POSTER ABSTRACTS

Photo by Tom Iraci

The H.J. Andrews Uneven-Aged Management Project: Alternative Silvicultural Approaches to Stand Conversion

Paul Anderson[1] and Jim Mayo[2]

The H.J. Andrews Uneven-Even Aged Management Project was undertaken to explore ecological and economical compatibility among silvicultural options for converting 40- to 50-year-old Douglas-fir plantations (*Pseudotsuga menziesii* (Mirb.) Franco) in western Oregon to mixed-species and uneven-aged condition. Three silvicultural prescriptions for conversion are being evaluated: (1) individual tree selection (light thin), (2) group selection (groups cuts, light thin of matrix and mixed species planting of gaps), and (3) heavy thin with mixed-species underplanting. In all three treatments, timing of subsequent entries will be based on stands achieving specified thresholds of relative density. The three treatments, as well as an untreated-control, were applied to stands 10-ha or larger and replicated in four blocks. Initial harvest entries occurred in 1999 with vegetation conditions being measured in 1997-98 (pretreatment) and in 2001 and 2003. This poster presentation summarizes herbaceous and shrub vegetation responses through 3 years following initial harvest entries. Analyses will describe dynamics of species richness, community composition and relative abundance in relationship to residual overstory cover. Observed vegetation responses will be discussed in the context of habitat quality and additional opportunities for small-mammal, arthropod, insect, and amphibian research.

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Variable-Retention Implementation Monitoring

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Weyerhaeuser's British Columbia Coastal Timberlands has adopted the variable retention approach to harvesting and silviculture for all of the company's public and private forest land. The phase-in of variable retention was accomplished over a 5-year period from 1999 through 2003. As part of our adaptive management program, we monitored operational implementation to see if our goals and standards were being met. Symmetree Consulting Group completed evaluations on 248 variable retention cutblocks over this period representing over 6 000 ha to monitor performance and identify areas for improvement. This represented a random sample of over 15 percent of all variable-retention harvesting. Evaluations included both the prescription and the results on the ground. This paper presents a summary of the methods and findings of this monitoring program. Statistics were compiled on the amount and type of retention, size of groups, type of stand attributes and ecological features retained, protection of small streams and riparian areas and the visual aesthetics of the block design. An overall rating of each block was also given based on the degree to which it met the goals for variable retention.

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Characterizing Vegetation Response to Variable Density Thinnings in Young Douglas-fir Forest of Western Oregon

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The Density Management Study was designed to investigate whether thinning to various densities within a stand can accelerate development of late-successional characteristics in young, managed Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) forests (40 to 70 years) while producing wood for the regional economy. Seven initial thinning study sites are located in the Coast Range and Cascade Foothills of western Oregon. The four treatments implemented at each site include an uncut control and units containing one of three levels of residual tree density (high, moderate, and variable density) with circular leave islands and patch cuts of three sizes (0.25, 0.5 and 1.0 acre). The patch cuts and leave islands represent a relatively small proportion of the overall treatment at each site (about 10 percent of the area is patch cuts and 10 percent is leave islands). The thinning treatments were designed to increase overall stand heterogeneity by thinning from below and by retaining hardwood tree species and conifers that were under-represented in the overstory canopy. We are investigating the response of overstory and understory vegetation to the harvest treatments. Preliminary results summarize differences in overstory and understory vegetation composition and structure in relation to the thinning treatments 1 and 5 years following harvest. In addition, we evaluate the relative influence of the patch cuts and leave islands on the understory vegetation response within the treatments.

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Black Spruce Regeneration in the Presence of *Kalmia Angustifolia* L.: Interactions with Irradiance and Nutrients

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Conifer regeneration failure in the presence of *Kalmia angustifolia* L. has been attributed to allelopathy, nutrient cycling, and root competition. This phenomenon challenges the sustainability of present harvesting practices in many boreal forests because reforestation of ericaceous-dominated sites in eastern Canada has been problematic. So far, few studies have focused on available light and soil fertility as possible factors controlling the competitive ability of *Kalmia*. We, therefore, monitored the growth of 120 spruce seedlings assigned to a split-plot field experiment in the southern boreal forest of Québec. Experimental treatments consisted of a factorial array three main-plot light levels (100-percent, 40-percent, 16-percent incident light), two subplot nutrient levels (unfertilized, fertilized), and two subplot competition levels (presence, absence of *Kalmia*). Following two growing seasons, the growth of black spruce seedlings was significantly higher at 100 percent light with fertilizer, than in the other treatment plots. The presence of *Kalmia* had no effect either alone or in interaction. Either both poor regeneration and abundance of *Kalmia* are effects of infertile soil, or the previous presence of carbon on the site had modified the soil properties and these modifications persisted after *Kalmia* was removed. Results are discussed in terms of forest management, as precommercial and commercial thinning are commonly applied silvicultural systems in the boreal forest of Québec. We suggest how a better comprehension of the effects of canopy openness and fertility on the black spruce-Kalmia dynamics could help develop innovative management practices and preharvest decisionmaking in boreal forests.

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Twenty-Five-Year Results of a Restoration Thinning, Redwood National Park

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INTRODUCTION

The current biological landscape of Redwood National Park has been affected by past logging. These second-growth forests are characterized by an extremely high density of trees, stagnated growth and development, high fuel loads, absence of understory vegetation, and a homogeneous vertical structure. Studies conducted throughout the Pacific Northwest on the effects of thinning in young forests have concluded that reducing stand densities can greatly increase structural characteristics associated with late-seral forests in a shortened period of time (Bailey and Tappeiner 1998, Newton and Cole 1987).

The Holter Ridge Thinning Study, located about 6 miles inland from the coast in the headwaters of Lost Man Creek, was initiated in 1978 on a 25-year old redwood *Sequoia sempervirens* (D. Don.) Endl.)/Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)/tanoak (*Lithocarpus densiflorus* (Hook and Arn.) Redh.) forest. Intended as an operational case study, the goals of this research are to observe effects of a low thinning with varying stand densities on mortality, growth, species composition, and structural characteristics. Densities ranged from 150 to 550 trees per acre (tpa) in the thinned units and from 1200 to 3200 tpa in the control at 25 years of age. Species composition varies from redwood/Douglas-fir, to redwood/Douglas-fir/tanoak, and to exclusively redwood. Results of this research are intended to increase the knowledge of stand development in young, mixed redwood/Douglas-fir/tanoak forests and inform future second-growth management within Redwood National and State Parks.

METHODS

Data taken in 1979, 1984, and 1995 showed an increase in basal area growth and reduced mortality related to lower stand densities. However, longer term quantitative analysis and research into stand structure and development are lacking in this study. During the summer of 2003, remeasurements of the original data were conducted on 28, 1/10-acre permanent plots. By using linear regression analysis, stand densities and species compositions are compared to changes in species composition, mortality, tree regeneration, understory vegetation, and height and crown differentiation. Measurements of understory vegetation include estimated cover by species and were analyzed for species richness and Shannon-Weiner diversity index. Stand structure was analyzed by using a modified Shannon-Weiner index in which basal area for a plot was proportioned into three separate indices: species, diameter class, and height class (Staudhammer and LeMay 2001). These indices were then averaged for a total structural index. Individual plots were also grouped post-facto according to post-treatment densities and species composition. These groups include control (~2000 tpa), low-density (~250 tpa), mid-density (~500 tpa), and redwood (~450 tpa).

RESULTS AND DISCUSSION

Mortality among redwood and Douglas-fir were highly correlated with residual stand densities, but tanoak was not significantly related. Changes in species composition in the control plots revealed a significant decrease in the numbers of redwood and Douglas-fir relative to tanoak. This trend will decrease as redwood and Douglas-fir occupy the overstory canopy with tanoak in the lower canopy. Changes in

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species composition for all thinning treatments were minimal suggesting that thinning in dense stands can restore and over time maintain desired species compositions.

Understory vegetation showed the greatest response due to thinning with post-treatment stand density accounting for 87 percent of the variation seen in the cover of understory species. Change in understory cover was dramatic with densities around 150 trees/acre showing an 80-percent increase from 1984 to 2003 and stands over 1000 trees/acre decreasing by 60 percent. Shannon-Weiner diversity index was calculated on the basis of percent cover in which stand density negatively correlated to diversity accounting for 65 percent of the variation. Species richness was not correlated to stand density and may be related more to overstory species composition.

Sprouting response of redwood and tanoak to thinning was compared to the number of redwood/tanoak thinned/acre. Redwood sprouting was positively correlated to the number of redwoods thinned but exhibited a patchy nature due to competing shrubs and closed canopies. The number of sprouts ranged from 0 to 3160 stems/acre while the number of redwoods cut ranged from 0 to 970 stems/acre.

