity and providing positive economic returns, vegetation and wildlife remain important focus groups in CFIRP. The most desirable situation is to have each harvest preceded and followed by wildlife and vegetation assessments comparable to those undertaken during the initial CFIRP research reported in this volume. At a minimum, sampling should include assessments of small mammals, breeding birds, and cavity nesters, and surveys that will document growth and mortality rates of regeneration and residual trees. Pre-treatment sampling prior to all future harvests serves two purposes: (1) to document the development of CFIRP stands a defined period of time after the initial harvest that can be compared with the immediate post-harvest results reported here, and (2) to serve as a comparative base against post-harvest conditions each time an entry occurs.

Because the practical implementation of alternative silvicultural treatments is strongly tied not only to investment returns (based on tree growth) but also to harvest costs of initial and subsequent entries, the CFIRP Oversight Committee also has identified harvest planning and cost analysis research as a critical study component each time CFIRP stands are harvested. Silvicultural treatments like those of CFIRP that incorporate green-tree retention and seek to retain snags through time likely have a high cost of implementation associated with them because of the additional measures needed during harvest operations to minimize damage to retained structures and to ensure worker safety. Well-designed studies that compare costs across initial silvicultural treatments and subsequent entries are rare; therefore, the continuance of CFIRP harvest studies during future stand treatments will provide currently unavailable comparative economic information that forest managers desire.

Although there is good reason to couple all CFIRP harvest operations with the basic research elements outlined above, a variety of supplemental studies can benefit from CFIRP site qualities during the interim between periodic cutting cycles. Current projects meeting this criterion were outlined in Section II above.

Recommended Monitoring

The research outlined in this summary publication concerns initial responses of vegetation, wildlife, and people to the CFIRP silvicultural treatments. As CFIRP reached the 10-yr post-harvest milestone in 2001, it became evident that certain data should be collected routinely regardless of harvest schedules to capture potential temporal fluctuations in species responses and stand conditions to treatments. The CFIRP Oversight Committee has identified the following forest ecosystem features as focal elements of a monitoring program: (1) snag condition and use by avian species (recommended assessment every 5 yr); (2) small mammal, amphibian, and bird abundance (recommended assessment every 5–10 yr); and (3) condition of retained green trees (recommended assessment every 5–10 yr). Ideally, basic information on tree growth and yield and the condition of regeneration will be gathered regularly as part of the established forest inventory. It is recognized that a timely and complete monitoring program is not likely to occur without stable funding.

Project Management

CFIRP Oversight Committee

To ensure the research integrity of CFIRP sites through time, to provide a central body to track activities associated with or having impacts on the sites, and to plan for the next phase of research, a CFIRP Oversight Committee within the College of Forestry was appointed in 1997. Prior to initiating research on CFIRP stands or proceeding with any management activities that may impact the stands, individuals are required to contact the Committee for operating approval. The maintenance of an open dialogue between the Committee, researchers, and managers ensures that the research integrity and potential of the sites is not compromised, that projects do not conflict, and that all functions involving CFIRP are recorded.

Research Data Bank

The collection and deposition of data into a single data bank is critical when multiple studies unite under a single research project and data from any study impacts the interpretation of data from a concurrent or a future study. Recognizing that CFIRP is a large long-term project with numerous sub-components, data collected in the context of the main CFIRP design are stored in the Forest Science Data Bank, a repository for large interdisciplinary and multidisciplinary data sets generated during research projects that have involved Forest Science researchers. Future researchers continuing the CFIRP mission may have access to past data sets by contacting the Forest Science Data Bank Systems Manager.

Buffer Policy

When harvest treatments initially were imposed on CFIRP stands, no buffer zone around the periphery of stands was defined or established. As a consequence of this original study design, when the issue of a buffer policy for CFIRP emerged in 1997 as a result of proposed harvest activities adjacent to CFIRP units, the CFIRP Committee agreed to retain the no-buffer status of the project regardless of the management activity or harvest intensity that might be associated with neighboring stands in the future.

Vegetation Control

Following the initial harvest, conifer seedlings were planted to reforest harvested CFIRP stands (see Chapter 2). To prevent regeneration competition as the stands mature, shrubs and hardwoods routinely are controlled with herbicides. The schedule and level of herbicide application is determined by the Reforestation Forester of the College Forests, and depends on the extent of competition observed and the reforestation requirements of the Oregon Forest Practices Act. Therefore, there is no uniform treatment of competing vegetation across time across all CFIRP stands. A file containing the schedule of herbicide applications is maintained and updated by the Reforestation Forester.

Salvage

The original CFIRP design included a snag distribution component (see Chapters 2 and 5). The majority of snags were generated by topping live trees, and the severed crowns served as dead wood input to the forest floor. Other than the criterion that the severed crowns be retained on site, no additional down wood guidelines were outlined for the future of the project. As residual trees have blown down through time, particularly in some two-story stands, it became evident that a salvage policy was required.

In large part because the initial project design did not include a down wood research objective, the CFIRP Committee, in consultation with the Forest staff, elected to manage down wood in a manner consistent with the McDonald-Dunn Forest Plan, with two exceptions. Down wood created from a significant blow down event amounting to more than the retention levels outlined in the Forest Plan can only be salvaged if the salvage operation does not conflict with research in progress or significantly impact the integrity of the site. Thus, salvage on the edge of units is most feasible, while salvage in the interior largely depends on the proximity of an established skid trail. Additional logging corridors will not be created within CFIRP units to provide for salvage activities.

When salvage is considered, the Forest staff notifies the CFIRP Committee of their intent to salvage, and provides the Committee with a quantitative assessment of the amount of down wood available and an outline of the salvage operation. The CFIRP Committee may make a site visit prior to approving salvage operations. A record of all CFIRP salvage is maintained in the College Forests office. As of 2003, salvage had occurred in Peavy 3, Saddle 7, and Saddle 8.

Large Down Wood Addition

In spring 2001, large down wood was added to six CFIRP stands to accommodate a coarse woody debris project (see Current Research #3, this chapter). Five mature Douglas-fir trees were felled in three small patch stands (Saddle 3, Peavy 3, Dunn 7) and left on site. An additional five mature Douglas-fir obtained from non-CFIRP sites were helicopter placed on three CFIRP clearcuts (Saddle 8, Peavy 2, Dunn 3). The down wood treatment target was 138 m^3/ha (600 ft^3/ac) within the area of study. GPS coordinates were obtained for each log and are available from the College Forests office.

Hazard Trees

On occasion, a CFIRP tree poses a hazard to forest workers or visitors. This typically is a tree near the edge of a unit that develops a lean across an hiking trail or road. Hazard trees are identified by the Forest staff and details concerning the hazard are conveyed to the CFIRP Committee. The fate of hazard trees, usually salvage or disposal into the unit, is determined following a dialogue between Forest staff and the CFIRP Committee. A record of removed hazard trees is maintained by the Assistant Director of the College Forests.

Stump Disposal

During spring 1998, approximately two-dozen large volume stumps excavated from a McDonald-Dunn Forest road construction project were deposited on the landing at the end of the 552 Road that passes through the Peavy 10 two-story unit and terminates at the upper end of the Peavy 11 clearcut unit. The stumps were relocated with the option of burning them in the fall or leaving them for wildlife habitat. Because CFIRP units do not have peripheral buffers nor is down wood managed for consistency in amount or placement, and because McDonald-Dunn Forest in general has low volumes of down wood, the CFIRP Committee approved the deposition of the stumps and recommended that they not be burned. The stumps were not burned.

Road Construction

In the winter of 1998, the 440 Road within the Dunn block of CFIRP experienced severe failure after a series of major rain events. After evaluation by the Forest staff, it was determined that the failed portion of the road had a high probability of experiencing future failures due to unstable soils. In consultation with and with approval of the CFIRP Committee, the decision was made to retire the failed portion of road and to facilitate maintenance of the integrity of the road system in the area by linking the 400 Road with the 440 Road west of the road failure via an extension of the 400 Road through the Dunn 3 clearcut (Figure 8-2). A small section of the extension would isolate approximately 0.4 ha (1 ac) of the north tip of Dunn 3 from the remainder of the unit. Despite the location of a permanent vegetation sampling point within the isolated area, the CFIRP Committee voted to exclude this portion of Dunn

3 from future participation in the CFIRP study, with total management control reverting back to McDonald-Dunn staff. The unstable section of the 440 Road was decommissioned in 2000 and construction to extend the 400 Road occurred in 2001.

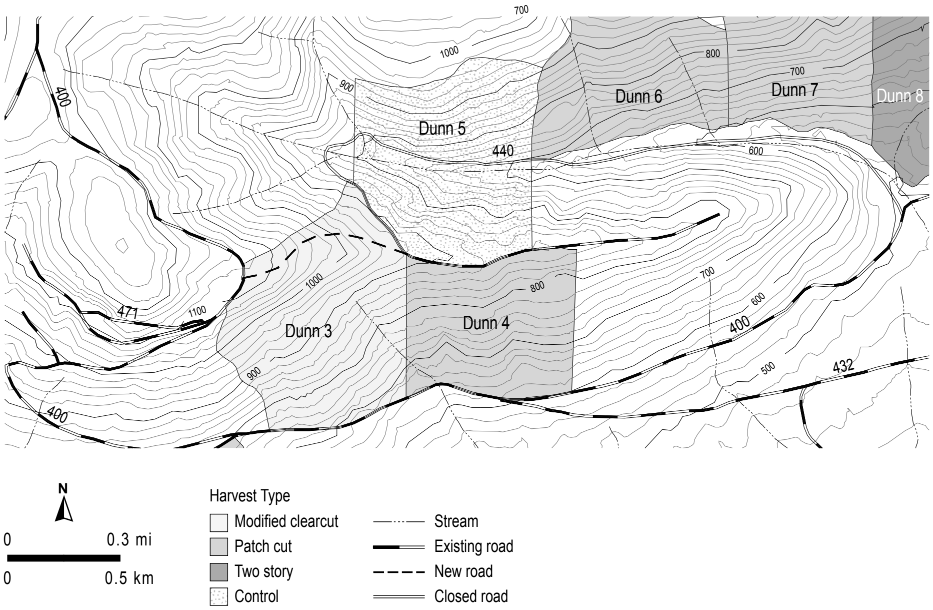
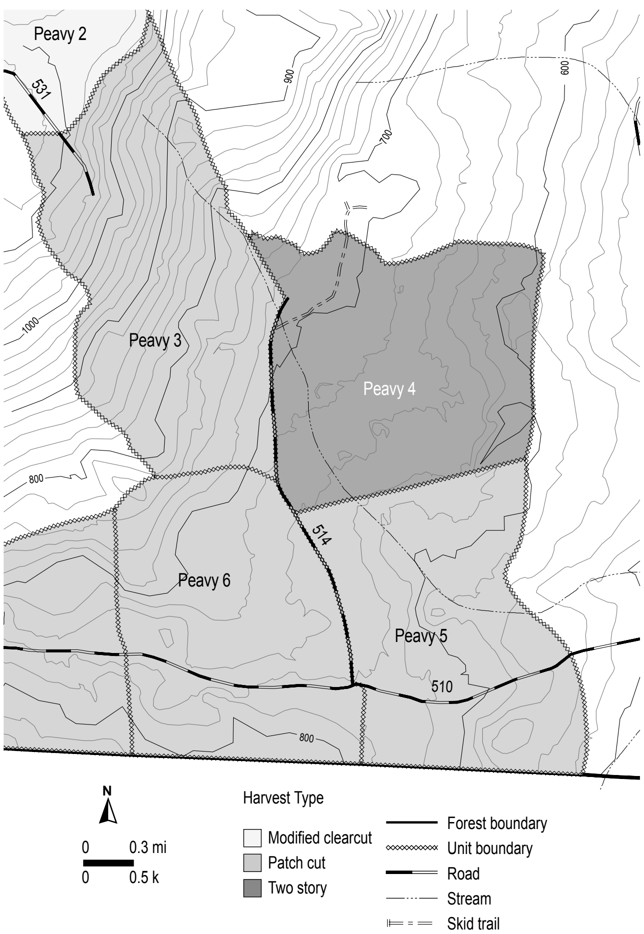


Figure 8-2. Location of the 440 Road closure on McDonald-Dunn Forest and the route of the 400 Road extension through the Dunn 3 clearcut. The 0.4-ha (1-ac) section of the north tip of Dunn 3 that was removed from future CFIRP status as a result of the road extension also is noted.

Skid Trail Extension

Harvest on the Woodpecker timber sale adjacent to CFIRP two-story stand Peavy 4 occurred in summer 1999. To provide for efficient removal of felled timber from the extreme south-west corner of the sale area, a skid trail approximately 213-m (700-ft) long and 3-m (10-ft) wide was constructed in the north-west corner of Peavy 4, linking the Woodpecker sale with an established CFIRP skid trail (Figure 8-3). This skid trail extension provided a direct haul route to the 514 Road. Although tree regeneration was sacrificed along the route of the extended skid trail, the CFIRP Committee determined that the benefits of the haul route through Peavy 4 far outweighed the minimal potential research information lost in the sacrificed seedlings and the road area taken out of productivity.



CFIRP Trail

Hundreds of individuals visit the CFIRP stands each year. Many visitors come as participants in organized field trips, but others encounter the stands during recreational activities in McDonald-Dunn Forest. To provide for a more educational experience when visiting the sites, a CFIRP Interpretive Trail was established in 1999. The trail is located in the Peavy block west of the Forestry Club Cabin and intersects with other established trails in the Forest (Figure 8-1).

