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Evaluating the Effects of Varying Levels and Patterns of Green-tree Retention: Experimental Design of the DEMO Study

Abstract

In western Oregon and Washington, recent changes in federal forest management policy contained in the Northwest Forest Plan have led to new harvest prescriptions on millions of acres of public lands. For example, on upland sites, standards and guidelines now require that live (green) trees are retained in at least 15% of the area within each harvest unit and recommend that at least 70% of this retention is in patches of moderate to larger size (0.2-1.0 ha or more). These prescriptions for green-tree retention were based on the professional judgement and collective knowledge of many of the biologists who have studied the organisms and ecological processes that characterize these forests, but they have not been rigorously tested nor implemented on a broad geographic scale. Several prescriptions for green-tree retention are being evaluated experimentally by the Demonstration of Ecosystem Management Options (DEMO) study. In this paper, we briefly review recent changes in forest management policy and existing information gaps that led to the establishment of the DEMO study. We then provide an overview of the criteria for site selection, the experimental design and harvest prescriptions, the scope of scientific inquiry, and the collaboration that has occurred between scientists and land managers. These discussions provide the context and experimental framework for the individual research papers that comprise the remainder of this volume.

Introduction

In the 1980s, public concern over the fate of the northern spotted owl (*Strix occidentalis caurina*) and of the old-growth Douglas-fir (*Pseudotsuga menziesii*) forests on which it depends (Gutiérrez and Carey 1985, Thomas et al. 1990) led to unprecedented local and regional interest in natural resource management in the Pacific Northwest. This interest, and the political activism it generated, elevated these issues to national prominence (Ervin 1989, Norse 1990). Lawsuits initiated by environmental groups resulted in injunctions from three separate federal district courts and brought timber sale programs to a standstill on federal lands managed by the USDA Forest Service and USDI Bureau of Land Management (Tuchmann 1995). In April 1993, in response to this 'timber crisis', President Clinton commissioned the Forest Ecosystem Management Assessment Team (FEMAT 1993, see also articles in Vol. 92(4) of the Journal of Forestry) to formulate and assess the consequences of an array of options for managing federal forest lands within the range of the northern spotted owl. This assessment was the first attempt to develop a comprehensive plan for ecosystem management on a broad geographic scale. The resulting management plan came to be known as the Northwest Forest Plan (Tuchmann et al. 1996). The Record of Decision (ROD) and associated standards and guidelines (S & Gs) for the Plan were published in April 1994 (USDA and USDI 1994a) and lawsuits against the Plan were resolved in favor of the government in December 1994.

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Among the changes in forest management policy brought about by the Northwest Forest Plan is a greater emphasis on maintaining the diversity of species, structures, and physical and ecological processes that are important to the functioning of mature, late-successional forest ecosystems. These include microclimates associated with interior-forest conditions, spatial heterogeneity in forest composition and structure, fungi, invertebrates, saprophytic plants, nongame wildlife, snags, down woody debris, and other structural and compositional features generally associated with old-growth forests (Franklin et al. 1981).

This is not the first time that forest management objectives have shifted in response to changing public perceptions or professional judgements. From the 1930s until the mid- to late-1940s, selective cutting of the largest and most vigorous trees was widely applied in old-growth Douglas-fir stands in the Pacific Northwest. Long-term studies revealed, however, that subsequent windthrow mortality was significant and offset increases in residual stand volume for at least 25 yr after harvest (Isaac 1956). Clearcutting replaced selective logging in most areas, and from the 1950s through the late 1980s, regeneration harvests consisted primarily of clearcuts of various sizes staggered in time and space, followed by slash burning and planting. This strategy was designed to meet legal mandates for multiple-use management on public lands while providing high volumes of timber at relatively low cost, dispersion of cumulative watershed effects, access for recreation, and habitat for deer and other game species associated with early successional forests.

Several studies are proposed or underway in the Pacific Northwest region to evaluate the effects of silvicultural prescriptions designed to accelerate the development of late-successional forest characteristics in young, managed stands that have regenerated after clearcutting (e.g., Tappeiner 1992, Harrington and Carey 1997, Carey et al. *in press*). Such experiments are both relevant and necessary. However, because of substantial differences in initial conditions—especially the vegetative and structural legacies typical of mature forests—responses to retention harvest in young, managed forests may be very different from those in mature forests. Mature forests generally have a broader array of structures, species, and functions, whereas managed plantations are often structurally and biologically simpler and the development of late-successional characteristics in these stands may require more intensive silvicultural manipulations. Large-scale harvest studies in mature, late-successional forests are lacking. In the Northwest Forest Plan, these forests are defined as single- and multi-storied stands dominated by conifers > 53 cm dbh (USDA and USDI 1994b; pp. 3&4-26). They comprise 682,300 ha of Matrix lands and Adaptive Management Areas (USDA and USDI 1994b; Table 3&4-8) and, thus, are available for timber harvest under the Northwest Forest Plan. Furthermore, old-growth forests are dynamic and it will not be possible to provide cathedral groves of ancient forests for future generations simply by preserving existing old-growth stands (DeBell and Curtis 1993). Today's mature forests will become the old-growth forests of the future; thus, if societal objectives are to maintain wood production while increasing the extent of forest stands with old-growth characteristics, we must begin to develop methods for managing mature forests for these objectives.