Stand structure was analyzed according to post-facto groupings. Diameter and height distributions revealed no stratification taking place in the controls while mid-density showed initial development into an upper canopy consisting of Douglas-fir and redwood and a lower canopy of redwood and tanoak. The low-density group showed a similar but more pronounced stratification by species. The redwood group developed a continuous canopy layer that was weighted towards the upper-canopy. The construction of a structural diversity index incorporating overstory horizontal, vertical, and species diversity yielded a positive correlation between stand density and structural diversity. Because the Shannon-Weiner index calculates a higher diversity for more classes and evenness, the control plots were given a higher value due to their high uniformity. The development of multiple strata in the lower density thinned plots led to lower values. The redwood plots showed a high diameter and height class diversity but scored low on species diversity due to its redwood dominance.

CONCLUSIONS

Overall, the reduction of stand densities from thinning in dense, young stands has the ability to accelerate stand development, mainly through bypassing the competition-exclusion stage of stand development. Characteristics associated with late-seral forests are consistently present in thinned stands, albeit in the beginning stages. Understory vegetation especially in the shrub and fern layer has become reestablished whereas in the unthinned stand it is now minimal to absent. The cutting of redwood and tanoak has created a patchy mosaic of advanced regeneration. Because of their high shade-tolerance, they may be released into future gaps created in the overstory. The development of multiple strata has taken place with lower densities showing a stronger separation into separate layers. Stand measures of structural diversity, in this case, do not represent the significant structural changes that have taken place due to thinning and cannot be relied on as a measure of desirable characteristics.

Long-term results such as those obtained here show that in some developmental characteristics, such as understory shrubs, the acquisition of those characteristics can take place in a relatively short time. Other characteristics, such as gaps or the release of advance regeneration into the mid-canopies, will take a significant amount of time before they are attained. Nevertheless, the development in stands with reduced densities will outpace those that remain at high-densities and more closely approach the desired future conditions of old forests.

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Density Management Study: Developing Late-Successional Habitat

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The Bureau of Land Management (BLM), working in partnership with the U.S. Geological Survey, Oregon State University, and the Pacific Northwest Research Station, initiated the Density Management Study (DMS) in 1994 to demonstrate and evaluate different approaches to managing 40- to 70-year-old, low-elevation forest stands for late-successional forest characteristics. Study treatments were installed from 1997 to 2001 on 12 BLM sites in western Oregon. There are seven initial thinning study sites where four stand treatments of 30 to 60 acres each were established. These treatments combine different residual tree densities, leave islands of three sizes, patch cuts of three sizes, and an untreated control. Alternative riparian buffer treatments were nested within the moderate density retention treatment. Buffer widths include (1) streamside retention, (2) variable width of approximately 50 feet, (3) one full tree height, and (4) two full tree heights. Rethinning studies were installed in five 60- to 70-year-old stands that had been previously thinned. Each study stand was split into two parts: one part as an untreated control, and the other part designated for rethinning. Rethinning treatments were installed to create horizontal variability in overstory tree density, but there were no specific leave island or patch cut objectives. Multiple studies are underway to assess the responses to these treatments. Primary components include vegetation (trees, shrubs, and herbs), aquatic vertebrates and habitats, aquatic and terrestrial arthropods, riparian microclimate and microhabitat, and the effectiveness of leave islands as refugia for mollusks, amphibians, ground arthropods, and herbaceous vegetation.

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Predicting Understory Light Availability Based on Neighborhood Height Data Derived From Vertical Point Sampling in Mature Douglas-fir Forests in the Western Cascades

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The survival and growth of understory trees is strongly influenced by light levels below the over-story canopy. An understanding of how stand composition and structure influence light is useful when developing management prescription to create favorable conditions for understory trees. The growth of many coniferous species increases in linear matter with light availability. Direct measurement of light levels with instruments has proven to be expensive and time-consuming. Models have been developed that predict light transmittance on the basis of crown or stand architecture, but they involve the collection of a detailed set of measurements to calibrate. To be useful for prescribing foresters, a model to characterize light should only include variables easily measured in stand examinations. Micro-site measures including density, total volume, total height and total diameter at breast height on fixed neighborhoods have proven to be strong predictors of understory light. Total summed height has been shown to be an especially good predictor because it incorporates both stand density and influence of height on angle of incidence of radiation to the forest floor. However, collecting total height data is often cost prohibitive. In this study, we examined if vertical point sampling is a potential alternative approach to collecting height data while retaining the structural attributes strong predictive power. Early results suggest that height data derived from angle sampling is statistically correlated with light availability between 20-100 percent of full sun. However, when the available light drops below 20 percent the performance of angle sample derived summed height data is very weak.

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An Application of Hierarchy Theory to Long-Term Sustainability

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Traditionally, the effects of cultural practices on long-term productivity of commercial forests have been investigated under the assumption that forest growth is substrate limited. Regarding regeneration, effects typically under consideration are soil compaction and organic matter removal that either limit root growth or reduce nutrient availability in the absence of erosion. Tree growth, however, is only weakly related to soil physical properties and nutrient availability. Furthermore, soil structure and organic matter recover with time, in many cases, leading to the conclusion that any effects that regeneration practices may have on forest growth are probably temporary.

One of the difficulties in assessing the long-term effects of cultural practices on forest productivity is the lack of a good measure of productivity. Productivity is the capacity to produce, which is difficult to measure directly. This is why many investigators use a soils-based approach to measure productivity.

Productivity is the outcome of a complex system, a system comprised of numerous levels of organization arranged within a hierarchy (Ahl and Allen 1996). The principal attribute of complex systems is asymmetric relationships between levels where the behavior of lower, relatively more dynamic levels are held in check by higher, relatively slower levels. Asymmetric relationships exist in many forms. The most easily recognized asymmetry is one where a higher level of organization places constraints on the range of activity exhibited by a lower level of organization. Another important form of asymmetry is where the higher level of organization buffers or filters factors influencing a lower level of organization. An example of buffering is the influence of a mature canopy on the understory microclimate.

Many of the constraints and buffers provided by the higher levels of organization are disrupted, if not eliminated, during the regeneration period of a commercial forest, especially in clearcut systems. For example, the exposure of saprophytic organisms to the unfiltered physical environment could be one source of significant changes in mineral nitrogen often detected in the soil at the start of the regeneration period. Constraints and buffers reestablish as the vegetation reestablishes, and mineralization returns to preharvest rates. Unless the same hierarchy reestablishes, however, productivity may be changed.

In commercial forestry production, productivity is often defined as the capacity to produce wood. In conifers, two meristems are principally responsible for wood production: the primary meristem on the terminal bud and the cambium. Height and diameter increments are difficult to correlate with any specific environmental variable; one of the reasons for this difficulty may be that higher levels of organization may buffer meristem activity from variation in the physical environment.

Results of past studies help identify levels of organization relevant to long-term productivity. Various pine species have shown a correlation between the length of the terminal bud and the final length of the elongated node produced from that bud. Research has also shown that the size of the overwintering bud depends on the vigor of the tree. Consequently, leader elongation and the stem appear to represent a hierarchical relationship with the stimuli influencing leader growth being buffered

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or constrained by the main stem. The crown may buffer factors influencing stem growth. A recent study reports that a large percentage of variation in cambial activity at breast height in several pine species is explained by seasonal increases in the amount and distribution of the leaf area. This poster reports preliminary results of the effects of harvesting intensity and site preparation on leader elongation and stem diameter from a hierarchical perspective.

In the west Gulf region of the United States, studies are underway to chronicle the effects of organic matter removal and soil compaction on growth of the subsequent generation of loblolly pine (*Pinus faeda* L.). The experiments differ in degree of control of treatment application. In the Long-Term Soil Productivity experiment (LTSP) of the USDA Forest Service, organic matter removal and soil compaction are carefully controlled and uniformly applied to the plot. In the Cooperative Research in Sustainable Silviculture and Soil Productivity (CRiSSSP) commercial forest studies, the degree of organic matter removal and soil compaction was dictated by the equipment used to harvest the stand; however, they include a minimum disturbance treatment comparable to the zero compaction level and the minimum removal of organic matter treatment of the LTSP study.

Both the LTSP study and each CRiSSSP installation were blocked with factorial combinations of the treatments randomly assigned within each block. Height was measured annually on every tree for the first 5 growing seasons. Measurement intervals varied after age 6. Diameter at breast height (d.b.h.) was measured on trees greater than 1.37 m tall. A simple power function was fit with nonlinear regression to the height—age data for each treatment combination across blocks. The first derivative of the fitted equation was plotted against height to evaluate the hypothesis that harvesting and site preparation change the hierarchical relationship between the main stem and elongation of the terminal shoot. The hierarchical relationship between cambium activity and amount and distribution of leaf area was investigated by inspecting the relationship between d.b.h., the product of leaf area, and the height to the middle of the crown defined by the uniform-stress principle of stem formation (Dean et al. 2002). Changes in this relationship suggests changes in xylem anatomy and physiological processes affected by xylem anatomy.

Harvesting had little if any effect on the relationship between leader elongation and tree height. With the exception of the first level of compaction in the LTSP study, compaction and organic matter removal slightly decreased the leader elongation associated with a given height relative to the control treatment. Conventional harvesting in the CRiSSSP studies also reduced leader length per unit height slightly at two locations but had no effect on the relationship at two other locations. Treatments that substantially reduced interspecific competition or improved soil nutrition did appear to significantly change leader elongation for a given height. With the exception of one location, these treatments increased the leader increment expected for a given height. Based on this analysis, competition control and fertilization seem more likely candidates than harvesting for affecting long-term productivity in terms of height accumulation.