Figure 8-3. Location of a 1999 skidtrail placed in the Peavy 4 two-story stand to facilitate timber removal on an adjacent timber sale area. The skidtreail linked with an established CFIRP skidtrail and was approximately 213-m (700-ft) long and 3-m (10-ft) wide.

Pending future funding, information kiosks will be constructed along the trail route to allow individuals to have a self-learning experience about the major research findings of CFIRP.

Memorandum of Understanding with College of Agriculture

When CFIRP was implemented, the Dunn 1 two-story and the Dunn 2 large patch-cut stand were under the jurisdiction of the College of Agriculture, although they were managed by the College Forests staff within the College of Forestry. In 1999, the Colleges of Forestry and Agriculture began to explore options to entrust both management and jurisdiction of the stands to the College of Forestry. Negotiations resulted in both Colleges agreeing to a land exchange involving stands with value comparable to the production potential of the two CFIRP units on College of Agriculture land (Figure 8-4). Dunn 1 and Dunn 2 penetrate into valuable grazing land and several days of winter grazing did occur on the two stands in 1997 and 1999; consequently, these two units are now fenced to prevent cattle from entering the sites.

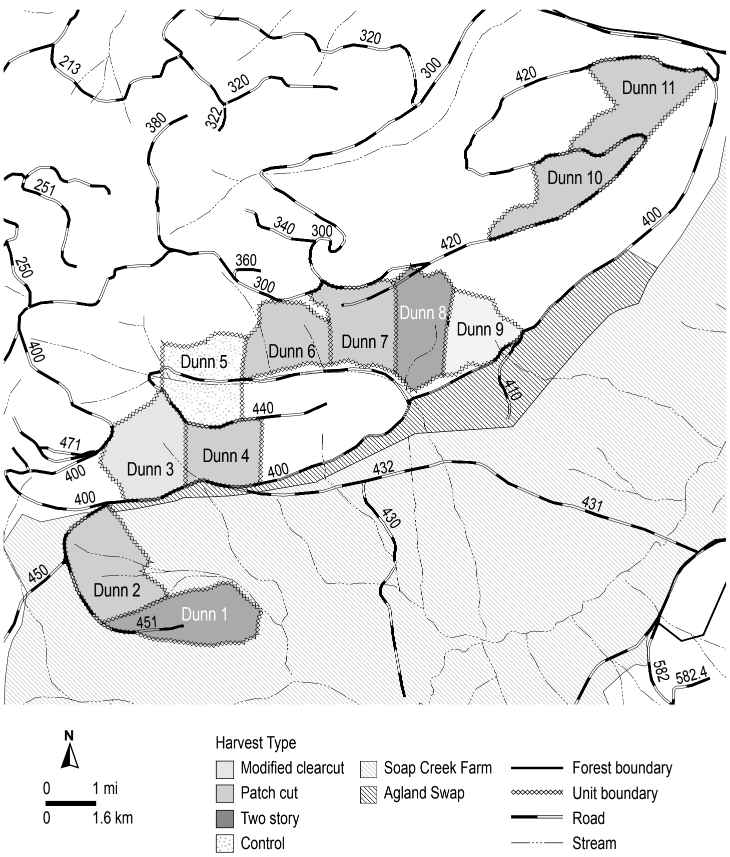


Figure 8-4. Location of the 2000 land exchange between the College of Forestry and the College of Agriculture resulting in Dunn 1 (two-story) and Dunn 2 (large patch cut) being relegated to College of Forestry ownership. Fences were constructed around the two stands to prevent cattle entry.

Appendix A. Location of silvicultural treatments within each of the three CFIRP location replicates: (1) Saddle, (2) Peavy, and (3) Dunn

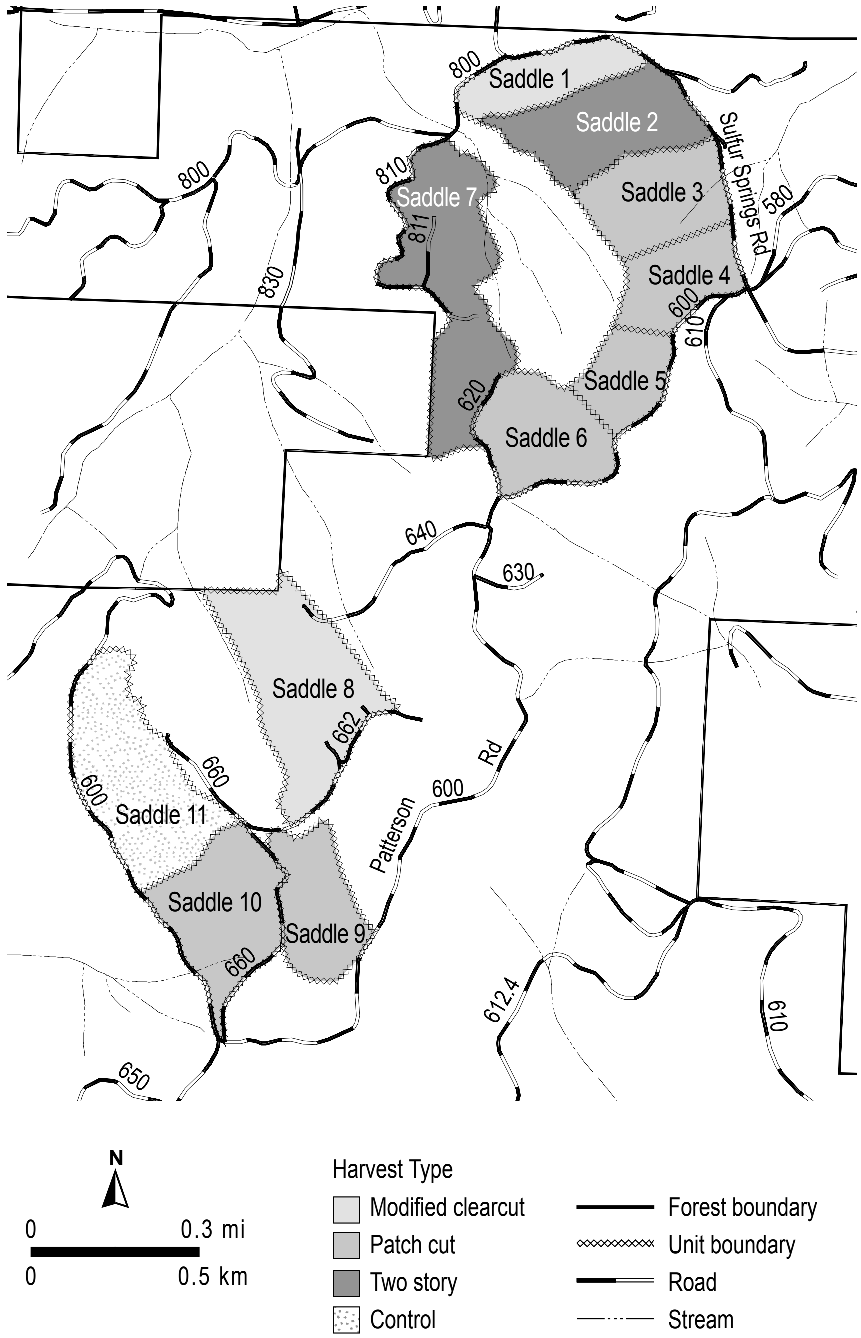


Figure A-1. Saddle, McDonald-Dunn Forest.

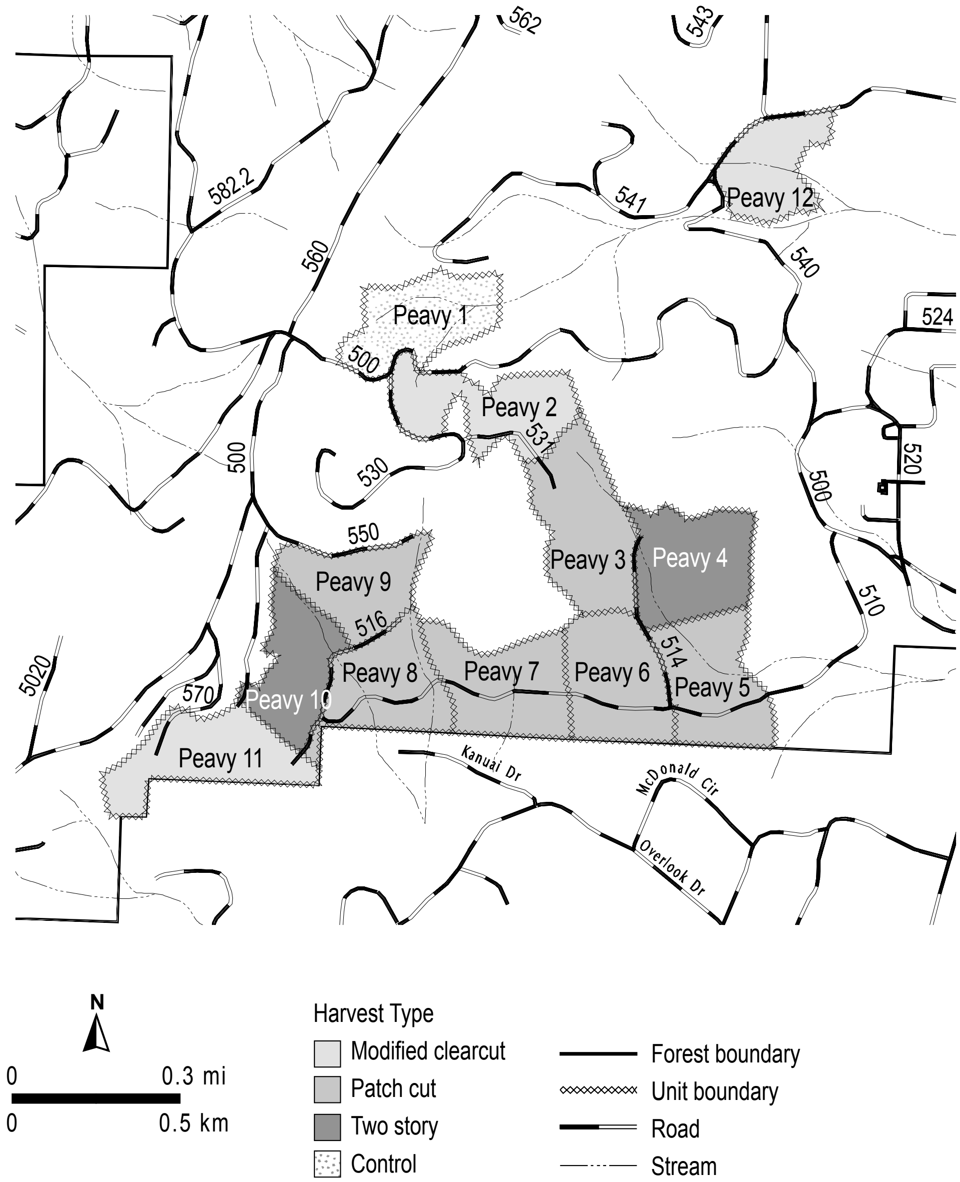


Figure A-2. Peavy, McDonald-Dunn Forest.

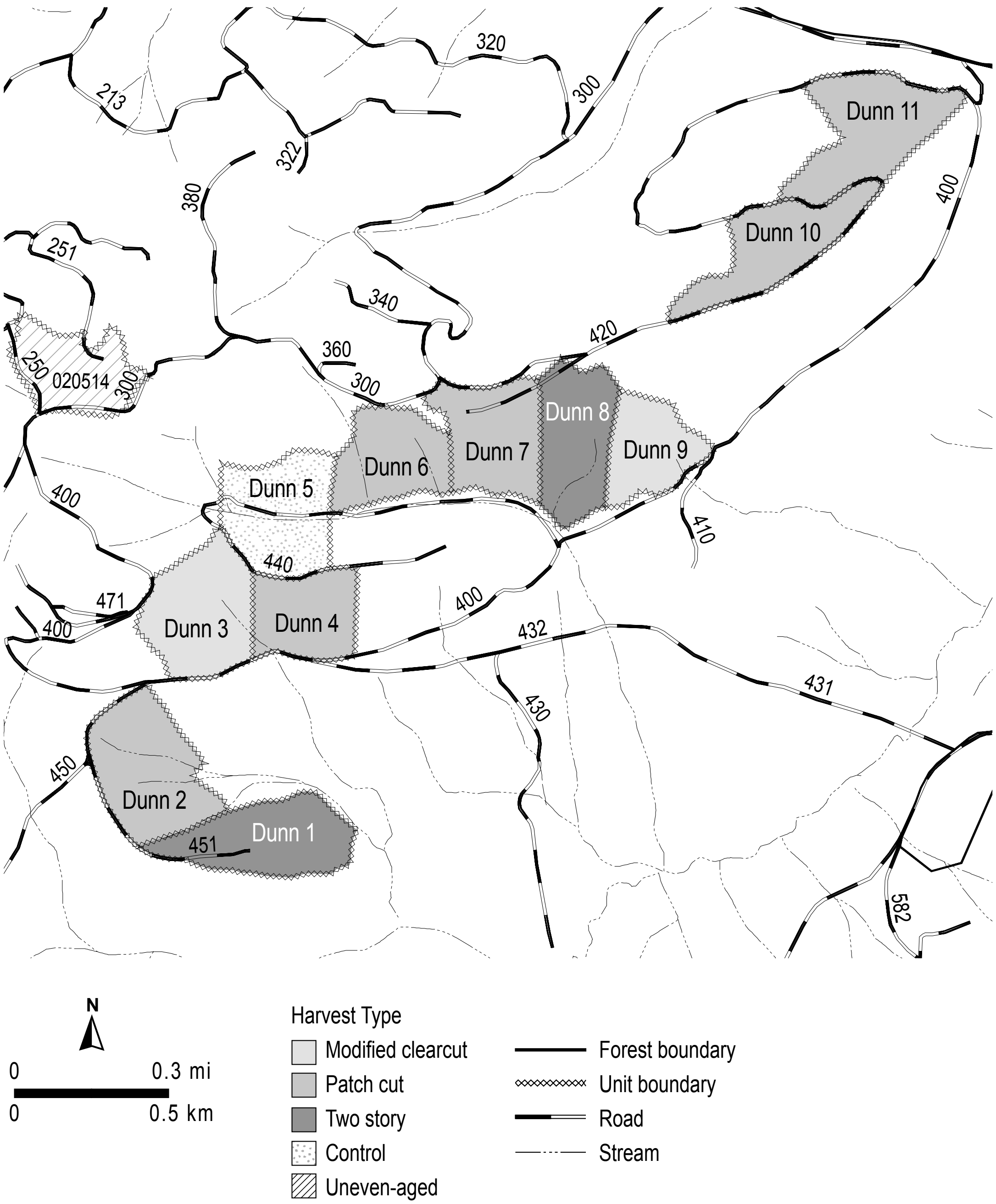


Figure A-3. Dunn, McDonald-Dunn Forest.