In the early 1990s, several private research institutions and public interest groups in Washington and Oregon sought federal funds for research aimed at addressing these information needs. In response to these lobbying efforts, the Pacific Northwest Region of the USDA Forest Service received Congressional direction in 1993 to establish a large-scale silvicultural experiment (see Franklin et al. 1999). The Region, in cooperation with the Pacific Northwest Research Station, subsequently established the Demonstration of Ecosystem Management Options (DEMO) study, a collaborative research effort with the Washington State Department of Natural Resources, University of Washington, Oregon State University, and University of Oregon to evaluate the ecological, physical, and social effects of retaining live (green) trees in harvest units in western Oregon and Washington. The DEMO study is designed to provide information to aid in the development of harvest strategies that will retain or accelerate the recovery of some of the species and key ecological features found in mature and old-growth forests.

In this paper, we briefly review recent changes in forest management policy and existing information gaps that led to the establishment of the DEMO study. We then provide an overview of the criteria for site selection, the experimental design and harvest prescriptions, the scope of scientific inquiry, and the collaboration that has occurred between scientists and land managers. These discussions provide the context and experimental framework for the individual research papers that comprise the remainder of this volume. Facilitating the integration of research findings among these disciplines was a guiding principle during development of many aspects of the DEMO study.

Management Needs

Adaptive management, a process by which information gained from monitoring the consequences of management actions is used to refine and improve future management strategies (Bormann et al. 1994), is expected to play an important role in shaping future forest management in the Pacific Northwest. To ensure that management prescriptions provide desired benefits, however, they should also be evaluated experimentally using a rigorous and replicated study design. Information gained through such experimentation, which enables researchers to apply inferential statistics to data collected and to minimize the confounding effects of extraneous sources of variation, will provide reliable and broadly applicable results. Several large-scale silvicultural experiments involving various levels of green-tree retention are underway in British Columbia in forests dominated by Pacific silver fir (*Abies amabilis*) and western hemlock (*Tsuga heterophylla*) (Arnott and Beese 1997, Coates et al. 1997, see also Franklin et al. 1999). However, there is little empirical information available to forest managers in the Douglas-fir region on the ecological responses or social and economic tradeoffs associated with various levels and patterns of green-tree retention (Franklin et al. 1997).

Standards and guidelines in the Northwest Forest Plan specify retaining green trees in at least 15% of the area within each cutting unit and recommend that 70% of this retention is in aggregates of moderate to larger size (0.2-1.0 ha or more), with the remainder dispersed either as single trees or in small clumps < 0.2 ha. In addition, to the extent possible, snags and large decadent trees in harvest units should be preserved in green-tree retention patches (USDA and USDI 1994a). These prescriptions reflect the professional judgements and collective knowledge of many of the biologists who have studied the organisms and ecological processes in these forests. However, the ecological and silvicultural effects of retaining various amounts or configurations of green trees in harvest units have not been quantified (DeBell and Curtis 1993). Aggregated and dispersed retention strategies are each hypothesized to have varying ecological consequences and silvicultural applications. Dispersed retention is believed to be most appropriate where ecological objectives require that certain target structures or conditions be uniformly distributed, such as provision of down woody debris and snags or mitigating microclimatological or hydrological impacts. Aggregated retention, on the other hand, is expected to be more effective in maintaining a broader array of structural elements and ecological conditions. For example, aggregates enable the maintenance of all canopy layers including understory vegetation, as well as snags of various sizes and decay classes, in ways that are not possible with dispersed retention. Intact patches of habitat also serve as refugia for various organisms, which may provide source populations for recolonization of nearby regenerating areas (Franklin et al. 1997).

Because empirical information on the ecological effects of retaining green trees in harvest units in mature stands is extremely limited, the short- and long-term consequences for biodiversity of implementing harvest prescriptions in the Northwest Forest Plan are largely unknown. Green-tree retention in mature forests will produce varying responses depending upon the amount and configuration of retained trees. For example, substantially reducing canopy coverage and dispersing retained trees is expected to accelerate the diameter growth of retained trees, but may have adverse consequences for understory species that have an affinity for late-seral or interior forest conditions (Halpern et al. 1999). Green-tree retention in mature stands will influence understory composition and structure; shape future levels of standing and down coarse woody debris; and affect the diversity, abundance, and distribution of many sensitive plant and animal species. Thus, information on the ecological consequences of green-tree retention in mature forests is needed if we are to effectively manage both young plantations and mature forests.

The DEMO study is expected to provide broadly applicable information on the ecological and silvicultural effects of green-tree retention in mature Douglas-fir forests. Results are expected to be applicable over a large proportion of public and private lands in western Oregon and Washington. The study focuses on regeneration harvests of mature forests dominated by medium- and large-sized conifers. In addition to the more than 680,000 ha of forest in these size classes in unreserved federal lands in the Pacific Northwest, DEMO results will be applicable to thousands of hectares of younger forest as they mature over the next several decades.

Research Questions

The DEMO study is designed to address the following general questions:

(1) How does the proportion of green trees retained at a site influence various biological, physical, and social values?

(2) Given a particular level of green-tree retention, is the spatial pattern of that retention important? In particular, are the effects of retaining trees in undisturbed patches different from those that result from distributing them evenly throughout the harvested area?

(3) If organisms, processes, and values are affected by the level and/or pattern of green-tree retention in the short term, are the effects maintained over time as stands develop?

(4) Do the effects of different levels or patterns of green-tree retention differ among geographic areas or forest communities?

Experimental Design and Site Selection

The DEMO study consists of a randomized block design involving six treatments representing varying levels and patterns of green-tree retention (Figure 1). Each treatment unit is a relatively homogeneous forest stand of about 13 ha, and is square or slightly rectangular (Figure 2). Treatment units consist of upland forest habitats; large streams or wetlands were avoided.