Harvesting also appears to have little or no effect on the relationship between d.b.h. and the amount and distribution of leaf area on the stem. In the LTSP study, while the coefficients for indicator variables representing the various treatment factors indicate a significant effect on the constant, plots of the equations for the various compaction and organic matter removal levels lie nearly on top of each other. Coefficients for indicator variables for harvesting in the CRiSSSP studies were not significantly different from zero. The only treatment having a significant effect on the relationship was fertilization. With fertilized trees, the d.b.h. associated with a specific combination of leaf area and height to the middle of the crown was substantially lower than unfertilized trees with the same combination of leaf area and height to the middle of the crown.

Based on these results, harvesting does not seem to affect these two, simple hierarchical relationships. Treatments that affect competition or nutrient availability, however, do seem to increase leader elongation for a given tree height, and fertilization reduces the d.b.h. associated with a particular combination of leaf area and height to the middle of the crown. Obviously, longer observation times are required before such changes in these hierarchical relationships can actually portend changes in long-term productivity; however, changes observed in this study suggest that hierarchical relationships may be useful in evaluating the effects of regeneration practices on long-term productivity.

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Design Issues for Small Mammal Studies in Silvicultural Experiments

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Wildlife studies face design constraints that may be minor problems for other disciplines in large-scale silvicultural experiments. To illustrate some of these issues, we use the small mammal research component of the Demonstration of Ecosystem Management Options (DEMO) project, as a case study. The DEMO study is a USDA Forest Service-initiated experiment examining effects of different patterns and amounts of green-tree retention harvests in mature coniferous forests of the Pacific Northwest.

Variability in small mammal communities across the region of interest may reduce the effective sample size for some analyses, and may contribute to variation in treatment effects across the study region. In the DEMO experiment, forest-floor small mammals were sampled with pitfall traps during two pretreatment years and during the first and second years after harvests. Many species were absent from two or four of six study blocks, lowering the number of replicates for analyses focusing on these species. Some species showed initial trends of opposite sign among study blocks. In a randomized block study, replication of treatments within blocks would address this community variation, but may require reducing the number of treatments implemented.

Wildlife population studies also must consider the number of animals of each focal species present, on average, on each study site, and the probability of observing each individual. Sampling precision decreases as population size decreases, reducing statistical power (Skalski and Robson 1992). Moreover, wildlife statisticians increasingly dismiss studies that analyze indices of abundance without examining whether capture probabilities (detectability) vary across sites (Anderson 2003). To meet rigorous statistical requirements, high numbers of captures for focal species on each site are needed. In the DEMO study, even species captured in high numbers overall were found in low abundance at some blocks. For the most abundant species captured (*Sorex trowbridgii*), estimated capture probabilities did not differ between forest and harvested sites, but did show high variation overall. We examine whether estimated detectability differed across treatments for other commonly captured small mammals in the DEMO study.

We frequently observed low densities and high local and regional spatial variability in the DEMO small mammal study. Our observations reinforce the need for replication of treatments locally (within block) and regionally, with experimental units big enough to support large sampling grids and relatively high captures of focal species. Sampling should conform to a statistical model allowing estimation of abundance and detectability (e.g., mark-recapture model). These factors may place strong constraints on the overall design of a silvicultural experiment with wildlife components.

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Potential of Green-Tree Retention as a Tool to Maintain Soil Function After Harvest

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The aim of this project is to assess the potential use of green-tree retention as a management tool to maintain soil functioning and site productivity after harvesting. Specifically, the project will identify the diversity and function of the "black box" of largely unknown soil organisms and changes in these communities with several variable retention harvesting systems to determine (1) if green-tree retention is a suitable management option for maintaining a healthy soil and (2) the size and density of retention patches most favorable for this purpose. The ultimate goal is to recommend the optimal design of variable-rentention systems for maintaining soil biodiversity and function.

There are three main questions of interest: (1) Do patches of green-tree retention retain the structure and function of soil biota of the uncut forest? (2) Is there a minimum retention patch size of green-tree retention necessary to do this? (3) How far does the effect of a green-tree retention patch extend into the harvested area, and does the "shadow" vary with green-tree retention patch size?

There is clear evidence that clear-cutting affects the biomass, diversity, and community structure of soil microorganisms (Jones et al. 2003) and soil invertebrates (Addison et al. 2003). There is also evidence that partial cutting has less of an effect than clear-cutting on soil organisms (Marshall 2000). It is less clear which type of partial cutting best protects soil biodiversity and functioning. This project brings together a unique, multidisciplinary group of researchers, applying a range of novel techniques to quantify changes in soil microbial and faunal diversity and function in response to harvesting. The project is using the second replicate of the STEMS (www.for.gov.bc.ca/hre/stems) installation near Elk Bay, Vancouver Island for the study. STEMS is a large, multidisciplinary field experiment that compares the ecological, biological and socio-economic effects of seven silvicultural systems including clear-cut, uncut, group selection, patch cuts, dispersed retention and aggregated retention. The site for the second replicate is CWHxm2—very dry Maritime Coastal Western Hemlock Subzone. The site series is 05 western redcedar—sword fern, a slightly dry to fresh soil moisture regime and a rich to very rich soil nutrient regime. The stand is 60 years old and has a site index of 35 m at 50 years. The advantage of using the STEMS experiment is that it allows us to examine the same soils pre- and post-harvest. We will sample 4 replicate aggregated retention patches of 4 sizes. In the first year (2004, preharvest) we will sample what will be (1) the center of each retention patch, (2) the edge of each retention patch and (3) 30 m from the edge of the retention patch. We will also sample four areas of what will be uncut control and clear-cut at the same distances to obtain a baseline comparison. In the second and subsequent years

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(2005 on, post-harvest) we will sample the patch center and then along a transect going 30 m out from the patch edge into the clear-cut. In year 3 we will compare treatments in STEMS replicate 1, (5 years, post-harvest), comparing the patches and associated openings with uncut forest and the dispersed retention treatment to determine whether the lighter influence shadow cast by dispersed retention retains community structure and function across more of the opening than does aggregated retention.

Microbial community structure will be characterized by phenotypic and molecular methods and function determined by using biochemical analyses. DNA will be extracted from soil and the community profiled through PCR-DGGE analysis of ribosomal RNA genes (rDNA) (Leckie et al. 2004). PCR primers specific for different phylogenetic groups will ensure fine resolution. Primers for catabolic genes characteristic of specific functional groups (e.g., NH_4 oxidizers, N_2 fixers) will be used to assess diversity of functional genes in different soils and treatments by T-RFLP. We will use primers designed to amplify the *nif*H subunit of nitrogenase, which have been widely used in functional ecology studies of nitrogen-fixing microbial communities. Ammonia oxidizing bacterial communities will be targeted by using primers for the *amo*A gene. The biomass and structure of the soil microbial community will be assessed by analyzing the ester-linked phospholipid fatty acids (PLFA) composition of the soil because certain groups of microorganisms have different "signature" fatty acids. PLFA will be extracted from soil, fractionated and quantified using the procedure described by Grayston et al. (2004). Microbial activity and catabolic diversity will be assessed using basal and substrate induced respiration using a variety of carbon (C) sources. A rapid microplate enzyme assay system will be used to compare the key enzymes involved in C, nitrogen (N), and phosphorus (P) cycling in soil. The enzymes measured will be C (cellulase, B glucosidase, phenol oxidase and lignin peroxidase), N (chitobiosidase, N acetyl glucosaminidase, urease and protease) and P (acid phosphatase). To assess fungal community structure, abundance of mushrooms (including chanterelles) will be determined, DNA extracted and analyzed by RFLP and sequencing.

Soil mesofauna (mites, collembolan, nematodes) will be extracted from the soil by using standard wet and dry extraction techniques, and will be identified to species or morphospecies (Addison et al. 2003). A digital library of images will be constructed to aid identification, allow remote species confirmations, and facilitate consultation with researchers world-wide. Functional roles of different species will be determined by using published literature, analysis of gut contents and mouth-part morphology. Coastal forests of Vancouver Island are unique in that they contain not only native earthworms, but a giant enchytraeid species, in addition to the keystone millipede *Harpaphe haydeniana*. The abundance and community structure of these elements of the soil macrofauna will be determined by using Tullgren funnels and wet sieving.

Nutrient availability in the field will be determined close to each sampling point in the transect, using ion-exchange membranes ((PRS)™-probes (Western Ag Innovations, Saskatoon, SK)), changed monthly during the year. Litter fall will be measured by collecting litter four times per year in 0.08 m^2 trays placed at the transect sampling points, to determine if patterns of soil biodiversity are related to the "litter shadow" of remaining trees.