Appendix B. CFIRP Stand Locations of Patch Cuts, Created Snags, and Variable Circular Plots (VCP), with Reference Points used in the Wildlife Studies

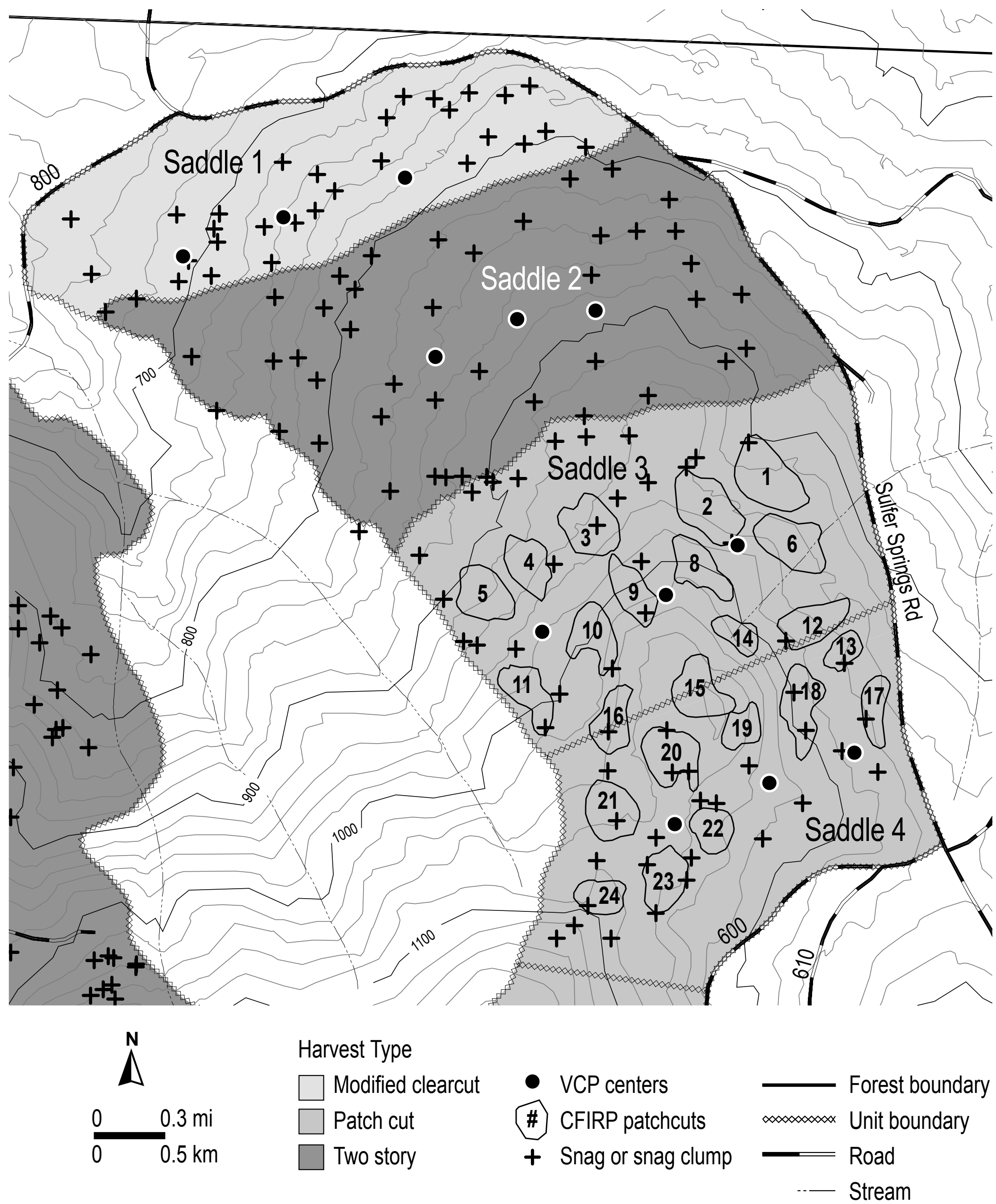


Figure B-1. Saddle 1, 2, 3, and 4, McDonald-Dunn Forest.

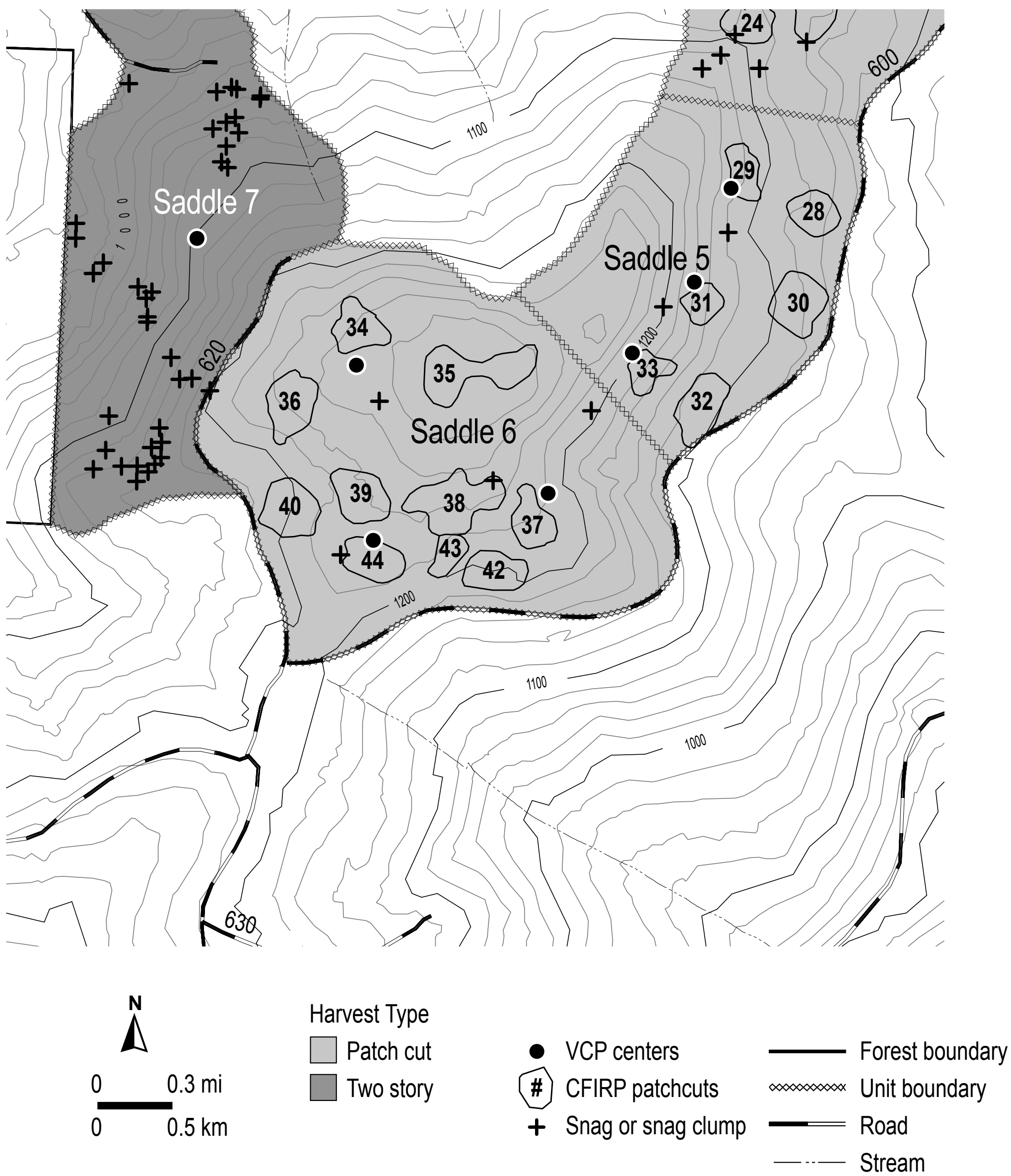


Figure B-2. Saddle 5 and 6, McDonald-Dunn Forest.

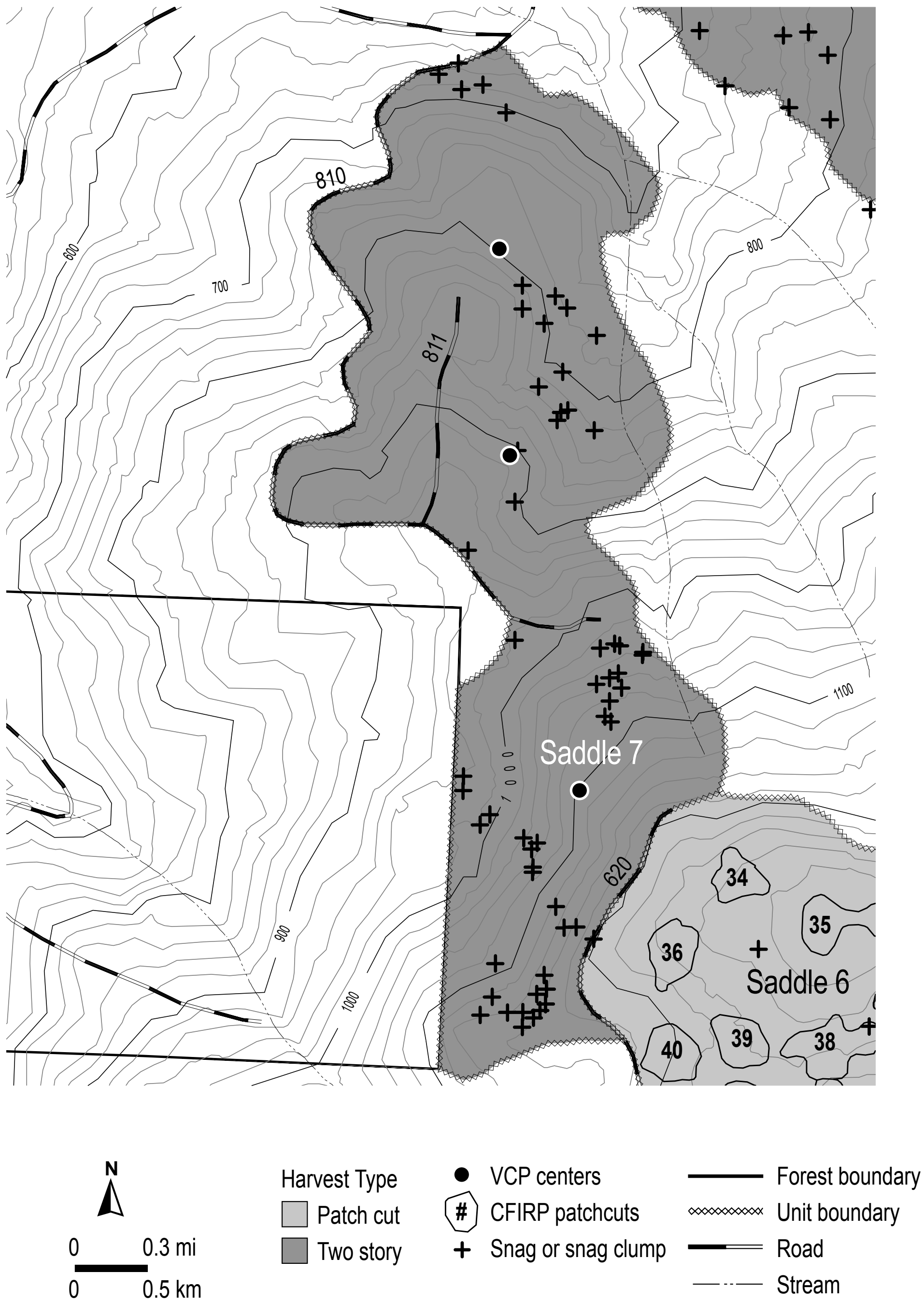


Figure B-3. Saddle 7, McDonald-Dunn Forest.