The six treatments are replicated in eight geographic locations (blocks), four in southwestern Washington and four in southwestern Oregon (Figure 3). Although selected blocks may contain a variety of forest communities, Douglas-fir is the dominant tree species in all blocks (see Table 1 in Halpern et al. 1999); forest ages range from about 70 to 200 yr or more (Table 1). Detailed descriptions of the physiographic environments and management histories for each block are presented in Table 1. Treatments were randomly assigned among six units within each block; the six treatments (Figure 1) are:

(1) *100% retention*—A control unit that provides a baseline for assessing the effects of harvest treatments on ecosystem composition, structure, and function.

(2) *75% aggregated retention*—Three circular 1-ha patches are harvested in a triangular array, removing 25% of the stand area. The pattern and distances between the gaps are consistent among blocks.

(3) *40% dispersed retention*—Dominant and co-dominant trees are retained in an even distribution throughout the treatment unit. The total basal area retained in this treatment varies among blocks, and is determined by the combined basal area (± 5%) in the five 1-ha patches of the corresponding 40% aggregated retention treatment.

(4) *40% aggregated retention*—Five undisturbed 1-ha circular patches are retained in the treatment unit; distances among patches are consistent among blocks (see Figure 2).

(5) *15% dispersed retention*—Dominant and co-dominant trees are retained in an even distribution throughout the treatment unit. The total basal area retained in this treatment varies among blocks, and is determined by the combined basal area (± 5%) in the two 1-ha patches of the corresponding 15% aggregated retention treatment.

(6) *15% aggregated retention*—Two undisturbed 1-ha circular patches are retained in the treatment unit. Each patch is located in a diagonal half of the treatment area; the distance between patches is consistent among blocks.

Responses of forest organisms to these treatments will vary depending on the life history characteristics and spatial requirements of the taxa under consideration, as well as the time since treatments were implemented (see Halpern et al. 1999, Lehmkuhl et al. 1999, Cazares et al. 1999, and Progar et al. 1999 for detailed discussions of predicted responses). In general, however, we predict that the diversity and abundance of species associated with unmanaged mature and old-growth forests (see Ruggiero et al. 1991) will decline with harvest intensity and will be lower in dispersed than in aggregated treatments. We also predict that species closely associated with late-successional forests will be unable to persist in the 15%

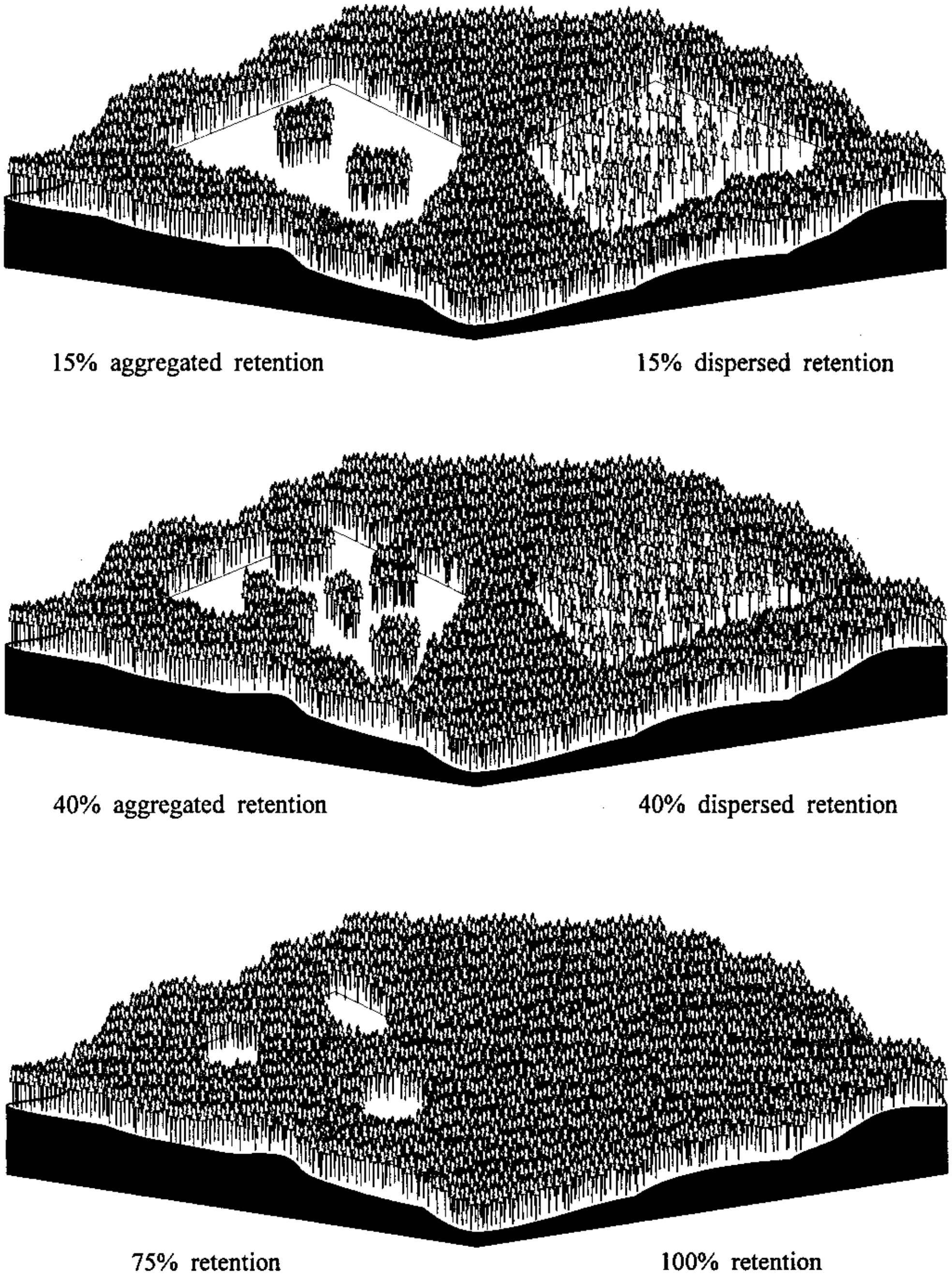

Figure 1. Schematic representation of the six treatments in the DEMO study (figure provided by Ken Bible).

retention treatments, although species with very small spatial requirements may survive in refugia created by the aggregates (see discussion of 'lifeboating' in Franklin et al. 1997).