The study is designed to run at least 5 years and provide new knowledge each year. In year 1, the project will identify the diversity of soil microorganisms and fauna in forest soils, producing molecular and taxonomic databases, culture collections, digital photographic records and species keys. In year 2 and subsequent years, the project will produce information on the initial effects of different retention treatments, which will allow us to make recommendations about the effectiveness of partial harvesting at maintaining soil diversity and function and the most appropriate retention level and spatial arrangement. In year 3, we will be able to make use of the longer time that replicate 1 of the STEMS experiment has been in place and make 5-year measurements on the control, clear-cut, dispersed retention, and aggregate retention treatments. We use these results to test our initial predications and will adapt our recommendations on the basis of new results. In year 4, we will use results and trends to date to identify key indicators soil diversity and soil functioning and will adapt our monitoring to emphasize these. We will generate hypotheses regarding the link between the indicators and keystone groups to critical soil processes, which we will test using manipulative experiments.

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Effects of Green-Tree Retention on the Availability of Arthropod Prey to Bark-Gleaning Birds

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Green-tree retention is gaining popularity as a forest management tool in the Pacific Northwest. The Demonstration of Ecosystem Management Options (DEMO) study is the first experimental attempt to provide the needed empirical evidence to evaluate ecological consequences of this silvicultural model to a wide range of forest organisms. The current study investigated the effects of varying levels and patterns of green-tree retention on the availability of arthropod prey to bark-gleaning birds, primarily the brown creeper (*Certhia americana*). This ongoing study has a randomized block design and utilizes three of the existing DEMO blocks in the western Cascade Range of Oregon and Washington. In each block, five 13-ha treatment units were used in the experiment, including (1) 15-percent aggregated tree retention, (2) 15-percent dispersed retention, (3) 40-percent aggregated retention, (4) 40-percent dispersed retention and (5) 100-percent retention (control). Arthropods were collected by using crawl traps installed on live Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) trees and snags and with D-vac sampling of tree boles during the brown creeper breeding season from May through August, 2003. Preliminary results showed that the bark arthropod community was dominated by Collembola (44 percent), Araneae (18 percent), Coleoptera (11 percent) and Hemiptera (10 percent). The total arthropod abundance tended to be higher on live trees than snags. Spiders appeared especially sensitive to different combinations of green-tree retention. Significant shifts in the spider guild structure were found among individual treatments and the abundance of these predators was generally higher in dispersed rather than aggregated treatments and at 15-percent rather than 40-percent tree-retention levels.

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Vegetation Responses to Varying Levels and Patterns of Overstory Retention: Early Results of the DEMO Experiment

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INTRODUCTION

Retention of overstory trees during timber harvest has become increasingly common in temperate and boreal ecosystems as land managers seek to balance the commodity and ecological values of managed forests. In the Pacific Northwest region of the United States, variable or green-tree retention has replaced clearcut logging on federal lands within the range of the northern spotted owl (*Strix occidentalis caurina*), with the expressed goal of enhancing the structural and biological diversity of regenerating forests. The Demonstration of Ecosystem Management Options (DEMO) study examines the ecological responses of forest ecosystems to variable-retention harvests. Specifically, it tests how the level of tree retention and its spatial distribution (dispersed or aggregated) influence the persistence and recovery of biological diversity. In this paper, we explore some of the early responses of forest communities to variation in the level and/or patterns of retention. We focus on post-harvest mortality of trees and on the responses of two groups of understory plants likely to be sensitive to changes in overstory structure—herbs associated with late-seral forests and ground-layer bryophytes.

EXPERIMENTAL AND SAMPLING DESIGNS

The full experimental design consists of six treatments, including a control, replicated at each of six locations (blocks) in southwestern Oregon and Washington (Aubry et al. 1999). In this paper we focus on five of these treatments: the control (100 percent retention), and four that contrast level of retention (40 vs. 15 percent of original basal area) and its spatial distribution (aggregated vs. dispersed). Treatments, assigned randomly to 13-ha experimental units within each block, were applied as follows:

- Control: no harvest
- 40-percent aggregated retention: five 1-ha circular aggregates were retained; all merchantable trees in the surrounding area were cut and removed
- 40-percent dispersed retention: the same basal area was retained as in the 40-percent aggregated retention, but as dominant and co-dominant trees evenly dispersed through the treatment area
- 15-percent aggregated retention: two 1-ha circular aggregates were retained; all merchantable trees in the surrounding area were cut and removed
- 15-percent dispersed retention: the same basal area was retained as in 15-percent aggregate retention treatment, but as dominant and co-dominant trees evenly dispersed through the treatment area

Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) dominated all sites, but forest age, structure, and understory composition varied considerably among blocks (Halpern et al. 1999). Treatments were implemented within each block

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within a period of 3 to 7 months during 1997 and 1998. Details on harvest prescriptions, yarding methods, site preparation, and planting can be found in Aubry et al. (1999), Halpern and McKenzie (2001), and Halpern et al. (2005).

Within each treatment unit, a systematic sampling grid (40-m spacing) was established prior to harvest. Nested vegetation plots were established for sampling overstory trees, tall shrubs, and ground-layer plants, with the number and distribution of plots varying by treatment. Overstory trees were sampled in circular plots of 0.04 ha area. Following harvest, all residual trees >5 cm d.b.h. were tagged, identified to species, measured for diameter, and assigned to a canopy class (e.g., suppressed, co-dominant). Post-harvest mortality was assessed annually for 2 to 3 years. Pre- and post-harvest measurements of shrub height and cover were taken along four perpendicular transects (total length 24 m). Presence of all herbaceous and bryophyte (moss and liverwort) species was recorded within 24, 0.1 m^2 quadrats from which species' frequencies were calculated. Species in the herb layer were analyzed by seral status (early seral, forest, and late-seral) to distinguish among taxa with differing successional roles and sensitivities to disturbance.

RESULTS AND DISCUSSION

Over 2 to 3 years of observation, the rates, patterns and causes of tree mortality were significantly affected by both level and pattern of overstory retention. Cumulative mortality was significantly greater at 15 percent than at 40 percent retention (4.0 to 8.4 percent vs. 1.9 to 3.6 percent, respectively). Additionally, at both levels of retention, aggregation of trees significantly reduced mortality: cumulative rates were 1.9 to 4.0 percent in aggregated treatments and 3.6 to 8.4 percent in dispersed treatments. Furthermore, mortality of co-dominant trees responded to level of retention, while suppressed trees showed a stronger response to retention pattern. Mortality of co-dominants was greater at lower levels of retention, particularly in dispersed treatments (7.3 percent in 15-percent dispersed vs. 1.4 percent in 40 percent dispersed). In contrast, suppressed trees had higher rates of mortality in dispersed than in aggregated treatments (8.2 to 10.9 percent vs. 2.2 to 4.9 percent, respectively). These differences are consistent with frequencies of bole damage induced by logging activities (17 to 27 percent vs. 2 percent in dispersed and aggregated treatments, respectively (Moore et al. 2002)). Among the dominant forms of mortality, wind damage (windsnap or wind throw) was particularly common in the 15-percent dispersed treatment (4.0 percent vs. 0.4 to 1.1 percent elsewhere).

In combination, these results lead to two general conclusions: (1) in the short-term, forest aggregates of 1-ha in size are fairly stable; and (2) at low levels of retention, dispersed patterns are susceptible to logging and wind damage that can lead to significant mortality, even among co-dominant trees. This latter result is especially relevant to the design of variable retention harvests in that these larger, more vigorous trees are typically selected for retention.

Among vascular understory plants, declines in species frequency and richness, and changes in species composition were significantly greater at lower levels of retention.

Pattern of retention, however, had surprisingly little effect on understory response. This latter result can be attributed to extremes in response within the aggregated treatments: post-harvest changes were small within the forest aggregates, but declines in adjacent harvest areas were large and generally greater than those in dispersed treatments. Late-seral herbs were particularly sensitive to these effects, experiencing more frequent extirpations from the harvested portions of aggregated treatments than from dispersed treatments. These initial responses to harvest are consistent with patterns of ground disturbance and slash accumulation which varied markedly among treatments (Halpern and McKenzie 2001). As effects of disturbance diminish with time, however, we expect that variation in overstory structure will play an increasingly important role in understory recovery.

Ground-layer bryophytes showed greater sensitivity to timber harvest than did vascular plants. Declines in total cover, richness, and species frequency were large and comparable among treatments. For most measures of response, declines in thinned plots (dispersed treatments) were as large as those in cleared plots (harvested portions of aggregated treatments). This is not surprising given the limited capacity of most shade-adapted bryophytes to tolerate heat or moisture stress. In contrast, changes within the 1-ha forest aggregates were generally small (comparable to changes within the controls).

Do our results suggest clear differences in vegetation response to different levels or spatial patterns of retention? Higher levels of retention clearly reduced wind throw of isolated or newly exposed trees and loss of herbaceous species associated with late-seral forests. Responses to pattern of retention, however, were mixed. Tree mortality was reduced in aggregated treatments, but the benefit of aggregated retention for understory plants was predictably localized within the forest aggregates; in adjacent harvest areas, species showed greater declines or more frequent extirpations than in dispersed treatments. For plant species that are sensitive to disturbance or dependent on deep shade or moist substrates, forest aggregates serve as temporary refugia, maintaining local populations through timber harvest. In the longer term, moreover, they can serve as sources for dispersal into adjacent harvest areas. Although these functions may be compromised by edge effects, our observations suggest that patches of 1-ha in size are sufficiently large to maintain viable populations of most species (see Nelson and Halpern, this issue).