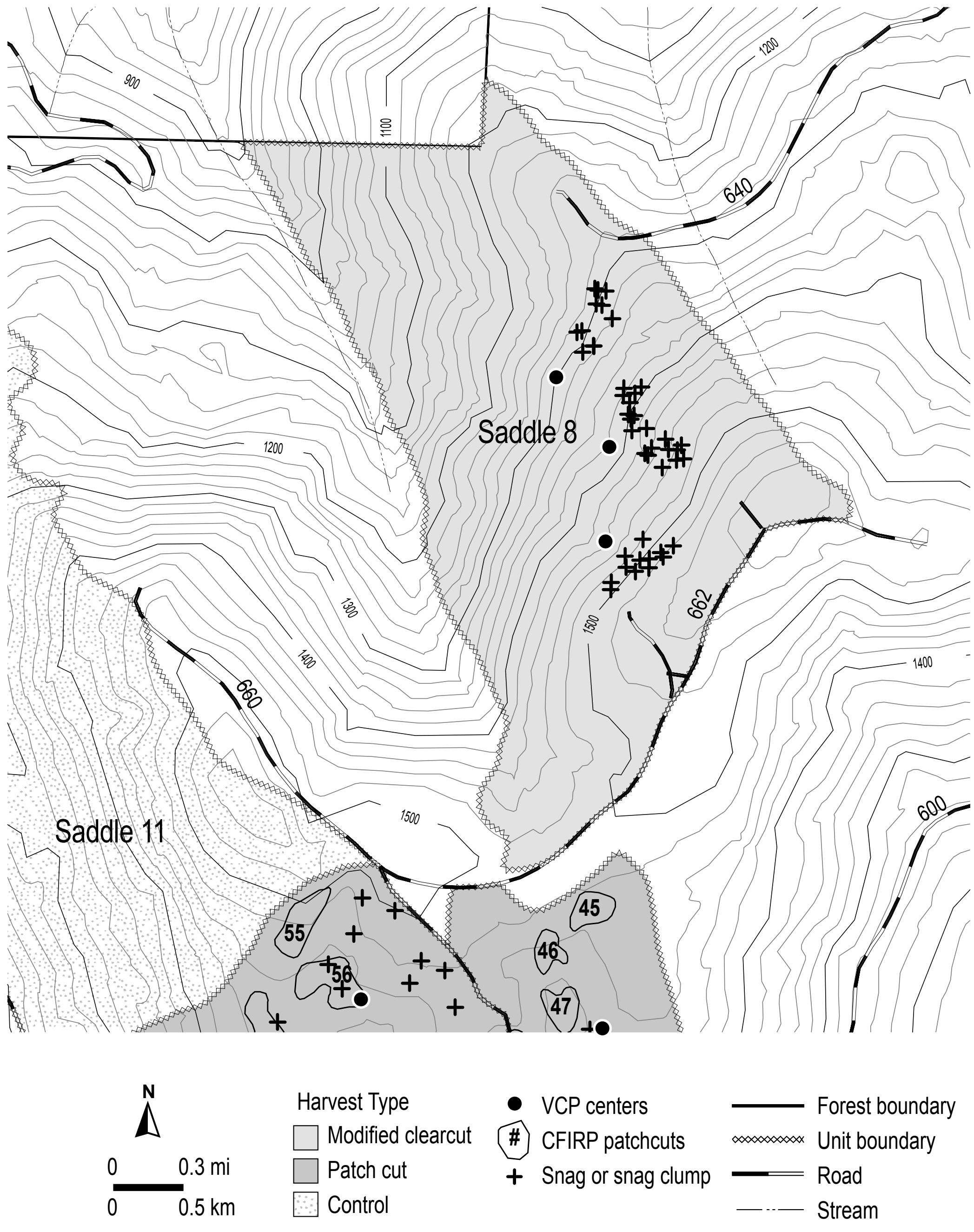


Figure B-4. Saddle 8, McDonald-Dunn Forest.

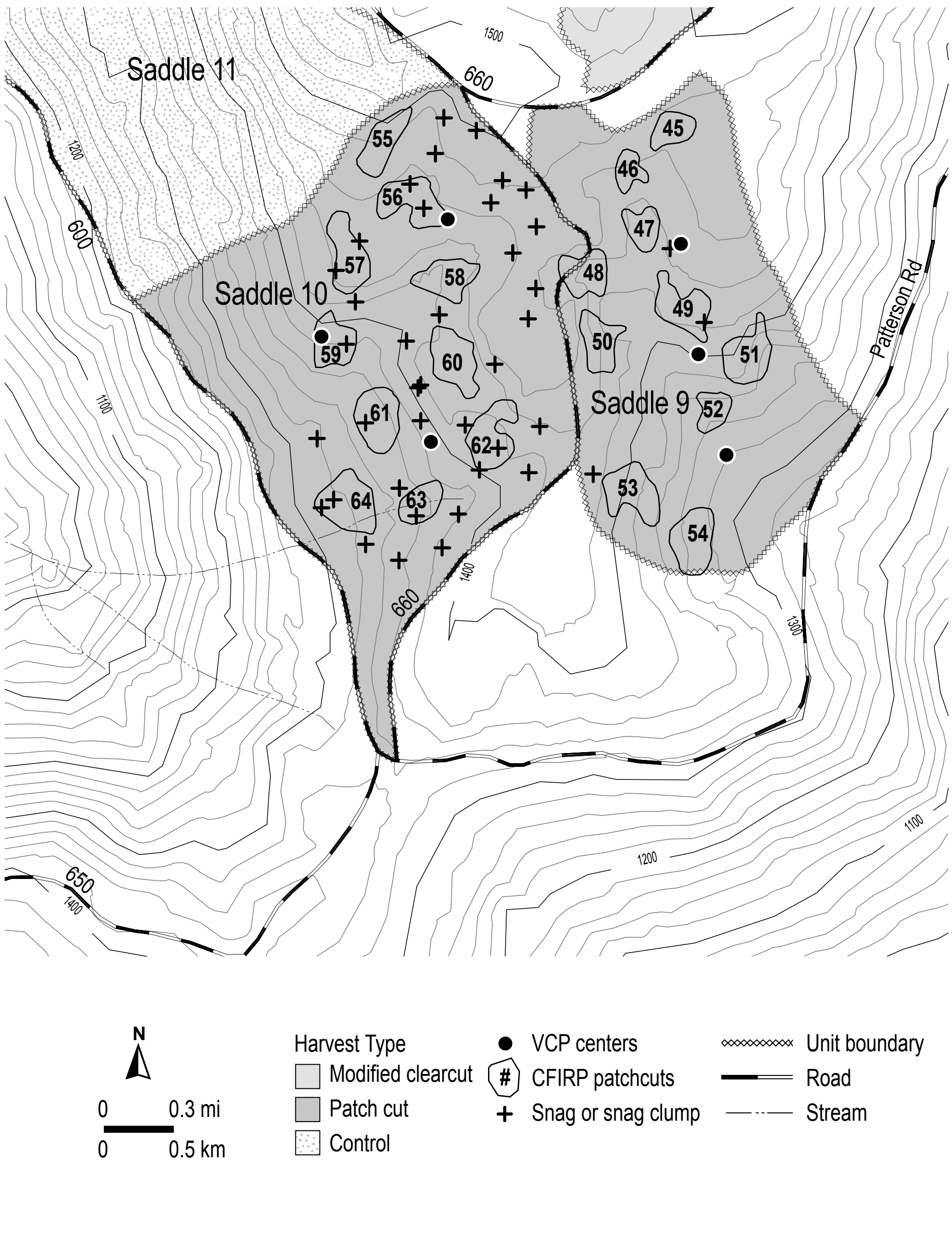


Figure B-5. Saddle 9 and 10, McDonald-Dunn Forest.

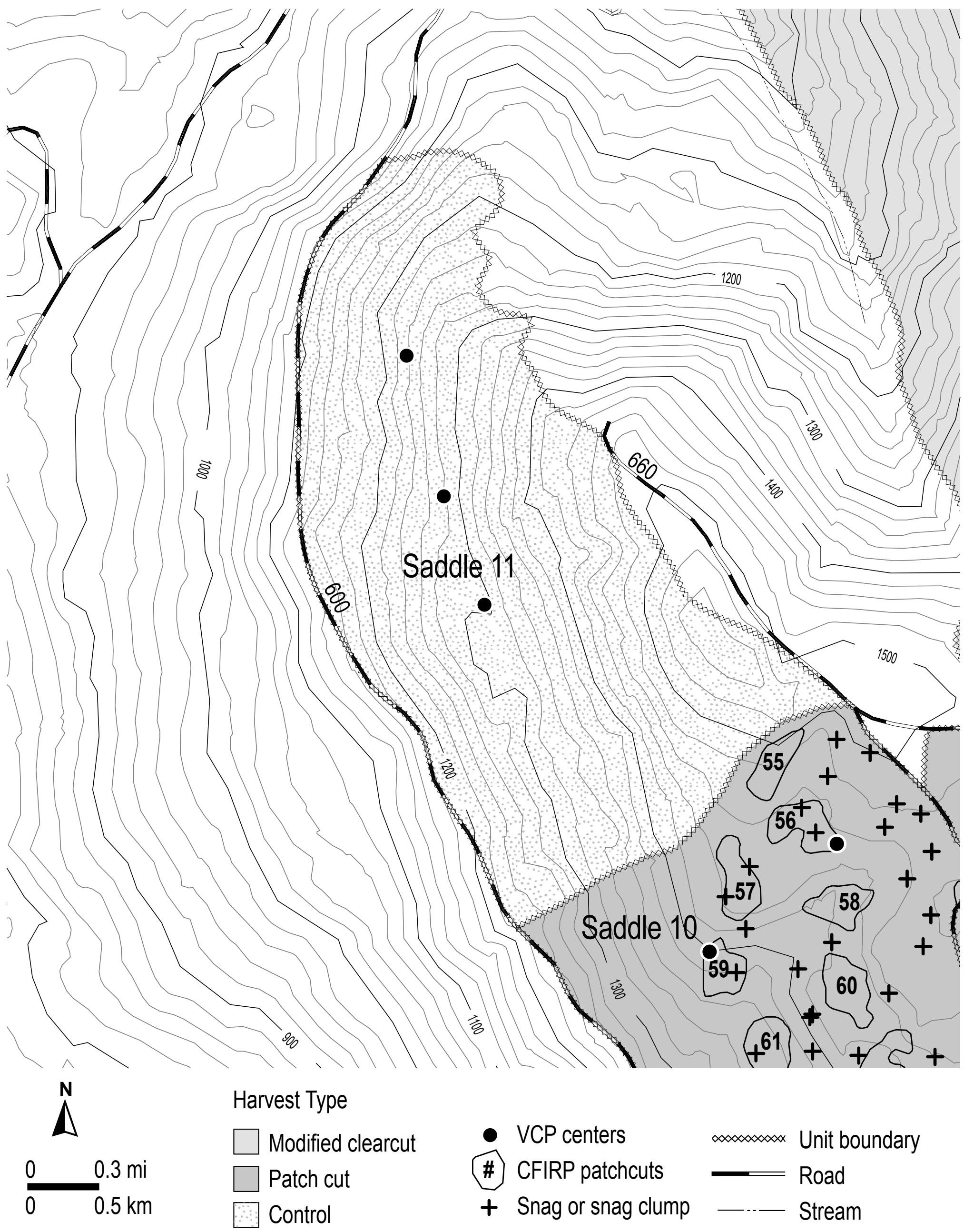


Figure B-6. Saddle 11, McDonald-Dunn Forest.