During the initial planning stages of the experiment, we considered comparing additional levels of retention or varying the sizes of aggregates, but practical constraints precluded these

Figure 2. Aerial view of the 40% aggregated retention treatment at the Paradise Hills block in Washington shortly after harvest (photo courtesy of Jon Nakae).

options (see Franklin et al. 1999). Given the limited availability of suitable areas large enough to effectively study most species of wildlife (especially arboreal rodents) and the funds available for this research, evaluating other levels of retention or sizes and shapes of aggregates was not possible. Site suitability was constrained by many factors, including variation in vegetative structure and composition, roads, management history and allocations, and the presence of streams or wetlands. In many of the blocks, implementation of the treatments required variances from current management requirements, such as those for riparian buffers in the Northwest Forest Plan (USDA and USDI 1994a). Justifications for these variances were reviewed by the interagency Regional Ecosystem Office (REO) and evaluated on a case-by-case basis. The REO concluded "that the review did not identify any unacceptable risks to the objectives of the standards and guidelines that would require modification or cancellation of the project"[1].

It was not possible to select study areas in which the surrounding forests were of uniform stand age, structure, and management history. Thus, we were not able to control the past or future management of surrounding stands; some treatment areas occur within a uniform matrix, while others have a more diverse landscape context. Consequently, landscape-scale influences of surrounding stands on the treatment units may vary. For many response variables, however, such influences are expected to be weak. Lehmkuhl et al. (1991) evaluated the influence of surrounding stands and landscapes on bird, small mammal, and amphibian abundances in unmanaged Douglas-fir stands in southern Washington and found that landscape indices alone were not useful for predicting vertebrate species richness or abundance. For the organisms they studied, physiographic position (especially elevation) and stand structure were much better predictors of abundance patterns than landscape indices. For other wildlife species that may be more strongly influenced by landscape context (e.g., flying squirrels, bats, woodpeckers) the influence of adjacent stands will be considered as covariates in post-hoc analyses of treatment responses.

Methods

Treatment Prescriptions

The experimental prescriptions in DEMO were extremely difficult to apply uniformly among all blocks. This was due partly to differences in geographic location, physical environment, and forest composition and structure, but also to the practical constraints of conducting harvest experiments of this magnitude on public lands (see Abbott et al. 1999). We have addressed these issues in several ways. All prescriptions were applied consistently among the six treatment units within each block. Harvest method, snag and log retention, slash treatment, and planting were similar in all treatment units within each block to ensure that these activities introduced as little extraneous within-block variation as possible. Maintaining complete uniformity in treatments among the eight blocks has proven impractical, but concerted efforts have been made to reduce variability in the implementation of treatments.

The Systematic Sampling Grid

In this study, we use either an 8 x 8 or 7 x 9 sampling grid (to provide flexibility in treatment unit placement) with a 40-m spacing between sample points. The edge of the treatment area extends at least 40 m beyond the outer grid points (Figure 4). The minimum size (13 ha) of the treatment units is based on the area necessary to generate reliable abundance indices for northern flying squirrels (*Glaucomys sabrinus*). Carey et al. (1991) recommended 10 x 10 grids with 40-m spacing