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Biodiversity at the Sicamous Creek Silvicultural Systems Project: Treatment, Edge and Site Preparation Effects in Subalpine Forest

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A multidisciplinary project at the Sicamous Creek Silvicultural Systems site in interior British Columbia, Canada, examines management alternatives for high-elevation Engelmann spruce–subalpine fir forests, by using a large-scale replicated experiment. Harvest treatments, each replicated 3 times, include: 10-ha clearcuts and surrounding wide leave strips, arrays of 1-ha patch cuts with 100 m wide leave strips, arrays of 0.1-ha patch cuts with narrow leave strips, uniform partial cuts and uncut forest. Each harvest treatment removed a third of the trees. Openings are square and regularly spaced to allow examination of edge effects into and out of openings unconfounded by changes in stand type or topographic features. Within each main treatment unit, 30 m x 30 m experimental plots allow comparison of 4 site preparation techniques: standard operational mounding, prescribed burning, organic-layer removal and undisturbed. More than 40 researchers at the site have examined a wide range of ecosystem components and resources. Here, we collate harvest treatment, site preparation, and edge effects from biodiversity studies, which include lichens, bryophytes, vascular plants, wildlife habitat structures, pine marten, spruce grouse, woodpeckers, songbirds, small mammals, and terrestrial invertebrates.

As expected, no single harvest treatment will best accommodate all species. However, many species showed similar responses to treatments using 10-ha and 1-ha openings, but different responses to 0.1-ha openings or uniform partial cuts. Recent operational changes from large clearcuts to 3- to 5-ha openings have reduced public concern about clearcutting, but may make little difference for most organisms. For many, but not all, species studied at Sicamous Creek, 0.1-ha patch cuts better retained sensitive species than uniform partial cuts. Maintaining small-scale heterogeneity with patch-cuts or group selection should be favored over more uniform, continuous cover harvest systems.

Most species that differed between openings and retained forest showed no edge effects in this naturally open forest type. A few species, such as three-toed woodpeckers, pine marten and grylloblattid insects, showed positive responses to edges. Some species associated with retained forest extended 5 to 10 m into openings. These effects support the use of small openings. Short-term negative edge effects were found for spruce grouse, though this species was not disproportionately impacted by small openings. Reductions in bryophyte abundance were measured up to 50 m into the forest from south-facing edges. These results suggest that even narrow leave strips and small retained patches can remain as suitable habitat for many forest-dwelling species. However, extensive windthrow observed near some edges of 1- and 10-ha openings may extend some negative edge effects further into the forest over time.

Site preparation options altered vegetation succession and had some strong initial effects on invertebrates and small mammals. The current operational practice of mounding was most similar to undisturbed sites, but did have some negative effects on a few species. These are likely due to mechanical damage to shrubs and logs by the excavator used to do the mounding, suggesting possibilities to reduce the impact with different machinery or operational practices where mounding is necessary for silviculture.

More extensive summaries of the results for harvest treatments, edge effects and site preparation at Sicamous Creek are available at http://www.for.gov.bc.ca/hfd/ pubs/Docs/En/En63.htm, …/En62.htm, and …/En65.htm

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Operational Comparisons and Experiments for Monitoring Habitat Structures in Weyerhaeuser's Coastal BC Variable Retention

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Weyerhaeuser's adaptive management program for monitoring and improving variable retention harvesting in coastal British Columbia, Canada, includes monitoring operational harvest blocks and replicated, randomized experimental treatments. Both the operational and experimental approaches were used for the monitoring because the advantages and disadvantages of each mean that neither one alone is sufficient for a complete program. Randomization in experimental sites removes some of the confounding effects between treatments and environmental variables typically found in operational settings. However, with limited replication, confounding with at least a few of the innumerable possible pre-existing site differences is still inevitable in experimental sites. Experimental sites have the advantage of allowing controlled manipulation of single important variables; the drawback is deciding which of the many possible important variables to study. Perhaps most importantly, experimental blocks allow a greater range of treatments than operational blocks, which have greater constraints due to economics and professional risk-aversion. On the other hand, monitoring operational blocks allows a greater sample size of common treatments to represent a diverse range of ecosystems. It is also necessary for determining the weakest points of operational practices and for measuring operational improvement over time. Operational blocks are readily available, in contrast to typically slow implementation of designed experiments; this enables faster short-term results to inform managers and to satisfy impatient funding institutions.

A critical part of learning from the operational monitoring is a sampling design that allows comparisons to address main management questions. Weyerhaeuser's design used in coastal British Columbia for operational monitoring of stand-level habitat structures (trees, snags, logs, cover layers, heterogeneity and others) includes primary comparisons of (1) different types of variable retention (dispersed, group and mixed), (2) unmanaged benchmarks versus variable retention blocks, (3) relationships with percentage of retention in variable retention blocks, (4) edge effects into and out of variable retention reserves, and (5) progress in retaining structures in operational blocks over time. To date, we have monitored structures in 180 variable retention blocks and 56 unmanaged benchmarks across the various ecosystems in coastal British Columbia under Weyerhaeuser's tenure. Additional sampling of operational blocks allows secondary comparisons of riparian versus upland reserves, older clearcuts, older remnant (pre-variable retention) patches and nonharvestable "scrub" sites. We present 5-year results, management feedback, and lessons we have learned about monitoring with designed operational comparisons and experimental treatments.

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Rediscovering What Works: The Stoddard-Neel Approach as a Case Study of Conservation-Oriented Sustainable Forestry

Steven Jack[1] and Kevin McIntyre[1]

Uneven-aged silvicultural approaches are often proposed as appropriate for many forest types in the United States to provide a sustainable balance of biodiversity and ecosystem "health" in addition to timber products. Several uneven-aged approaches have been well-documented and widely applied, but most are focused primarily on the production of wood products in regulated systems. In thinking about appropriate new approaches to sustainable forestry, it is wise to remind ourselves of approaches that have a long history of achieving the desired objectives. One such example is the Stoddard-Neel approach developed by Herbert Stoddard and Leon Neel over several decades in open pine-grassland ecosystems (with particular attention to longleaf pine) on the Southeastern Coastal Plain. The Stoddard-Neel approach is unique not for its uneven-aged focus or method for selecting trees for removal, but rather in its overall guiding philosophy of resource management and what is selected to remain on the site after each harvest entry. In the Stoddard-Neel approach, the production of timber and subsequent economic return are byproducts of a central focus on long-term stewardship. That is, rather than a primary focus on timber management with other resources and amenities as secondary or ancillary, the Stoddard-Neel approach seeks to preserve all characteristics of the ecosystem and then determine how much timber is available for harvest while maintaining a balance of ecological, economic, conservation and aesthetic values. We will describe the Stoddard-Neel approach to forest management, including key tenets and objectives, and provide an example using long-term records from one property.

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Extended Rotation Red Pine Stands in Minnesota

Christel Kern[1] and Brian Palik[1]

Extended rotation stands are rare in most regions, but will likely be more common in the future because of the high conservation value placed on old forests by society. Quantitative data on growth and yield of extended rotation stands are not common, making economic predictions and ecological expectations difficult to assess. This reflects the practice of basing rotation age on culmination of mean annual volume increment (CAI) in unthinned stands, without necessarily factoring in the influence of periodic thinning on growth. We are studying extended rotation red pine (*Pinus resinosa* Soland.) stands to better understand the ecological, growth, and yield consequences of managing long-lived species beyond the traditional rotation age (70 to 90 years for red pine). Our study uses a level of growing stock study that was installed in 85-year-old red pine stands in 1950. Treatments consist of five levels of residual basal area from 14 to 32 m^2/ha. The stands have been thinned five to seven times. By age 138, mean annual increment had not culminated in the low basal area treatments, holding steady at around 2.5 m^3/ha. Mean annual increment in the higher basal area treatments show signs of culmination between ages 115 to 135 years. Our study reaffirms a growing belief that CAI has limited value for determining rotation age, given objectives that are more inclusive of conservation and ecological goals. This study also reflects the value of long-term experiments, even if established for other reasons, for addressing emerging silvicultural questions.