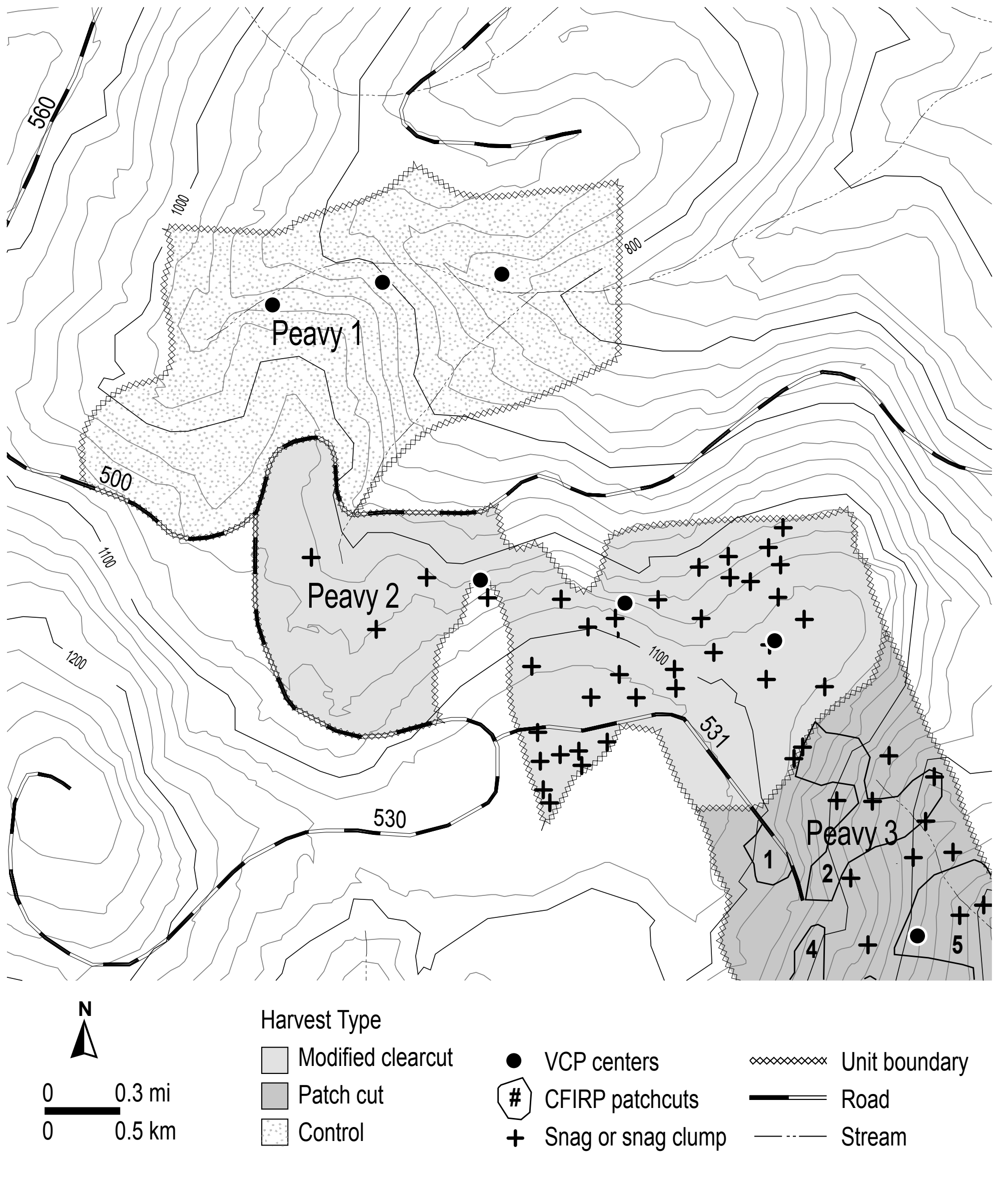


Figure B-7. Peavy 1 and 2, McDonald-Dunn Forest.

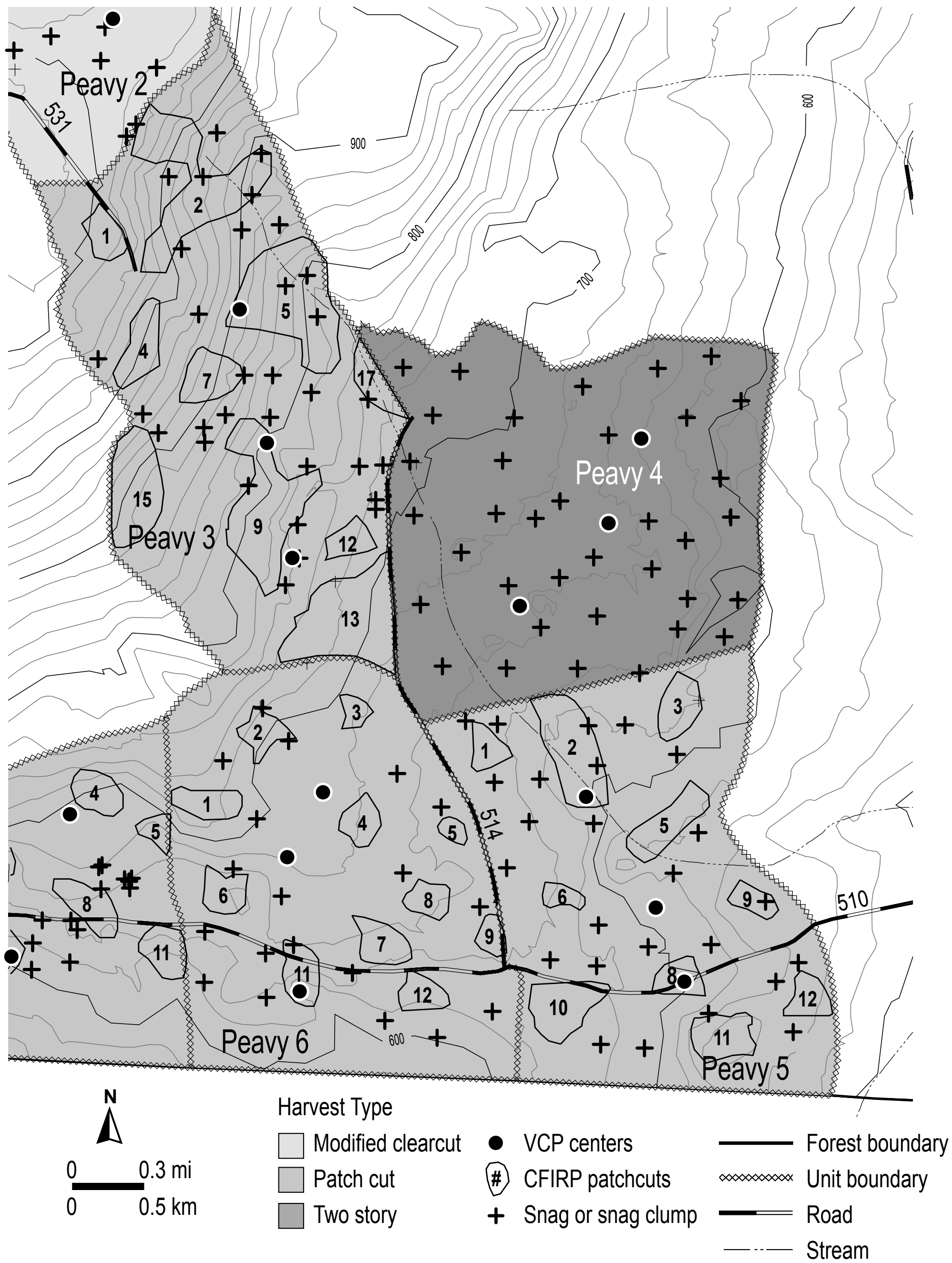


Figure B-8. Peavy 3, 4, 5, and 6, McDonald-Dunn Forest.

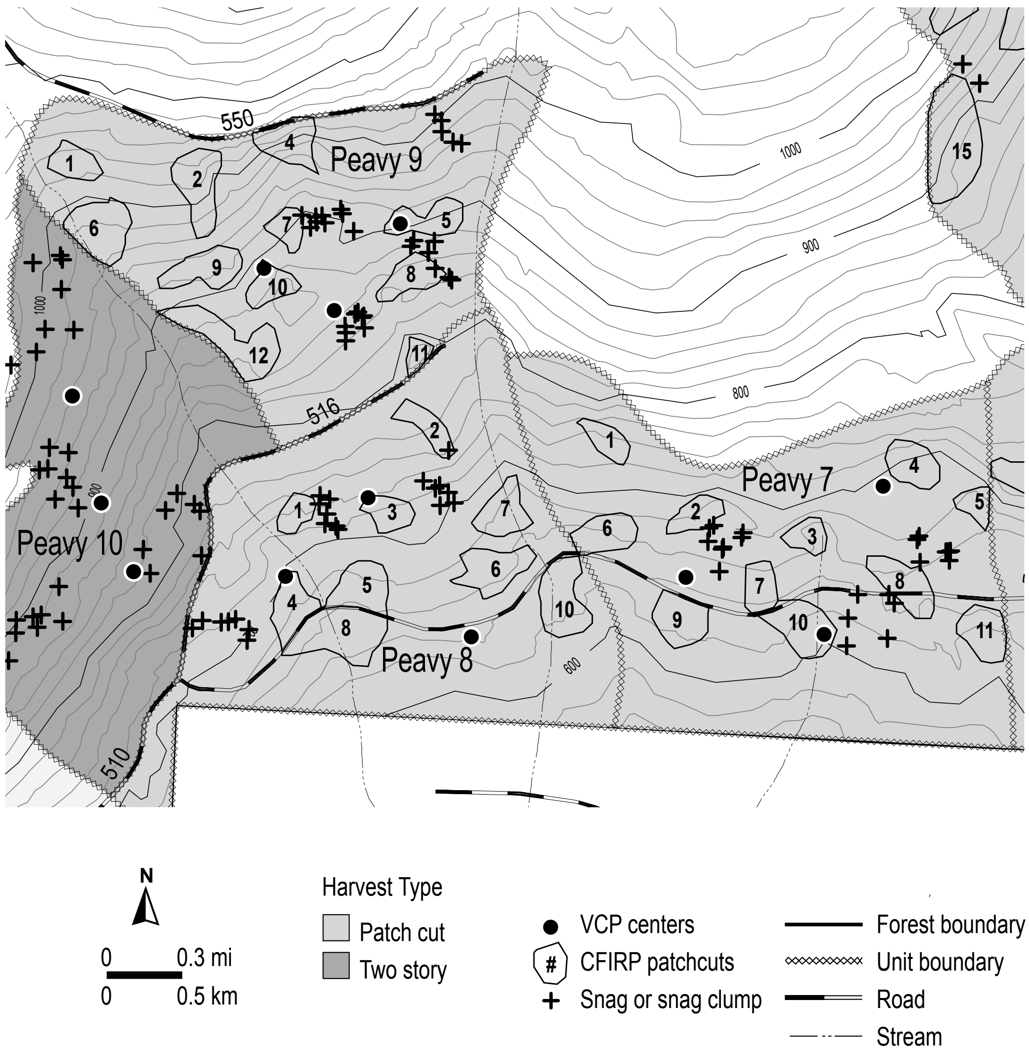


Figure B-9. Peavy 7, 8, and 9, McDonald-Dunn Forest.

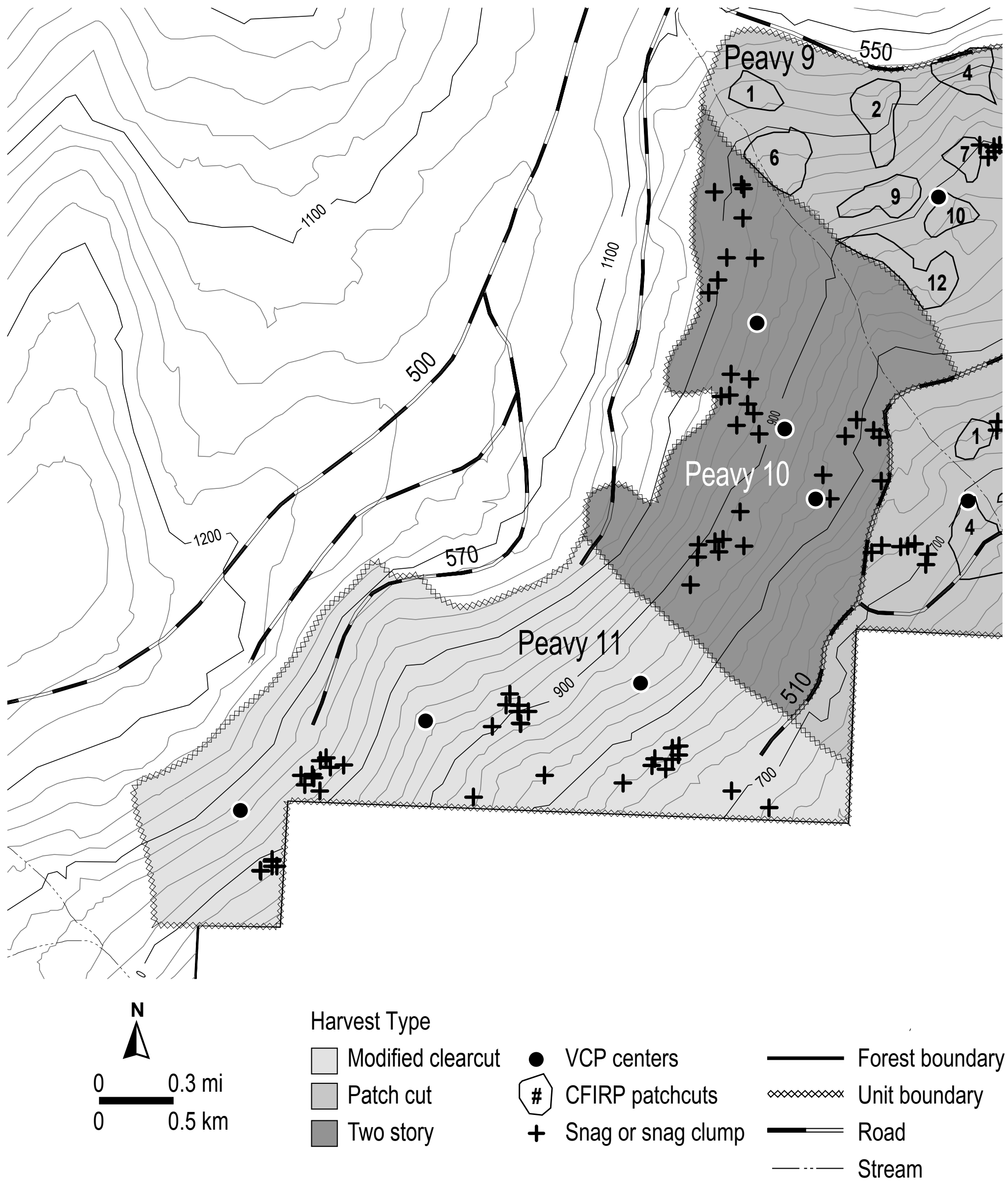


Figure B-10. Peavy 10 and 11, McDonald-Dunn Forest.