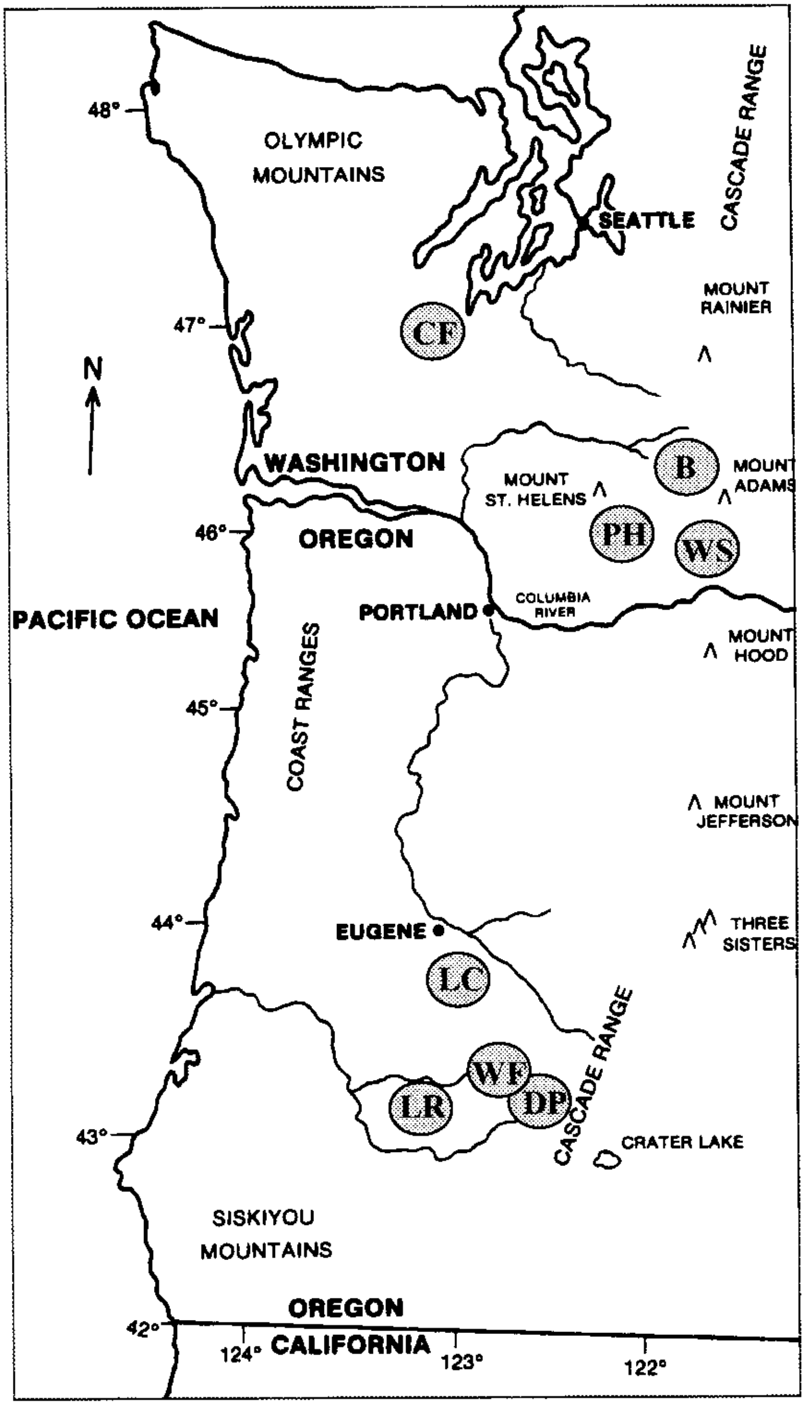

Figure 3. Location of the eight experimental blocks of the DEMO study in Oregon and Washington. Block codes from north to south are: CF = Capitol Forest, B = Butte, PH = Paradise Hills, WS = Little White Salmon, LC = Layng Creek, WF = Watson Falls, LR = Little River, and DP = Dog Prairie.

TABLE 1. Environmental features and stand characteristics of the eight experimental blocks in the DEMO study. Ranges are based on mean values for each of the six treatment units in each block.

Location/Block	Elevation (m)	Slope (degrees)	Aspect	Stand age (yr)	Management history	Riparian zones[1]
Oregon: Umpqua National Forest						
Watson Falls	945-1310	4-7	flat	110-130	salvage logged (1970-1978)	class IV stream (1 unit)
Little River	1220-1400	14-40	varied	200-520[2]	salvage logged (2 units)	class II streams (2 units); class III stream (1 unit); class IV streams (2 units)
Layng Creek	490-790	20-41	SE	60-80	second-growth; thinned (1984-1989)	class III streams (6 units)
Dog Prairie	1460-1710	34-62	SW	165	thinned (1986)	class IV stream (1 unit)
Washington: Gifford Pinchot National Forest						
Butte	975-1280	40-53	E-SE	70-80	none	class III streams (2 units); class IV streams (4 units)
Little White Salmon	825-975	40-66	NW-NE	140-170	none	class III stream (1 unit); class IV streams (5 units)
Paradise Hills	850-1035	9-33	varied	110-140	none	class III streams (3 units); class IV streams (4 units)
Washington: Department of Natural Resources						
Capitol Forest	210-275	28-52	varied	65	second-growth	class III streams (2 units); class IV streams (4 units)

[1]Class II stream = fish-bearing perennial stream; class III stream = non-fish bearing perennial stream; class IV stream = non-fish bearing intermittent stream.

[2]One treatment unit with tree ages of 400-520 yr; remaining units with tree ages of 200-325 yr.

between sample points (16-ha sampling area) for estimating densities of flying squirrels, but indicated that smaller grids (e.g., 7 x 9; 10 ha) were adequate, particularly if the goal was to calculate relative abundance values rather than actual densities (see also Carey et al. 1996).

Study grids were designed so that flying squirrel populations could be included as response variables for several reasons: they are forest obligates associated primarily with mature and old-growth conifer forests, use both canopy and forest-floor habitats, have relatively large home ranges (about 0.8 ha), and are important prey for the northern spotted owl in the DEMO study area (Carey 1991). Thus, the DEMO treatments, which primarily involve manipulating the density and configuration of the forest canopy, are expected to strongly influence flying squirrel populations (see Lehmkuhl et al. 1999). Addressing the needs of spotted owls was a primary objective during the development of the Northwest Forest Plan (USDA and USDI 1994b; pp. 2-72), thus, the response of flying squirrel populations to the DEMO treatments will have important implications for assessing the efficacy of green-tree retention strategies for maintaining or enhancing spotted owl foraging habitat in harvest units.