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Demonstrating Conservation Forestry: Increasing Exposure to Increase Acceptance in the Southeast

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There is increasing interest in alternatives to production-oriented resource management among landowners in the Southeastern Coastal Plain of the United States, where almost 70 percent of the forestland is held in nonindustrial private ownership. Most nonindustrial private landowners rely on forest consultants and extension programs for forest management expertise, yet many of these sources of information offer a limited perspective that often focuses heavily on traditional production-oriented silvicultural approaches. The Joseph W. Jones Ecological Research Center is located at Ichauway, a 11 700-ha property in southwestern Georgia that includes 7300 ha of fire-dependent longleaf pine dominated forests. The Center, with missions in research, conservation and education, is a proponent of conservation-oriented resource management where no single characteristic or factor is maximized at the expense of other resources, and a balance is sought between biodiversity values, timber production, wildlife management, and overall aesthetics of the land. To further our mission goals and to provide relevant information to regional landowners we are developing a 400-ha demonstration area that brings together many of the components of this conservation management approach in one easily accessible location. Specific aspects of this demonstration project include (1) multiple and integrated resource management for forest, wildlife and biological diversity values, including examples of uneven-aged forestry practices, native groundcover maintenance, wildlife management (including nongame and endangered species), and ecological restoration; (2) quantification of inputs to and outputs from the demonstration area, both tangible and intangible, to enable economic comparisons between resource management alternatives; and (3) implementation of basic and applied research projects within the managed landscape.

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Contribution of Monitoring Research to Forest Certification and Ecologically Sustainable Forest Management in the Yamanashi Prefectural Forest, Central Japan

Takuo Nagaike[1]

Yamanashi Prefectural Forest (YPF, 158 000 ha) comprises 35 percent of the Yamanashi prefecture, central Japan. Because the people of the prefecture now expect ecologically sustainable forest management rather than solely timber production from the YPF, the management policy of the YPF has changed. Yamanashi Forest Ecosystem Monitoring Project, which is a research project about criteria and indicators based on Montreal Process, was started in 1997 to contribute to ecologically sustainable forest management in the YPF (Nagaike 2002, Nagaike and Hayashi 2003). Because the forest in the project area is dominated by *Larix kaempferi* plantations between 40 and 50 years old, it is desirable to change this age structure. Thus, I studied the effects of stand age on the plant species diversity in plantations. I found the species composition of understory plants in 40- to 50-year-old plantation to be different than in older plantations (Nagaike et al. 2003; Nagaike and Hayashi, in press). The YPF was certified by Forest Stewardship Council (FSC) in 2003. Although the YPF received the FSC certification, the assessment team pointed out 17 stipulated conditions. The important points of the conditions were assessment and monitoring of forest management and landscape management. I will discuss the relationship between the conditions and the project and other related research.

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Short-Term Responses of Vascular Plants and Bryophytes in Forest Patches Retained During Structural Retention Harvests

Cara Nelson[1] and Charles Halpern[1]

INTRODUCTION

Aggregated retention of overstory trees is now a standard component of timber harvest prescriptions on federal lands in the Pacific Northwest. Patches of remnant forest (hereafter, forest aggregates) retained during harvest are thought to enhance the structural and biological diversity of managed forests, but the extent to which they maintain components of the original understory or promote recovery in adjacent harvest areas has not been tested. Although small forest aggregates can have high conservation value, fragmentation or edge influences may diminish their ecological functions. We examined short-term (1 and 2 year) responses of understory plants to disturbance and creation of edges in structural retention harvest units at two sites in western Washington. Our design uses pre- and post-treatment measurements of permanent plots, allowing us to reliably quantify the spatial pattern, magnitude, and time course of vegetation response. We pose the following questions: (1) Do species richness and community composition remain stable in forest aggregates? (2) Do aggregates retain disturbance-sensitive plants that decline in, or are lost from, adjacent areas of harvest? (3) Within forest aggregates, are there edge-related gradients in vegetation response (changes in species richness, community composition, or abundance of individual species) and, if so, do these gradients correlate with changes in light availability or disturbance?

FIELD METHODS

This study was conducted in mature Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) forests on the Gifford Pinchot National Forest, in conjunction with the Demonstration of Ecosystem Management Options (DEMO) experiment (Aubry et al. 1999, Halpern et al. 1999). Sampling occurred in two 13-ha aggregated retention harvest units, in which five 1-ha (56-m radius) circular forest aggregates were retained (Nelson and Halpern 2005). In the surrounding area, all merchantable trees (> 18 cm diameter at breast height) were cut and removed. Pretreatment sampling was conducted in 1996 and post-treatment sampling in 1998 and 1999 (years 1 and 2). At each site, two of the five 1-ha circular aggregates marked for retention were randomly selected. In each of these, we established four perpendicular transects, 81 m in length, which extended in cardinal directions from the aggregate center and ended 25 m into the surrounding area to be harvested. Twelve bands of permanent plots were established along each transect, eight in the area marked for retention (at distances of 0, 5, 10, 15, 20, 30, 40, and 50 m from the edge) and four in the area marked for harvest (at distances of 5, 10, 15, and 25 m from the edge). Each band consisted of five, 1-m^2 subplots, within which we estimated the cover of all vascular plant species, and five 0.1-m^2 microplots, within which we estimated the cover of ground-layer bryophytes. To explore possible correlates of vegetation change, we quantified cover of logging slash and disturbed soil (year 1) and light availability (year 2). Cover of logging slash and disturbed soil was estimated along the interior edge of each band by using the line-intercept method. Light availability was estimated with a CI-110 digital canopy imager with a 150-degree lens. Digital photographs were taken from the end points of each band at a height of 1 m from the ground surface. Digital images were analyzed using Scanopy 2.0b software to calculate percent open sky.

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ANALYSES

We considered three types of response variables: richness, community composition, and species abundance. Separate richness calculations were made for vascular plants classified as forest understory species, those classified as early-seral species, and bryophyte species. Changes in community composition were expressed as the percent dissimilarity (PD) between pre- and post-treatment measurements (vascular plants only), using the quantitative form of Sørensen's community coefficient. Abundance was measured as percentage of cover for vascular plants and frequency of occurrence for bryophytes. To standardize for spatial variation in species richness and abundance prior to treatment, a change value was computed for each variable as the arithmetic difference between pre- and post-treatment values.

Responses Within Forest Aggregates and Adjacent Areas of Harvest

We assessed the comparative responses of vascular plants in forest aggregates and adjacent areas of harvest by conducting a series of two-sample t-tests using mean "change values" (or mean PD for community composition) as the measure of response. Bryophyte responses were assessed using a series of paired t-tests to compare pre- and post-treatment values within each environment (harvest areas and forest aggregates; $n = 4$). Tests of individual species' responses were limited to taxa that (1) occurred in at least three of the four replicates (i.e., forest aggregate/surrounding harvest area pairs) and (2) had greater than 10 percent frequency (percentage of all possible bands); we refer to these as "common species."

Edge-Related Gradients in Vegetation Response and Physical Environment Within Aggregates

Edge-related gradients in vegetation response were assessed by calculating Spearman rank correlation coefficients between mean values of vegetation variables (changes in richness and cover, and PD) and distance from the aggregate edge, with separate analyses for each post-treatment year. Species-level analyses were limited to the common taxa noted above. Environmental variables (open sky, logging slash, and disturbed soil) were also correlated with distance from edge and with vegetation responses.

RESULTS AND DISCUSSION

Differences Between Forest Aggregates and Adjacent Areas of Harvest

Compared to harvested areas, forest aggregates showed minimal change in species richness and composition 2 years after treatment (Nelson and Halpern 2005). Aggregates were largely resistant to colonization by early-seral species and remained stable with respect to forest species richness. Eight of 29 common vascular plants showed significant differences in response between environments: seven of these showed greater magnitudes of decline in harvest areas than in aggregates; only one showed a significantly greater increase in abundance in harvest areas than in aggregates. Ninety percent of bryophytes declined in the harvest area; however, only five of the eight common taxa showed significant declines. In the short-term, forest aggregates provide refugia for shade-tolerant herbs and ground-layer bryophytes that are extirpated from, or decline in, adjacent areas of harvest. Because most forest species do not maintain a viable seed bank, local persistence in and subsequent dispersal of seeds from aggregates may greatly facilitate reestablishment of populations in harvested areas.

Gradients in Environment and Vegetation Response Within Forest Aggregates

Within forest aggregates, increased light availability and harvest-related disturbance were limited to a 10- to 15-m-wide band, leaving approximately 50 percent of the forest aggregate unchanged for these attributes (Nelson and Halpern 2005). This large outer band was notably altered, however, with logging slash covering 38 percent of the ground surface and open sky roughly double that at the center of the aggregate. Spatial gradients in community composition, species richness, and the abundance of individual species correlated to varying degrees with proximity to forest edge (Nelson and Halpern 2005). Changes in community composition were most apparent at the forest border (0-5 m). We also found slightly reduced richness of vascular plants at the edge, reflecting declines of some forest species (with minimal establishment of early-seral species). We anticipate gradual increases in vascular plant richness near aggregate edges with time, as early-seral species become more abundant in adjacent harvested areas. We found significantly reduced richness of ground-layer bryophytes with proximity to edge, primarily due to extirpations of less common taxa. Although none of the common shrub or moss species showed significant responses, 8 of 23 common herbs and 1 of 2 common liverworts declined near edges. A marked increase from year 1 to 2 in both the number of species showing significant declines and the magnitude of decline suggests that edge effects will become more apparent with time.