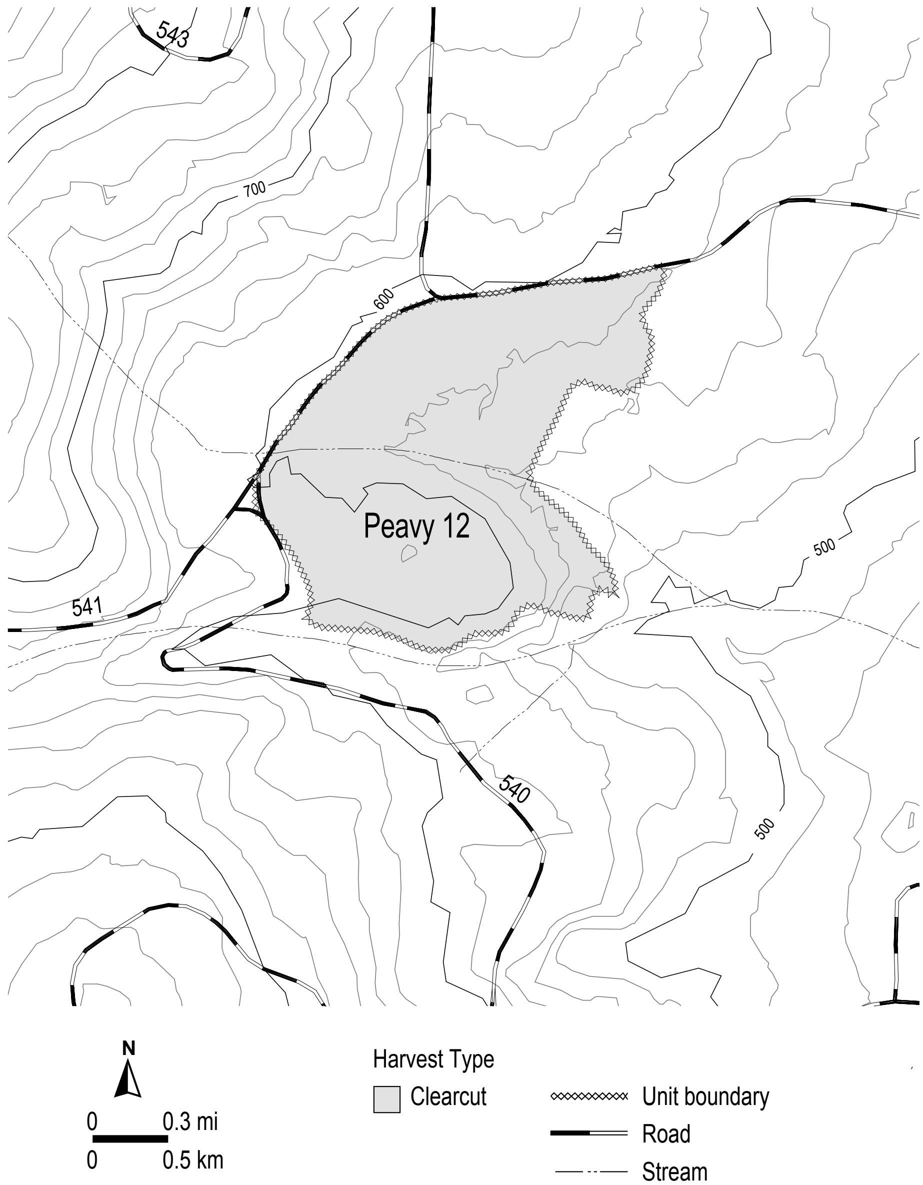


Figure B-11. Peavy 12, McDonald-Dunn Forest.

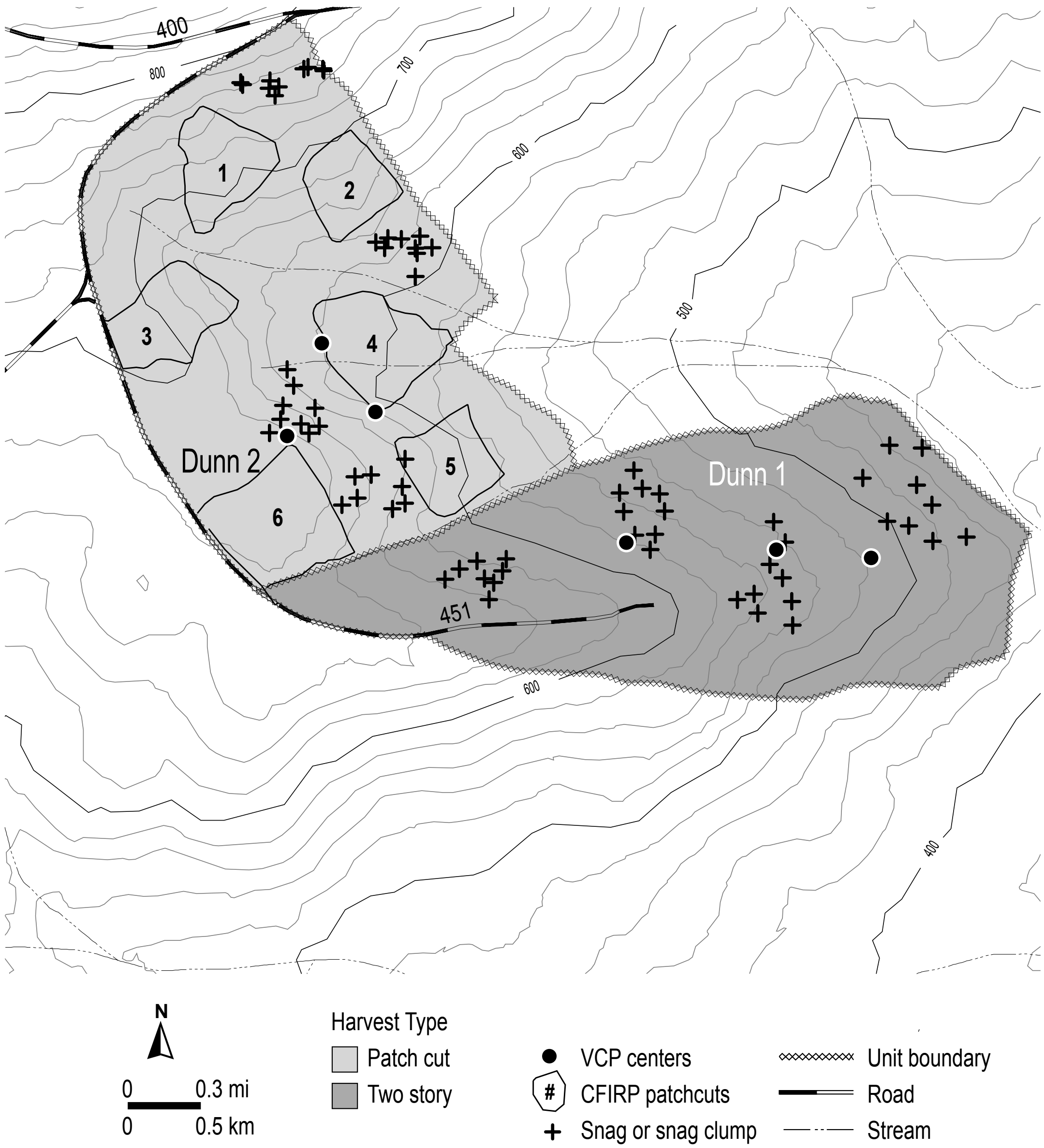


Figure B-12. Dunn 1 and 2, McDonald-Dunn Forest.

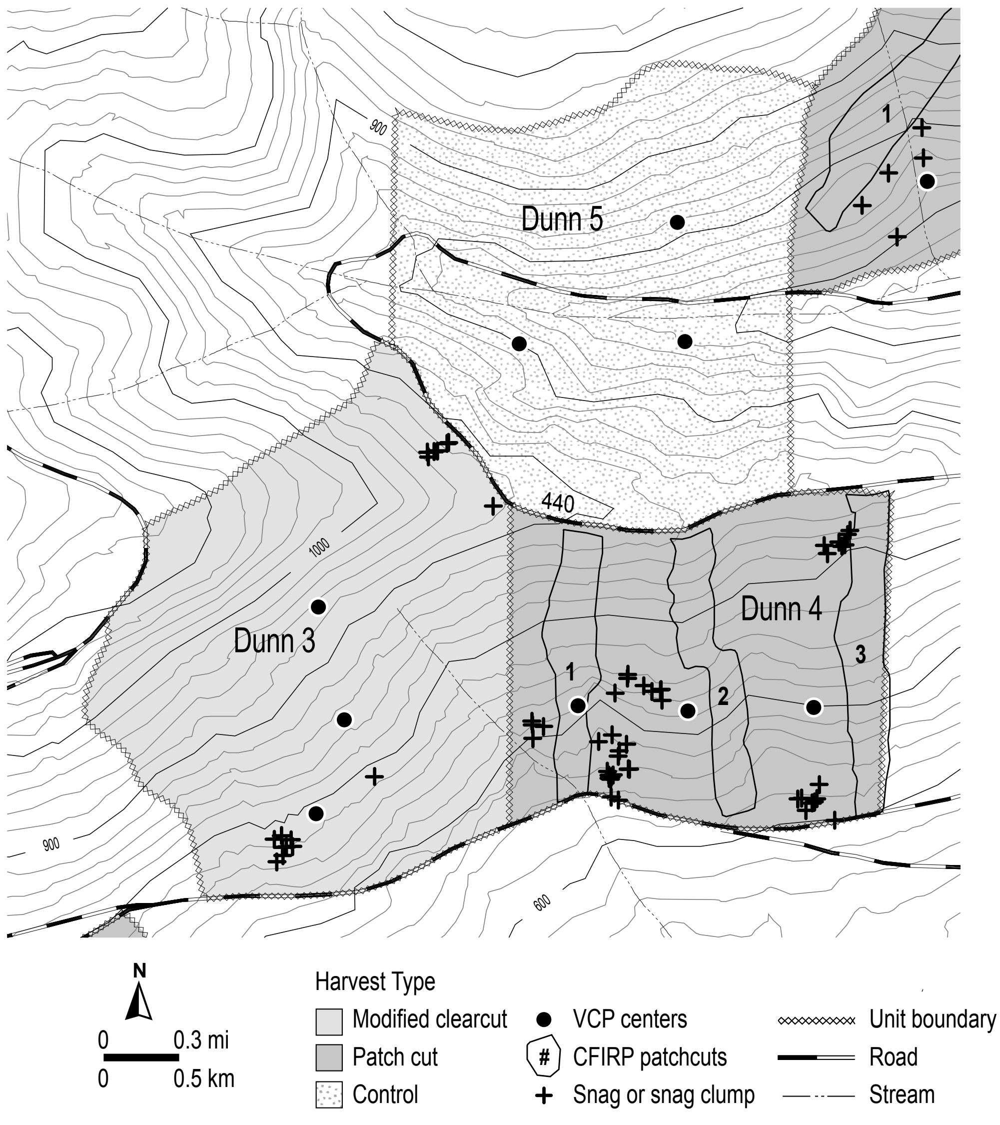


Figure B-13. Dunn 3, 4, and 5, McDonald-Dunn Forest.

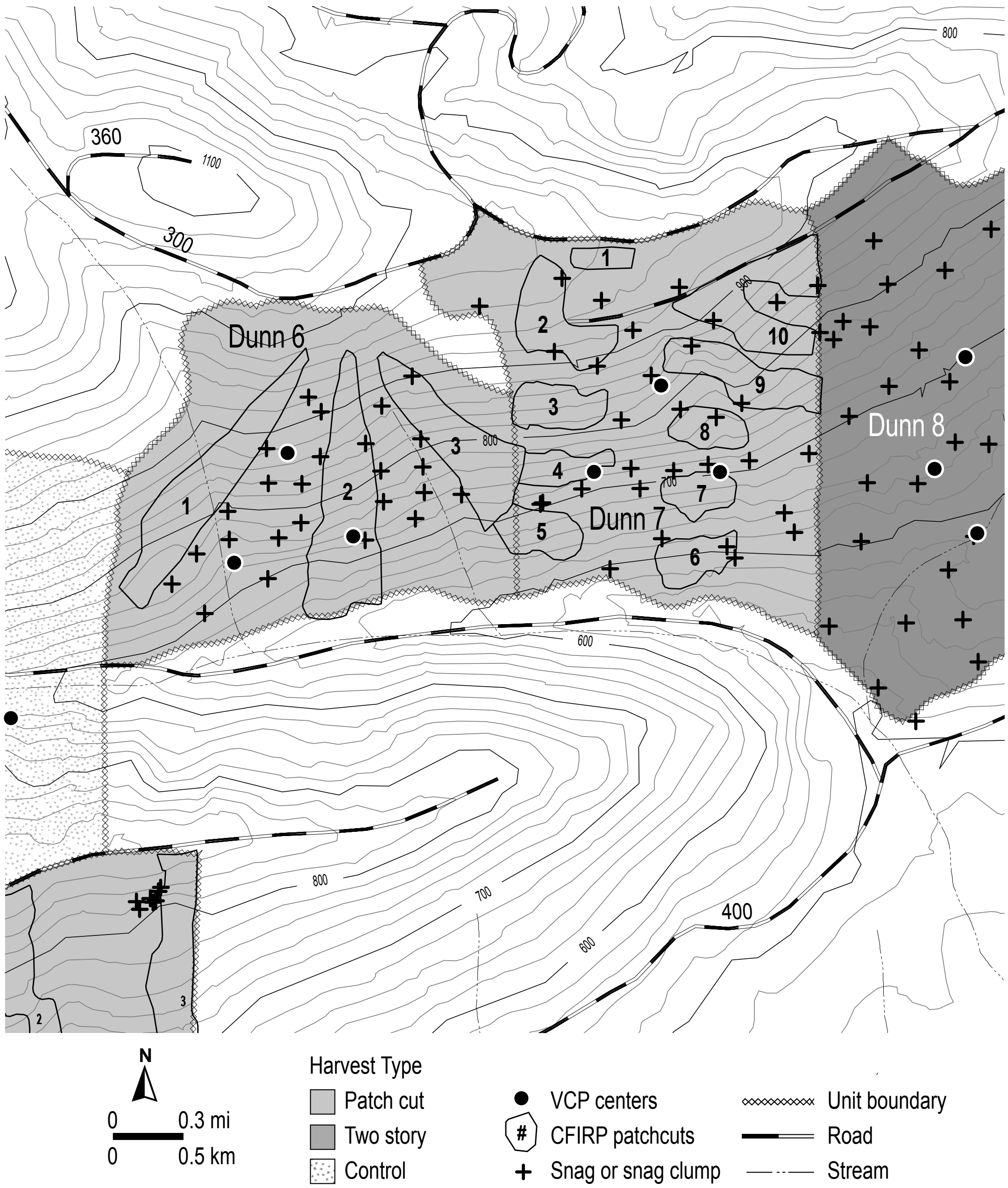


Figure B-14. Dunn 6 and 7, McDonald-Dunn Forest.