The permanent grid system (or a subsample thereof) will also be used to sample the responses of various ecosystem components such as vegetation, other wildlife, and ectomycorrhizal fungi. The grid facilitates integration among these studies and ensures that the same environments will be sampled within each stand for the duration of the

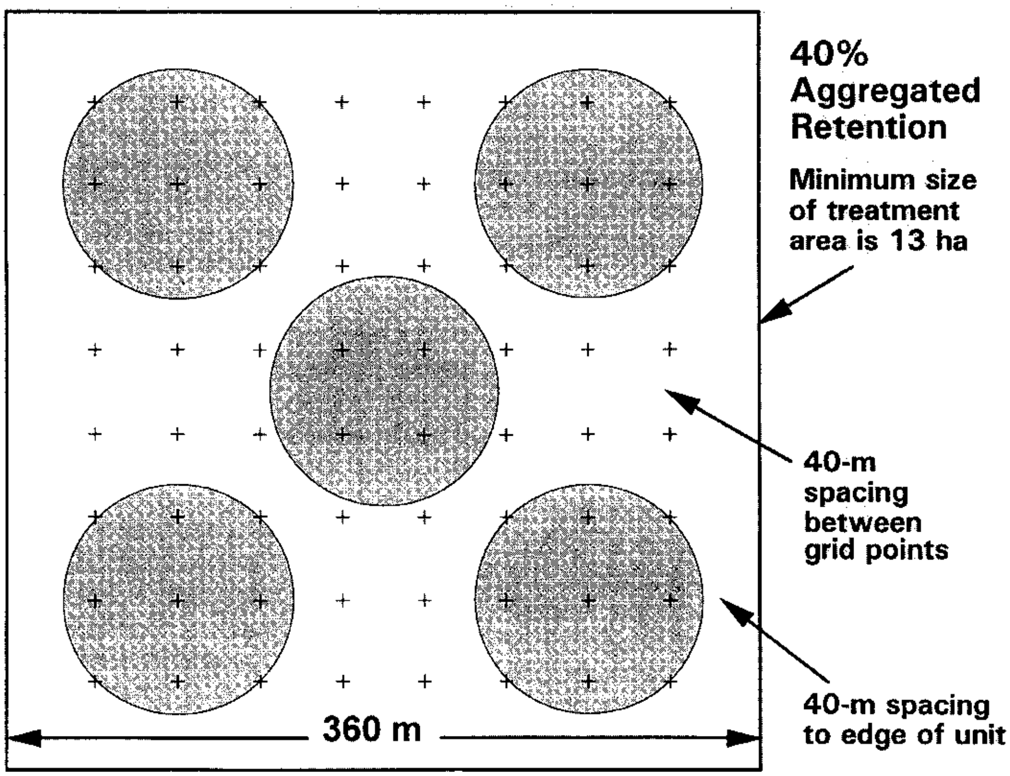

Figure 4. Schematic representation of the DEMO experimental grid as configured for an 8 x 8 square grid in a 40% aggregated retention treatment unit.

project. In the three aggregated retention treatments (75, 40, and 15%), in which two contrasting environments will be created (intact forest and clearcuts), the grid will also permit analyses of within-treatment patterns of variability and the contributions of each of these environments to treatment-level responses.

Timber Harvest

Methods for harvesting timber in each block were determined by local forest managers. We recognized that appropriate timber harvest methods would vary in different forest and topographic conditions; thus, it was not practical to use the same harvest method in all blocks. Several constraints were imposed, however: the same method was used in all treatment units within each block, treatment units within a block were harvested in the same year and logging contractors avoided felling trees into retention patches. Four blocks were helicopter logged, two shovel/loader logged, one skyline cable logged, and one block (Capitol Forest, Washington) was logged with a combination of systems due to unusual topographic conditions in one treatment unit.

Snags

During harvest, existing snags that did not pose a safety hazard were retained. To provide snags for future stands and to meet minimum snag requirements specified in the Northwest Forest Plan, contractors left an additional 6.5 dominant or codominant green trees per ha in all harvested areas within each treatment unit for snag creation. These 'snag trees' were retained in addition to the green trees that contribute to the 15, 40, or 75% retention levels in treatments 2 through 6. When possible, trees selected for snag creation were those that were already decayed or had broken tops. These trees will be killed within one growing season of harvest by removing the crown with a chain saw.

Down Woody Material

Down woody material on site was retained during harvest, but no prescriptions for creating large down woody material were implemented. Green trees that inadvertently fell into unharvested areas of the 75% retention treatment or unharvested patches of the 15% or 40% aggregated retention treatments were removed. When necessary, such trees were limbed prior to removal to minimize disturbance to reserve areas; resulting branches were also removed from the leave areas.

Slash/Fuels Treatment

After harvest, forest managers and researchers evaluated slash loadings to assess potential fire hazards and effects on regeneration and accurate sampling of response variables. If further treatment was necessary, it was accomplished with as little disturbance to the site as possible, using methods determined jointly by forest managers and researchers. Although various methods for fuel-reduction (e.g., yarding tops or hand-piling and burning) were used among blocks, slash treatments were applied consistently among treatment units within each block. Sites having low to moderate amounts of slash were left untreated to provide for soil stability and future nutrient inputs.

Retention of Submerchantable Trees

To the extent possible, trees that were too small in diameter to be merchantable, including advance regeneration (seedlings established naturally under the canopy), were protected in all treatment units.

Riparian Protection

The number of potential study areas that met the size requirements of the study was extremely limited; consequently, it was not possible to avoid small streams or seeps in all treatment units (Table 1). However, to avoid confounding the effects of the primary treatments, undisturbed riparian buffers were not maintained in any of the treatment units.

Reforestation

The Resource Management Plans of the Umpqua and Gifford Pinchot National Forests require minimum stocking densities of 312 trees per ha after 5 years. Evaluation of adequate stocking will be based on planted trees, advance regeneration, and subsequent natural regeneration. Although more than 312 trees per ha may be planted in some blocks to ensure adequate survival, planting density will be set as low as possible to encourage natural regeneration, minimize the need for site preparation, and reduce potential confounding effects on understory vegetation. As with all other prescriptions, planting densities and species composition will be consistent among treatment units within each block and will be determined jointly by forest managers and researchers.

Other Post-harvest Treatments

The use of fertilizers, seeding for erosion control, or herbicides is prohibited on DEMO study sites. Manual release of tree seedlings must be approved by both forest managers and DEMO researchers.