Management Considerations

Identifying minimum sizes for protected areas is an important issue in conservation biology. Although large reserves are clearly necessary for many ecosystem processes and components (e.g., interior-forest microclimate and wide-ranging carnivores), smaller forest remnants also may have high conservation value, especially in landscapes that are intensively managed for timber production. Our results suggest that, over short timeframes, aggregates at least 1 ha in size may provide a refugium for disturbance-sensitive species and a local dispersal source for recolonization of harvested areas once microclimatic conditions become suitable for establishment. However, 1-ha remnant patches may not be large enough to prevent declines of less common bryophyte taxa. Furthermore, temporal trends suggest that edge effects judged to be small in the short term may become more prominent with time. Additional research at these and other sites in the Pacific Northwest is necessary to identify the temporal and spatial scales over which forest aggregates serve their intended ecological functions.

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Effects of Four Riparian Buffer Treatments and Thinning on Microclimate and Amphibians in Western Oregon Headwater Forests

Deanna Olson[1] and Samuel Chan[1,2]

We examined the effects on microclimate and amphibians of four riparian buffer widths (ca. 6 m, 17 m, 62 m, 120 m; untreated control) with thinning to 200 trees/ha in adjacent upland headwater forests, in 30- to 70-year-old stands previously managed for wood production in western Oregon. Gradients in the summer microclimate (air and soil temperature, relative humidity), measured at 4 p.m., were evident along transects from streams into the thinned upland forest (N = 6 sites). Mean (4 p.m.) summer air temperature and relative humidity tended to be ca. 4 °C higher and 15 percent lower respectively, in the thinned upland forest vs. the control. Riparian buffers averaging as narrow as 17 m wide mitigated the microclimates associated with thinning. Thinning did not affect riparian buffer soil temperature and the temperature of the stream. Amphibian richness was relatively high (12 spp), but species abundances often were low and spatially variable, which may account for few treatment effects in stream and bank animals (n = 11 sites), and variable upslope effects (1 of 2 sites). The occurrence of the headwater-associated torrent salamander at 10 of 11 sites, and 33 of 68 stream reaches was notable. Regardless of treatment, the steepest change in microclimate was often observed within 5 m from the center of the stream where most amphibians were captured. To hedge uncertainty in long-term effects of riparian management on headwater resources, a mix of buffers might be considered for zero-, first-, and second-order streams across subdrainages.

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Aesthetic Perceptions of Green-Tree Retention Harvests in Vista Views: The Interaction of Cut Level, Retention Pattern and Harvest Shape

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The scenic beauty of timber harvests affects perceptions of the social acceptability of forest management. Aesthetic perceptions of green-tree retention options within harvests were investigated. Study scenes depicted close-up vista views of clearcuts, an unharvested forest, and a full set of harvests that varied by amount and pattern of green-tree retention and by the design of cut block shapes. These attributes were tested to explain differences in scenic beauty estimates derived from 331 respondents. Higher scenic beauty was associated with increased dispersed green-tree retention levels. An important finding was that all levels of aggregated retention, with different amounts of clearcut patches inside harvests, were perceived as ugly. Dispersed retention levels below about 25 percent are likely to produce various degrees of perceived ugliness, whereas those with about 25 percent or more retention tend to be seen as beautiful. The design of harvest shapes to look more irregular, rather than geometric, improved scenic beauty slightly only among harvests with 15 percent or lower retention, irrespective of retention pattern.

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Restoration of a Forested Coastal Watershed: Ellsworth Creek, Washington

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In the Willapa Bay area of southwest Washington, The Nature Conservancy is embarking on an ambitious effort to protect and restore a highly productive and biologically diverse coastal watershed. The Ellsworth Creek watershed is a low-elevation coastal rainforest ecosystem with remnant old-growth trees, a rich freshwater aquatic system, and connectivity to the fertile estuarine waters of Willapa Bay. Although 92 percent of the primary forests in Ellsworth Creek have been logged, biological inventories indicate that the area still harbors much of its historic biological diversity within refugia found throughout the watershed. Because of its ecological and strategic significance, The Nature Conservancy is dedicated to making Ellsworth Creek a model for watershed conservation where an adaptive management process closely links active restoration and scientific investigation.

Specific goals for the conservation and restoration project at Ellsworth Creek include

1. Managing lands and waters within the project area by using stewardship practices that earn respect and build positive relationships with the local community and partners throughout the forest management industry.
2. Restoring the Ellsworth Creek watershed to provide ecologically functional aquatic and upland forest habitats that are capable of supporting a large diversity of biological communities and species typical of natural primary or late-successional forest landscapes of the Pacific Northwest coast.
3. Developing a scientifically-driven adaptive management framework for the project and maximizing opportunities for exporting scientific knowledge and best management practices to other forest and aquatic conservation projects in the Pacific Northwest.

Ellsworth Creek is a small (2035 ha), highly productive low-elevation watershed comprised of mixed-aged coniferous forests, a freshwater stream system, and large estuary. Ellsworth Creek supports high-quality remnant low elevation western redcedar (*Thuja plicata* Donn ex D. Don), Sitka spruce (*Picea sitchensis* (Bong.) Carr), and western hemlock (*Tsuga heterophyllaI* (Raf.) Sarg.) old-growth forest stands. The approximately 130 ha of old-growth forest represents one of the largest remaining stands within the Willapa Bay ecosystem and contains five distinct natural forest community types—including 2 km of riparian associated forests. The watershed strategically connects protected old-growth habitats of the Willapa National Wildlife Refuge and the Washington Department of Natural Resources Ellsworth Creek Natural Resource Conservation Area (NRCA), which is located in the adjacent Smith Creek drainage. These conservation areas, together with the nearby South Nemah NRCA, Bear River restoration project (Bear River Partnership), and Chinook River restoration project (Sea Resources) create a functional forest, freshwater, and estuarine landscape of approximately 32 800 ha along the southern fringe of Willapa Bay.

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Forests stands in the Ellsworth Creek watershed have been harvested since the turn of the century, and the remaining old-growth stands are small and fragmented. Approximately 145 ha of old-growth forest remain in the watershed with much of it being found near the mainstem of Ellsworth Creek. Some of these stands were selectively harvested in the past, including by the United States Spruce Production Division in 1918 during the search for Sitka spruce during World War I. Additional legacy trees, or small groves, are found throughout forest stands older than 45 years of age (470 ha) with these stands typically having a varied composition of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), western hemlock, western redcedar, and Sitka spruce. Forest stands between 20 and 45 years of age (675 ha) have generally been precommercially thinned and are dominated by planted Douglas-fir with many stands displaying significant sign of Swiss needle cast (*Phaeocryptopus gaeumannii*) infestation. Young stands, less than 20 years old (625 ha), are often composed of extremely dense hemlock and Douglas-fir with stem densities as high as 3200 trees/ha. Existing stand conditions will provide a challenge for forest restoration; however, the combination of a productive growing environment, diverse stand composition, and the existence of substantial legacy forest structures should aid in the recovery and development of forest complexity.

Inventories within old-growth forest habitats at Ellsworth Creek have documented many avian, amphibian, mollusk, lichen, and fungi species of state and federal concern. Marbled murrelets (*Brachyramphus marmoratus*) are found in all remnant old-growth patches and also appear to occupy stands with scattered legacy structures, such as large trees with mistletoe platforms, to a limited extent. A high diversity of amphibian species is also found in the watershed, including particularly high population densities of many regionally endemic amphibian species such as the Columbia torrent salamander (*Rhyacotriton kezeri*), Van Dykes salamander (*Plethodon vandykei*), Dunn's salamander (*Plethodon dunni*), and tailed frog (*Ascaphus truei*). Initial surveys within the project area, however, have focused on old-growth forest stands leaving managers with little understanding of the general distribution of these species. Research and monitoring is needed to better assess the current distribution of target species and track their dispersal into young forest stands as those stands mature and develop greater habitat complexity over the next few decades.

The freshwater aquatic system contains one of the highest spawning densities of chum salmon (*Oncorhynchus keta*) in the entire Willapa Bay watershed with close to 8,000 fish reported over a 1.9 km index reach in 2002. Systematic inventories of other fish species are not known from the watershed. Anecdotal observations, however, have indicated significant coho salmon (*Oncorhynchus kisutch*) and coastal cutthroat trout (*Oncorhynchus clarkii clarkia*) populations. Lamprey (*Lampetra* spp.) are also present in the system with smolts being found in mid-order stream reaches within the watershed. In addition to anadromous fish, the freshwater stream system provides habitat for many amphibian species, invertebrates, and other resident native fish species.

Stream inventory work in 2003 and 2004 has begun to quantify habitat variables and the spatial distribution of habitat forming processes within the watershed. Comparing observed wood loading at Ellsworth with observed values for unmanaged streams of similar size, headwater stream segments were found to meet or exceed expected values, while mainstem segments were depauperate of instream wood. Headwater stream segments also had higher than expected wood abundance and a greater number of key pieces, while wood volume was not significantly different than observed values for unmanaged streams. Mainstem segments, however, had significantly lower abundance, volume, and number of key pieces than would be expected for unmanaged streams of a similar size. These results are consistent with the findings of others who have reported an overall increase in the number of wood pieces but distinct decreases in the percentage of large instream wood (>50 cm in diameter) in moderately and intensively harvested watersheds. Threshold relationships also appear in Ellsworth Creek between drainage area and woody debris abundance, volume, and the density of key instream wood pieces. Similar relationships were found for stream gradient, the portion of channels devoid of alluvium, and the portion of channels dominated by fine sediments. These relationships suggest that dominant habitat forming processes are distinct for stream segments on either side of a threshold of 200 ha in upstream drainage area. The high variance of habitat variables within headwater stream channels suggests that habitat formation is dominated by catastrophic events for channels in these areas. Habitat formation processes downstream of the threshold appear to be dominated by fluvial and riparian processes.