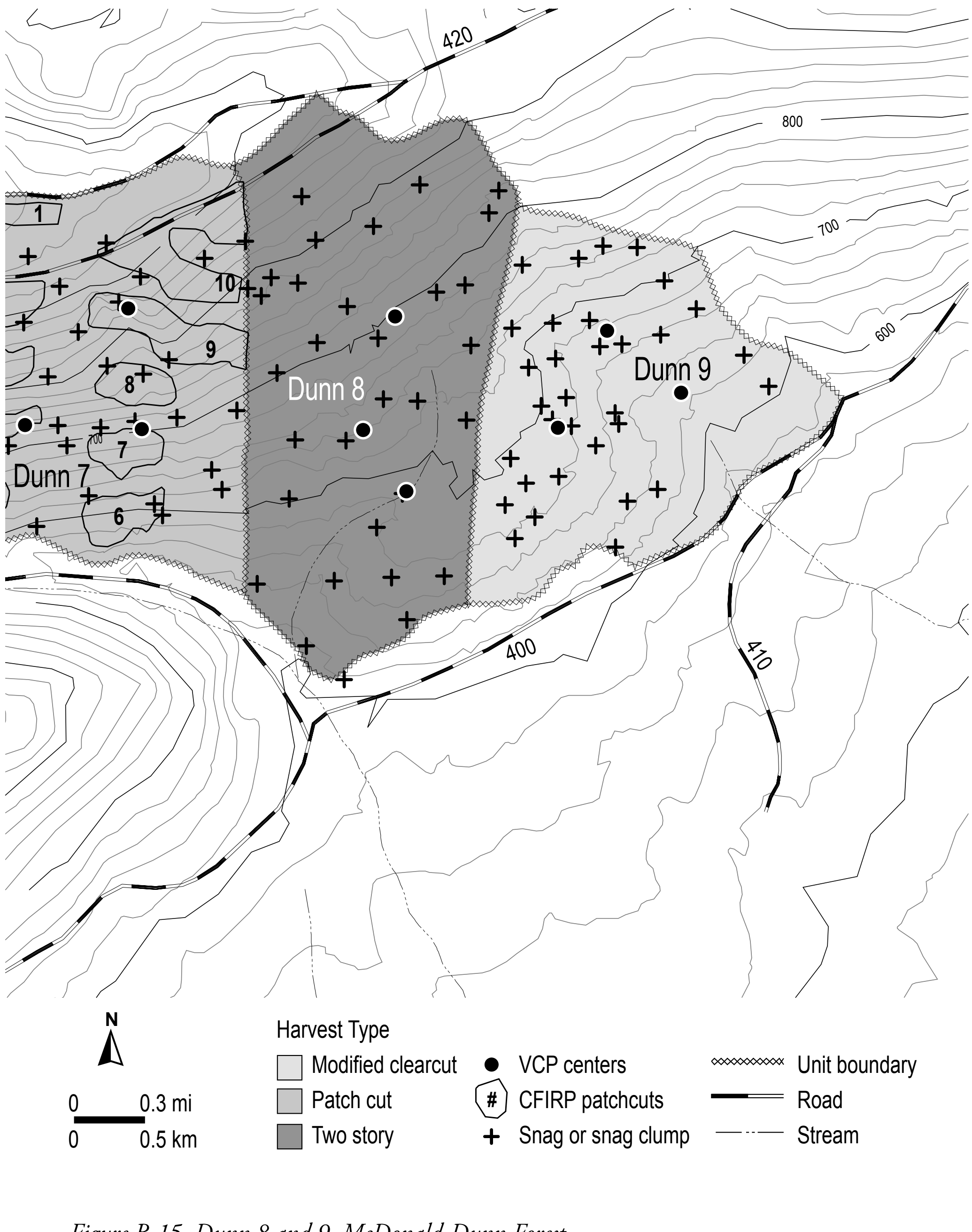


Figure B-15. Dunn 8 and 9, McDonald-Dunn Forest.

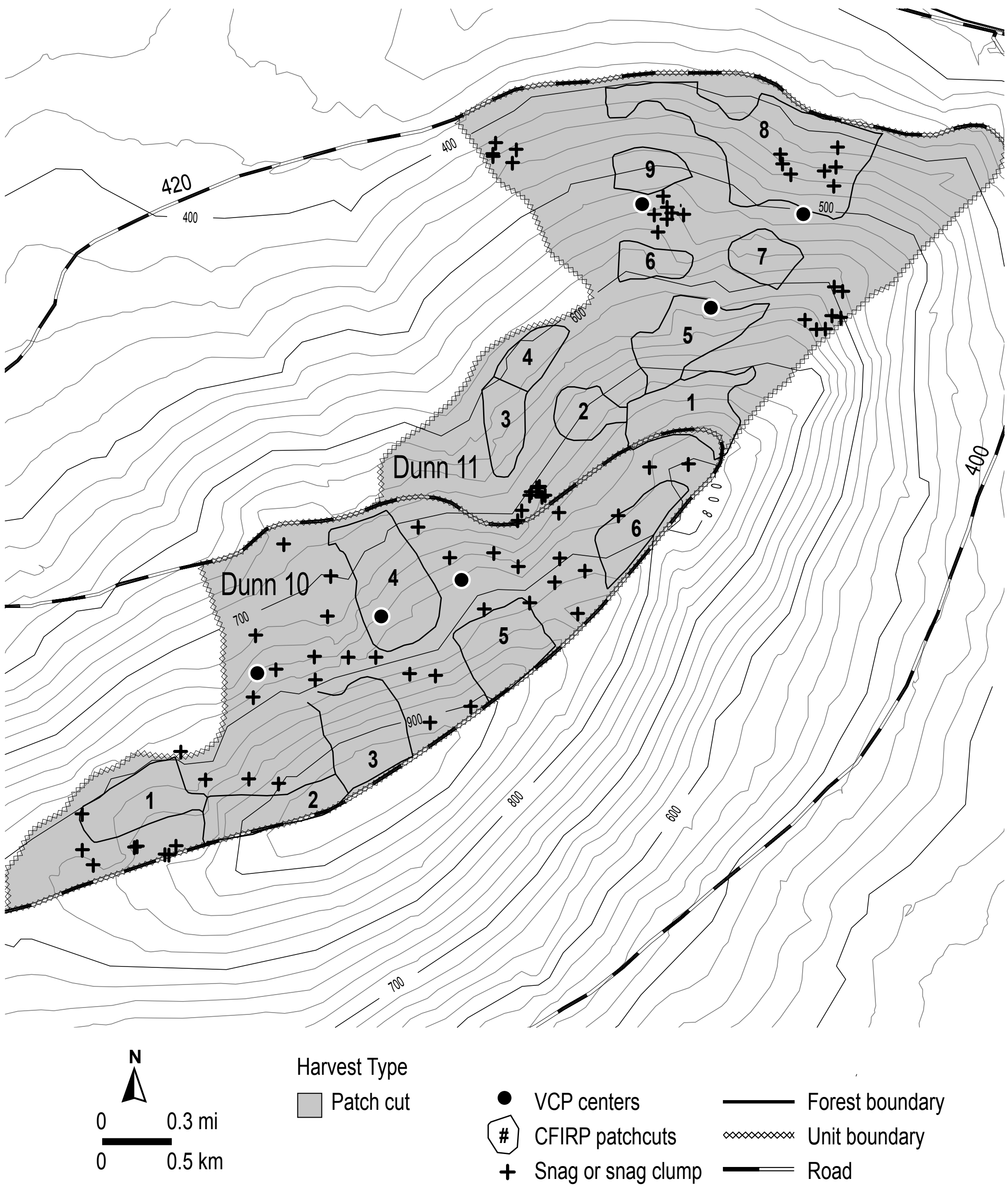


Figure B-16. Dunn 10 and 11, McDonald-Dunn Forest.

Appendix C. Plant species encountered during CFIRP vegetation studies

Common Name	Scientific Name
Trees	
Big-leaf maple	*Acer macrophyllum*
Bitter cherry	*Prunus emarginata*
Douglas-fir	*Pseudotsuga menziesii*
Grand fir	*Abies grandis*
Oregon ash	*Fraxinus latifolia*
Oregon white oak	*Quercus garryana*
Pacific dogwood	*Cornus nuttallii*
Pacific madrone	*Arbutus menziesii*
Red alder	*Alnus rubra*
Shrubs	
Bald hip rose	*Rosa gymnocarpa*
Cascade Oregon grape	*Mahonia nervosa*
Cascara	*Rhamnus purshiana*
Common snowberry	*Symphoricarpos albus*
Elderberry	*Sambucus* spp.
English holly	*Ilex aquifoliaceae*
Evergreen blackberry	*Rubus laciniatus*
Hazel	*Corylus cornuta*
Himalayan blackberry	*Rubus discolor*
Oceanspray	*Holodiscus discolor*
Pacific poison oak	*Toxicodendron diversilobum*
Red huckleberry	*Vaccinium parvifolium*
Salal	*Gaultheria shallon*
Scouler's willow	*Salix scouleriana*
Serviceberry	*Amelanchier alnifolia*
Thimbleberry	*Rubus parviflorus*
Trailing blackberry	*Rubus ursinus*
Vine maple	*Acer circinatum*
Western brackenfern	*Pteridium aquilinum*
Western swordfern	*Polystichum munitum*
Annual herbs	
Annual hairgrass	*Deschampsia danthonioides*
Australian fireweed	*Erechtites minima*
Bachelor button	*Centaurea cyanus*
Bedstraw	*Galium aparine*
Bull thistle	*Cirsium vulgare*
Canada thistle	*Cirsium arvense*
Candy-flower	*Montia sibirica*
Chickweed	*Stellaria media*
Coast tarweed	*Madia sativa*
Common sow-thistle	*Sonchus oleraceus*
Common centaury	*Centaurium umbellatum*
Common groundsel	*Senecio vulgaris*
Common tarweed	*Madia gracilis*
Cut-leaf geranium	*Geranium dissectum*
Fireweed	*Epilobium angustifolium*
Hedgehog dogtail	*Cynosurus echinatus*
Italian ryegrass	*Lolium multiflorum*
Leafy peavine	*Lathyrus polyphyllus*
Oxeye daisy	*Leucanthemum vulgare*
Prickly lettuce	*Lactuca serriola*
Prickly sow-thistle	*Sonchus asper*
Roberts geranium	*Geranium robertianum*
Rough hawksbeard	*Crespis setosa*
Scouler's harebell	*Campanula scouleri*
Sedge	*Carex* spp.
Silver hairgrass	*Aira caryophyllea*
Skunkweed	*Navarretia squarrosa*
Small blue forget-me-not	*Myosotis discolor*
Small-flowered lupine	*Lupinus micranthus*
Small-flowered willow-herb	*Epilobium minutum*
Small-flowered deervetch	*Lotus micranthus*
Small-flowered nemophila	*Nemophila parviflora*
Smooth hawksbeard	*Crespis capillaris*
Soft chess	*Bromus mollis*
Stinking dogfennel	*Anthemis cotula*
Tall annual willow-herb	*Epilobium paniculatum*
Teasel	*Dipsacus sylvestris*
Twiggy godetia	*Clarkia purpurea viminea*
Varied-leaf collomia	*Collomia heterophylla*
Venus' looking-glass	*Triodanis perfoliata*