Forest managers have agreed to protect the DEMO study sites from activities that are not part of the planned prescriptions for 10 years after harvest. At that time, managers and researchers are expected to re-evaluate the status of experimental sites and research progress, and assess the need for new study plans, contractual agreements, and additional silvicultural treatments.

Major Areas of Investigation

Given limited time, funding, and human resources, areas of investigation have been restricted to those of highest priority and with the greatest potential for integrative analyses. These include vegetation, wildlife, fungi, invertebrates, hydrology, social perceptions, and harvest costs.

Vegetation

Vegetation studies will examine post-harvest changes in the composition, structure, and diversity of overstory and understory communities both among and within experimental treatments. Variables of interest include the growth, damage, and mortality (including windthrow) of residual trees; recruitment, growth, and mortality of regeneration (natural and planted); changes in species composition of ground-layer bryophytes and lichens, herbs, and shrubs; and the dynamics of snags and down woody debris. Because understory and overstory measurements are spatially linked, understory patterns can be interpreted relative to initial treatment effects as well as to changes in overstory characteristics. Changes in many of these variables will be used to interpret the responses of organisms and processes under investigation in companion studies (see Halpern et al. 1999 for additional discussion).

Wildlife

Wildlife studies will evaluate patterns of habitat use and provide estimates of relative abundance for diurnal forest birds, arboreal rodents, bats, forest-floor small mammals, and amphibians. Wildlife research will focus primarily on wildlife species with home ranges smaller than the 13-ha treatment areas but, whenever possible, information will be gathered on habitat use by wider ranging mammals and birds. Because animal populations vary annually, 2 yr of pre-treatment data have been collected; additional years of sampling would have been desirable, but were precluded by limitations of both time and funding. Pre-treatment data revealed that flying squirrel populations were too low in several of the blocks to enable meaningful comparisons with post-treatment data. Consequently, flying squirrel populations are only being studied in four of the experimental blocks (two in each state); other wildlife sampling is being conducted in all eight blocks (see Lehmkuhl et al. 1999 for additional discussion).

Fungi

Fungi research will investigate the abundance, community structure, dietary importance for wildlife species, and dynamics of ectomycorrhizal fungi in four of the eight experimental blocks (two in each state). Fungi play a key role in wildlife food webs and influence forest recovery and productivity after disturbance. In addition, the economic importance of edible mushrooms has greatly increased in the Pacific Northwest in recent years; we know little, however, about the effects of green-tree retention harvest on these organisms (see Cazares et al. 1999 for additional discussion).

Invertebrates

Invertebrate studies will address treatment effects on canopy invertebrate diversity, community structure, and population abundances. Canopy invertebrates are important food items for many vertebrate species and are influential in forest ecosystems as both pests and biological control agents. In addition, they affect plant species composition, leaf area, canopy-atmosphere interactions, and nutrient fluxes to the forest floor. Hence, responses of canopy invertebrate communities to forest management practices are particularly important to ecosystem function and forest health (see Progar et al. 1999 for additional discussion).

Hydrology

Hydrologic investigations will focus on snow hydrology, especially rain-on-snow events. Because these winter studies are logistically difficult to implement simultaneously at multiple locations, snow accumulation and melt will be measured at only one experimental block (Watson Falls, Oregon). Supporting meteorological data will be collected so that the physical processes affecting snowmelt and accumulation can be understood for different harvest levels and patterns. Rain-on-snow events are among the most important factors in cumulative watershed impacts, such as flooding, yet little is known about the influence of green-tree retention on this process (see Storck et al. 1999 for additional discussion).

Social Perceptions

Social perceptions of varying approaches to green-tree retention harvest will initially be measured as judgments of acceptability and scenic beauty based on a mail survey of within-stand photographs in several of the harvested blocks. This research will include an evaluation of the influence of demographic characteristics and attitudes toward (1) public forest management practices, (2) the forest products industry, and (3) the potential commodity and non-commodity benefits of the treatments on such perceptions. Once all treatments are implemented, a more intensive survey involving focus groups will be conducted to evaluate public perceptions of the DEMO green-tree retention treatments based on both within-stand and vista views (see Ribe 1999 for additional discussion).

Harvest Costs

Initially, economic studies were proposed as a major component of the DEMO study (Anonymous 1996) but attempts to track logging costs among treatments were confounded by unanticipated problems in cost accounting. Modifications to the study design to overcome these problems were not possible given practical limitations and funding constraints; consequently, this component of the study was dropped. However, data collected during helicopter logging on the Butte block in Washington will be used to develop a helicopter production and cost simulation model that will be of immediate practical value to forest managers in the region.

Additional Studies

The DEMO harvest treatments and baseline data from each site will provide many short- and long-term opportunities for additional studies that can be accomplished at significantly lower costs than if they were conducted independently. For example, the composition and diversity of arboreal lichen communities have already been studied in several of the Washington blocks as part of a master's thesis (Pipp 1998) and pre-treatment vegetation data provided the ecological context for that study. The DEMO sites and infrastructure are available to other researchers and we welcome additional research partners with extramural funding to establish new, non-destructive studies on the DEMO experimental sites to build upon the baseline research being conducted. Of interest would be studies of treatments effects on microclimate and hydrology, nutrient cycling and decomposition, plant physiology, conifer seed production, and canopy epiphyte and soil invertebrate populations, among others.

Data Collection, Management, and Analysis

An interdisciplinary team of scientists from Oregon State University, University of Oregon, University of Washington, and the Pacific Northwest Research Station are conducting pre- and post-treatment sampling using standard sampling and data collection protocols (see other papers in this volume). Collection of pre-treatment data was completed in 1997 and harvest treatments will be completed in 1999; post-harvest data collection on several blocks began in spring 1998. Although many of the ecological effects will take decades to express themselves, initial post-treatment assessments will be completed within 2-3 yr after harvest. Future assessments, conducted at 5-, 10-, or 20-year intervals, when changes in canopy structure dominate stand-level responses, will be necessary to fully realize the potential benefits of this study and to provide forest managers with comprehensive information on management options for maintaining late-successional conditions in mature forests managed for timber production.

Data management is centralized at Oregon State University's Quantitative Sciences Group, Forest Science Data Bank in Corvallis, Oregon. Comprehensive data entry, verification, and management protocols have been developed, as well as programs to manipulate and reduce the data for subsequent statistical analyses. All data are non-proprietary, but agreements will be developed among participants to govern publication activities. An information management plan has been developed that specifies data management policies, and discusses data input, access, sharing, and security (Anonymous 1996).

No previous studies have been conducted in Douglas-fir forests that involve the experimental treatments, response variables, and geographic scope encompassed by the DEMO study. In addition to standard statistical methods, some innovative biometrical techniques will be applied. Natural variation in forest ecosystems is high and occurs at all spatial scales; consequently, we will partition the variation in ways that separate treatment responses from those associated with environmental variation and other sources of experimental error. Initial analyses will involve the application of standard ANOVA (analysis of variance) tests in accordance with the basic experimental design. Because of the scope and complexity of this study, however, data analyses will not be limited to standard statistical approaches.

Three of the treatments (15% and 40% aggregated retention and 75% retention) will generate two distinct environments within the treatment area—undisturbed forest and clearcut. Response variables for which measurements in the undisturbed forest are not independent of those taken in the clearcuts, such as bird or small mammal abundance values, will be analyzed using treatment-level means. However, for other organisms with more discrete spatial requirements, these treatments will create two distinct responses. Thus, important within-treatment variation may be obscured by only analyzing treatment-level means; for these variables, analyses will also include finer scale considerations of within-treatment responses (e.g., Halpern et al. 1999).

In addition, there is substantial natural variation both within and among blocks that will influence responses to the treatments; that is, the natural variation present will contribute in specific ways to the effects of the treatments. Sources of variation may include differences in site environment, disturbance history, species composition, or stand structure (e.g., basal area, density, and size structure). Furthermore, in treatments with aggregated retention, the patches contain an intact canopy and have not been disturbed by logging equipment; cut areas in both aggregated and dispersed retention treatments, however, have had their canopies altered and have also been impacted in various ways by the process of removing the trees. Thus initially, the effects of canopy retention will be difficult to separate from the variation in harvest-related disturbance among treatments. However, fine-scale sampling of the types and levels of disturbance (see Halpern et al. 1999) will permit us to evaluate the relative effects of disturbance and retention. Separating these potentially confounding influences may also require the application of more complex analytical approaches, such as longitudinal data analysis (Anonymous 1996).

Integration and Cooperation

The primary vehicles for achieving integration of research activities are the common use of the systematic sampling grid, consistent and uniform implementation of treatments, a centralized and coordinated data management system, and designated scientific and management coordinators working in close collaboration. Many opportunities exist for integration across scientific disciplines including relationships among vegetation, wildlife, fungi, and animal diets; vegetation, birds, bats, and invertebrates; down woody material, snags, and wildlife; hydrology and forest structure; and visual quality and vegetation.

The DEMO study represents a large-scale attempt to conduct comprehensive studies that have direct relevance to ecosystem management. Both planning and implementation have required explicit, ongoing interaction among researchers and managers and, for many, it represents the first opportunity for such collaboration (see Abbott et al. 1999). This process has broadened our collective appreciation of the respective roles and contributions of these two groups in the management of forested ecosystems. These interactions have also presented some challenges, in large part because of legal constraints and differing objectives and approaches among scientists and managers (see Abbott et al. 1999, Franklin et al. 1999). Managers seek to minimize or mitigate potential negative impacts, whereas researchers are concerned with evaluating those impacts in a systematic, unbiased way.

During the design and implementation of the DEMO study, numerous compromises were necessary to resolve conflicting objectives (see Franklin et al. 1999). Research objectives were modified to reduce the number and area of harvest units, and potentially adverse environmental impacts (e.g., those that violate NEPA restrictions) were minimized by avoiding sites that were particularly sensitive to disturbance. Nevertheless, harvest units are larger and silvicultural prescriptions more rigid and restrictive than managers would otherwise implement. In addition, the research requirement for random assignment of treatments contrasts with approaches that would optimize current land management objectives. In most cases, however, managers have been willing to implement rigid treatments and involve the public in ways that differ from current practices (see Abbott et al. 1999).

Scientists and managers will benefit equally from direct involvement in this study. Technical information will be transferred directly to managers, resource specialists, and the public; researchers will gain a new understanding and appreciation of the management process; and fundamental assumptions used to develop green-tree retention standards and guidelines in the Northwest Forest Plan will be tested. The constraints under which resource managers must work are little known to most researchers, and the experiences gained from this study will be useful in designing future studies that contribute to the information needs of those who manage public forests. This sharing of knowledge and experience is central to the DEMO study, and will become more critical as we implement the concepts of adaptive ecosystem management and develop closer working relationships between scientists and land managers. The DEMO study sites will serve as evolving demonstration areas and outdoor laboratories for resource managers, scientists, educators, and the public for decades to come.

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Endnote

[1]Memo from Donald R. Knowles, Executive Director, Regional Ecosystem Office to Charles W. Philpot, Station Director, Pacific Northwest Research Station dated May 31, 1995.