Common Name	Scientific Name
Wall lettuce	*Lactuca muralis*
Wild oat	*Avena fatua*
Wild carrot	*Daucus carota*
Willow lettuce	*Lactuca saligna*
Wood groundsel	*Senecio sylvaticus*
Yellow salsify	*Tragopogon dubius*
Perennial herbs	
American vetch	*Vicia americana*
American wintercress	*Barbarea orthoceras*
Bigflower agoseris	*Agoseris grandiflora*
Bittersweet nightshade	*Solanum dulcamara*
California false hellebore	*Veratrum californicum*
California brome	*Bromus carinatus*
Celery-leaved lovage	*Ligusticum apiifolium*
Columbia brome	*Bromus vulgaris*
Common velvet grass	*Holcus lanatus*
Common burdock	*Arctium minus*
Common sweet-cicely	*Osmorhiza chilensis*
Common lomatium	*Lomatium utriculatum*
Common St. John's-wort	*Hypericum perforatum*
Common dandelion	*Taraxacum officinale*
Cow parsnip	*Heracleum lanatum*
Crinkle awn fescue	*Festuca subuliflora*
Douglas aster	*Aster subspicatus*
Enchanter's nightshade	*Circaea alpina*
Fairy lantern	*Disporum smithii*
False Solomon's seal	*Smilacina racemosa*
False-brome	*Brachypodium sylvaticum*
Field milk-thistle	*Sonchus arvensis*
Five-finger	*Potentilla gracilis*
Fowl bluegrass	*Poa palustris*
Fringecup	*Tellima grandiflora*
Hairy honeysuckle	*Lonicera hispidula*
Hal's bentgrass	*Agrostis hallii*
Indian-pipe	*Monotropa uniflora*
Inside-out-flower	*Vancouveria hexandra*
Largeleaf sandwort	*Arenaria macrophylla*
Little buttercup	*Ranunculus uncinatus*
Menzies' larkspur	*Delphinium menziesii*
Orchard-grass	*Dactylis glomerata*
Oregon bigroot	*Marah oreganus*
Oregon iris	*Iris tenax*
Pacific snake-root	*Sanicula crassicaulis*
Pathfinder	*Adenocaulon bicolor*
Pearly everlasting	*Anaphalis margaritacea*
Pig-a-back plant	*Tolmiea menziesii*
Purple snake-root	*Sanicula bipinnatifida*
Red fescue	*Festuca rubra*
Red baneberry	*Actaea rubra*
Sedge	*Carex* spp.
Self-heal	*Prunella vulgaris*
Slender wheatgrass	*Agropyron caninum*
Small windflower	*Anemone lyallii*
Snow-queen	*Synthyris reniformis*
Spanish-clover	*Lotus purshiana*
Spotted cats-ear	*Hypochaeris radicata*
Spreading dogbane	*Apocynum androsaemifolium*
Star-flowered Solomon's seal	*Smilacina stellata*
Stream violet	*Viola glabella*
Tall trisetum	*Trisetum canescens*
Timothy	*Phleum pratense*
Trillium	*Trillium ovatum*
Trumpet honeysuckle	*Lonicera ciliosa*
Twinflower	*Linnaea borealis*
Vanilla leaf	*Achlys triphylla*
Western columbine	*Aquilegia formosa*
Western fescue	*Festuca occidentalis*
Western starflower	*Trientalis latifolia*
Western meadowrue	*Thalictrum occidentale*
Western waterleaf	*Hydrophyllum occidentale*
Western rattlesnake-plantain	*Goodyera oblongifolia*
White-flowered hawkweed	*Hieraceum albiflorum*
Wild bleedingheart	*Dicentra formosa*
Wild strawberry	*Fragaria vesca*
Yarrow	*Achillea millefolium*
Yerba buena	*Satureja douglasii*

Appendix D. Animal species encountered during the CFIRP wildlife studies.

Common Name	Scientific Name
Reptiles	
Northern alligator lizard	*Elgaria coerulea*
Western fence lizard	*Sceloporus occidentalis*
Amphibians	
Ensatina salamander	*Ensatina eschscholtzii*
Pacific treefrog	*Pseudoacris regilla*
Rough-skinned newt	*Taricha granulosa*
Mammals	
California ground squirrel	*Spermophilus beechyii*
Coast mole	*Scapanus orarius*
Deer mouse	*Peromyscus maniculatus*
Dusky-footed woodrat	*Neotoma fuscipes*
Ermine	*Mustela erminea*
Northern flying squirrel	*Glaucomys sabrinus*
Oregon vole	*Microtus oregoni*
Pacific jumping mouse	*Zapus trinotatus*
Pacific shrew	*Sorex pacificus*
Pacific water shrew	*Sorex bendirii*
Red tree vole	*Phenacomys longicaudus*
Shrew-mole	*Neurotrichus gibbsii*
Townsend's chipmunk	*Tamias townsendii*
Townsend's mole	*Scapanus townsendii*
Townsend's vole	*Microtus townsendii*
Trowbridge's shrew	*Sorex trowbridgii*
Vagrant shrew	*Sorex vagrans*
Western red-backed vole	*Clethrionomys californicus*
Birds	
American crow	*Corvus brachyrhynchos*
American goldfinch	*Carduelis tristis*
American robin	*Turdus migratorius*
Band-tailed pigeon	*Columba fasciata*
Barn swallow	*Hirundo rustica*
Bewick's wren	*Thryomanes bewickii*
Black-capped chickadee	*Poecile atricapillus*
Black-headed grosbeak	*Pheucticus melanocephalus*
Black-throated gray warbler	*Dendroica nigrescens*
Blue grouse	*Dendragapus obscurus*
Brown creeper	*Certhia americana*
Brown-headed cowbird	*Molothrus ater*
Bushtit	*Psaltriparus minimus*
Cassin's vireo	*Vireo cassinii*
Cedar waxwing	*Bombycilla cedrorum*
Chestnut-backed chickadee	*Poecile rufescens*
Chipping sparrow	*Spizella passerina*
Common raven	*Corvus corax*
Common yellowthroat	*Geothylpis trichas*
Dark-eyed junco	*Junco hyemalis*
Downy woodpecker	*Picoides pubescens*
European starling	*Sturnus vulgaris*
Evening grosbeak	*Coccothraustes vespertinus*
Golden-crowned kinglet	*Regulus satrapa*
Gray jay	*Perisoreus canadensis*
Great-horned owl	*Bubo virginianus*
Hairy woodpecker	*Picoides villosus*
Hammond's flycatcher	*Empidonax hammondii*
Hermit thrush	*Catharus guttatus*
Hermit warbler	*Dendroica occidentalis*
House wren	*Troglodytes aedon*
Hutton's vireo	*Vireo huttoni*
Lazuli bunting	*Passerina amoena*
MacGillivray's warbler	*Oporonis tolmiei*
Mountain quail	*Oreotyx pictus*
Mourning dove	*Zenaida macroura*
Northern flicker	*Colaptes auratus*
Northern pygmy owl	*Glaucidium gnoma*
Olive-sided flycatcher	*Contops cooperi*
Orange-crowned warbler	*Vermivora celata*
Pacific-slope flycatcher	*Empidonax difficilis*
Pileated woodpecker	*Dryocopus pileatus*
Pine siskin	*Carduelis pinus*

Common Name	Scientific Name
Purple finch	*Carpodacus purpureus*
Red crossbill	*Loxia curvirostra*
Red-breasted nuthatch	*Sitta canadensis*
Red-breasted sapsucker	*Sphyrapicus ruber*
Red-tailed hawk	*Buteo jamaicensis*
Ruffed grouse	*Bonasa umbellus*
Rufous hummingbird	*Selasphorus rufus*
Sharp-shinned hawk	*Accipiter striatus*
Song sparrow	*Melospiza melodia*
Spotted towhee	*Pipilo maculatus*
Steller's jay	*Cyanocitta stelleri*
Swainson's thrush	*Catharus ustulatus*
Townsend's warbler	*Dendroica townsendi*
Tree swallow	*Tachycineta bicolor*
Turkey vulture	*Cathartes aura*
Varied thrush	*Ixoreus naevius*
Violet-green swallow	*Tachycineta thalessina*
Warbling vireo	*Vireo gilvus*
Western bluebird	*Sialia mexicana*
Western tanager	*Piranga ludoviciana*
Western wood-pewee	*Contopus sordidulus*
White-crowned sparrow	*Zonotrichia leucophrys*
Wild turkey	*Meleagris gallopavo*
Willow flycatcher	*Empidonax traillii*
Wilson's warbler	*Wilsonia pusilla*
Winter wren	*Troglodytes troglodytes*

APPENDIX E. PUBLICATIONS CITING CFIRP INFORMATION

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List of Contributors to the CFIRP Book (and those currently involved in CFIRP research)*

W. Thomas Adams
Department of Forest Science
Richardson Hall
Oregon State University
Corvallis, Oregon 97331
541-737-6583
w.t.adams@orst.edu

Kristin A. Babbs
Oregon Department of Forestry
801 Gales Creek Road
Forest Grove, Oregon 97116
503-359-7466
kbabbs@odf.state.or.us

Ann Bennett-Rogers
NRCS–Pendleton Service Ctr
1229 SE 3rd St
Pendleton, OR 97801-4196
541-278-8049, ext. 101
ann.rogers@or.usda.gov

Mark W. Brunson
Department of Environment and Society
College of Natural Resources
Utah State University
Logan, Utah 84322
435-797-2458
mark.brunson@usu.edu

Carol L. Chambers
School of Forestry
Northern Arizona University
P.O. Box 15018
Flagstaff, Arizona 86011
carol.chambers@nau.edu

William H. Emmingham, Emeritus
Department of Forest Science
Richardson Hall
Oregon State University
Corvallis, Oregon 97331
541-737-6078
bill.emmingham@oregonstate.edu

Joan C. Hagar
USGS-FRESC
777 NW 9th St, Suite 400
Corvallis, OR 97330
541-750-1017
joan_hagar@usgs.gov

John P. Hayes
Department of Forest Science
Richardson Hall
Oregon State University
Corvallis, Oregon 97331
541-737-6589
john.hayes@oregonstate.edu

Debora L. Johnson
Oregon State University
College Forests
8692 NW Peavy Arboretum Road
Corvallis, Oregon 97331
541-737-2377
debora.johnson@oregonstate.edu

Rebecca L. Johnson
Academic Affairs and International Programs
Kerr 628
Oregon State University
Corvallis, Oregon 97331
541-737-0740
becky.johnson@oregonstate.edu

Loren D. Kellogg
Department of Forest Engineering
Peavy Hall
Oregon State University
Corvallis, Oregon 97331
541-737-2836
loren.kellogg@oregonstate.edu

Rick G. Kelsey
USDA Forest Service
Pacific Northwest Research Station
Forestry Sciences Laboratory
3200 Jefferson Way
Corvallis, Oregon 97331
541-750-7368
rkelsey@fs.fed.us

J. Scott Ketchum
Boise Cascade
Northwest Oregon Regional Headquarters
450 N Pacific Hwy
Monmouth, Oregon 97361
503-838-1610
scottketchum@boisebuilding.com

Susan Lambrecht
Department of Biological Sciences
One Washington Square
San Jose State University
San Jose, CA 95192
408-924-4838
slambrec@email.sjsu.edu

* Current affiliations

Jessica Leahy
Department of Forest Resources
University of Minnesota
115 Green Hall
1530 N. Cleveland Ave.
St. Paul, MN 55108
612-625-0298
leah0024@umn.edu

Chris C. Maguire
Oregon Department of Transportation
Geo-Environmental Section
Natural Resources Unit
355 Capitol Street NE
Salem, Oregon 97301
503-986-3477
chris.maguire@odot.state.or.us

Brenda C. McComb
Department of Natural Resources Conservation
University of Massachusetts–Amherst
Amherst, Massachusetts 01003
413-545-1764
bmccomb@forwild.umass.edu

Ginger V. Milota
Corvallis, Oregon

Logan A. Norris, Emeritus
Department of Forest Science
Richardson Hall
Oregon State University
Corvallis, Oregon 97331
logan.norris@oregonstate.edu

Steven R. Radosevich
Department of Forest Science
Richardson Hall
Oregon State University
Corvallis, Oregon 97331
541-737-6081
steve.radosevich@oregonstate.edu

Bo Shelby
Department of Forest Resources
Peavy Hall
Oregon State University
Corvallis, Oregon 97331
541-737-1490
bo.shelby@oregonstate.edu

Edward E. Starkey
USGS - BRD - FRESC
Forestry Sciences Laboratory
3200 Jefferson Way
Corvallis, Oregon 97331
541-750-7397
ed.starkey@oregonstate.edu

Margo A. Stoddard
Department of Wildlife Ecology and Conservation
110 Newins-Ziegler Hall
University of Florida
Gainesville, FL 32611
352-846-0643
mstodd@ufl.edu

John C. Tappeiner, Emeritus
Department of Forest Resources &
USGS - BRD - FRESC
Peavy Hall
Oregon State University
Corvallis, Oregon 97331
541-737-3055
john.tappeiner@oregonstate.edu

Jennifer J. Thatcher
Northwest Research Obsidian Studies Laboratory
1414 NW Polk Avenue
Corvallis, Oregon 97330
541-754-7507
jthatcher@obsidianlab.com

David L. Waldien
Bat Conservation International
P.O. Box 162603
Austin, TX 78716
512-327-9721
dwaldien@batcon.org

Scott T. Walter
USDA Forest Service
Bent Creek Experimental Forest
1577 Brevard Road
Asheville, NC 28806
828-667-5261
swalter@fs.fed.us

Forestry Communications Group
Oregon State University
256 Peavy Hall
Corvallis, OR 97331-5704

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