Because the watershed has been significantly modified through a century of timber management, The Nature Conservancy is expecting active restoration to play a significant role in the recovery of the Ellsworth Creek forest ecosystem. Other than the impacts from timber management to forest and stream habitats noted above, a legacy of forest roads threaten aquatic systems with sediment delivery and hydrologic modification and fragment forest habitat.

Road density in the watershed is approximately 3.9 km/km^2, and many roads show signs of imminent failure or other structural concerns. Road abandonment and upgrades, therefore, will be an immediate management priority. In forest stands, variable-density thinning and other silvicultural treatments are expected to be tested as tools for increasing structural and compositional diversity and hastening the development of late-successional forest attributes. Other active management strategies could include underplanting with native plant species, the creation of snags and downed wood, and reintroduction of lichens and fungi that are associated with late-successional forests. More specific restoration strategies will be developed as habitat variables within forest and stream habitats are further quantified during additional inventory work in 2004 and an adaptive management framework is subsequently developed for the project.

The Nature Conservancy's proposed restoration strategy relies on using the best available science so lessons learned at Ellsworth Creek can be used to inform future forest conservation and management decisions throughout the Pacific Northwest. To help accomplish this strategy, a scientific advisory group is being integrated into the early stages of project design and management. Group members will have considerable practical research experience in Pacific Northwest forest ecosystems and come from a variety of scientific disciplines. The advisory group is expected to add scientific credibility, state-of-the-art knowledge, and critical review that will raise the level of on-the-ground restoration accomplishments and aid in leveraging conservation lessons beyond the project's boundaries.

Using Ethics to Educate Consumers of Natural Resources

Viviane Simon-Brown[1]

At Oregon State University (OSU) and other land-grant institutions, we focus our educational efforts on teaching students to professionally manage natural resources. However, as population, economic, and consumption pressures increase, addressing the responsibilities of the consumers of natural resources becomes a viable educational tool. Since 1998, the Sustainable Living Project at OSU has been offering intelligent consumption programming to typical American adults and older youth, thus creating an ethical foundation to support sustainable management of natural resources. Intelligent consumption is about managing ourselves. It acknowledges the role ethics play in decisionmaking. Contemplating cultural, economic and environmental ethics, considering the barriers to living sustainably, examining national trends, and determining personal priorities are components of educating the public about their consumer choices.

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Assessing Threats to the Conservation of Siskiyou Mountain Salamanders in Oregon

Nobuya Suzuki[1] and Deanna Olson[2]

Assessing threats to the conservation of rare species requires enormous time and effort. Our objective was to develop GIS maps to effectively assess threats to conservation of Siskiyou Mountain salamanders (*Plethodon stormi*) in southwestern Oregon. Using GIS layers, we quantified potential risks within 100 and 1000 acres of 5875 random landscape points and developed GIS maps showing threats to conservation. The threats we assessed included land-use pattern, road density, wild-land-urban interface, and catastrophic fire. Cumulative scores of all the risks at the random points were used as z-values to create 3-dimensional maps. To identify suitable habitats on the landscape, we developed a logistic regression model in which probability of salamander occurrence was negatively associated with solar illumination. Of 86 conservation areas proposed by experts based on salamander occupancy and habitat suitability, our maps identified 11 and 21 areas, at scales of 100 and 1000 acres, respectively, as moderate to high risk for the species. Experts may likely overlook threats at a broader spatial scale without the aid of our maps. We conclude that our maps illustrating threats to conservation can be effectively used to select low-risk areas for reserves and to increase consistency and objectivity of conservation planning.

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Chronosequencial Changes in Forest Stand Structure and Composition—Comparison Between the Post-Harvest Secondary Deciduous Broadleaf Forests and the Plantation Forests of Evergreen Japanese Cedar (*Cryptomeria japonica*)

Hiroshi Tanaka,[1] Kaoru Niiyama,[1] Mitsue Shibata,[1] Tsutomu Yagihashi,[1] Hanae Niwa,[2] Hiroshi Yabe,[3] Atsuko Hayashi,[4] and Takuo Nagaike[4]

INTRODUCTION

Drastic conversion from the primary broadleaf forests, coppice broadleaf forests, and semi-natural grassland to conifer (Sugi (Japanese cedar: *Cryptomeria japonica*) and Hinoki (Hinoki false cypress: *Chamaecyparis obtusa*)) plantations occurred between the 1940s and 1980s in the mountainous area of Japan. To achieve the sustainable management of the mosaic forest landscape composed of secondary broadleaf forests and conifer plantation, it is important to know the contribution of each forest type to the maintenance of regional biodiversity. To obtain the scientific basis for the management, we addressed the following two questions: (1) How does conversion from deciduous broadleaf forest to evergreen conifer plantation impact species and structural diversity? (2) How does structural and biological diversity change (recover) in both plantation and secondary natural forests? Instead of monitoring controlled field experimental sites, we compared sample stands of different ages scattered in a typical landscape.

STUDY SITE AND METHODS

The studied forests covered about 200 km^2 (ca. 600 to 800 m elevation) of the southern Abukuma mountains, central Japan. We examined forest structure and composition in 11 post-harvest, secondary deciduous broadleaf forests (DB) and 11 conifer (Sugi) plantation forests (CP) along a chronosequence from just after the clear-cutting to mature condition. A preserved deciduous broadleaf forest was also studied as a reference of old-growth condition. In each forest, we established a 10 m x 100 m belt-shaped study plot to cover all topographic variation of the forest. Trees and vines taller than 2 m and larger than 5 cm d.b.h. (diameter at breast height) were tagged and their g.b.h. (girth at breast height) was measured for forty 5 m x 5 m quadrats along a 100 m line. A census of forest floor vegetation (vegetation height < 2 m) was conducted following the Braun-Branque method for 1 m x 1 m quadrats in each 5 m x 5 m quadrat. Standing dead stems > 5cm d.b.h. were also tagged and measured. We also recorded the names of all woody plants taller than 2 m found in each 5 m x 5 m quadrat. Light condition on the forest floor was also measured by hemispherical photographs taken 1 m above ground in each 1 m x 1 m quadrat.

RESULTS AND DISCUSSION

The patterns of changes in structural attributes along a chronosequence were different among the attributes and between the two forest types. The increasing curves of maximum d.b.h. were almost the same between the broadleaf stands and conifer plantations, but the increasing curves of mean d.b.h. were segregated. The patterns of the change in basal area (BA) showed that tall trees occupy large space more quickly in the conifer plantations than in the broadleaf stands. Management practices in plantation forests (improvement felling and thinning) strongly affected the structural attributes such as stem density and mean d.b.h..

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According to the growth of trees, number of tree species > 5 cm d.b.h. increased in the broadleaf stands as stand age increased, but it was continuously low in the conifer plantations. Number of species (both woody > 2 m height and forest floor) was the highest at the early stage after the clear cutting for both types of the forests. As the stand age increased, the number of woody species gradually decreased in the broadleaf stands. The number of forest floor species first decreased and then slowly increased in broadleaf stands. The number of woody species and forest floor species sharply decreased and then gradually increased in the conifer plantations. Higher numbers of woody species in the younger forests were explained by abundant liana and shrub species. In both the broadleaf stands and the conifer plantations, the number of forest floor species had negative correlation with stem density ($p < 0.05$), which reflects the forest floor light condition.

Ordination and cluster analyses showed the compositional differences of both woody and herbaceous species between the broadleaf stands and conifer plantation. The differences in species composition among stands may be explained largely by the forest age. When forest age increased, both woody and herbaceous species composition of the conifer plantation became closer to those of broadleaf stands. To evaluate the contribution of conifer plantations and broadleaf stands of different ages to the maintenance of regional plant diversity, further understanding on the mechanisms shaping the species composition is necessary. The number of species which had distributional bias to the broadleaf stands was larger than that of the species which had no significant bias to either type of forest or bias to the conifer plantations. Functional characteristics of these species groups should be analyzed for the next step.

Influence of Silvicultural Intensity and Compositional Objectives on the Productivity of Regenerating Acadian Forest Stands in Maine

Robert Wagner,[1] Mike Saunders,[1] Keith Kanoti,[1]
John Brisette,[2] and Richard Dionne[3]

A mosaic of young, naturally regenerated stands of largely mixed wood (hardwood-conifer) composition dominate cutover areas within Maine's Acadian forest. Tremendous opportunity exists to improve the composition, quality, and growth rates of these stands while they are in an early successional stage. Two factors determine the long-term outcome of stand development: silvicultural intensity and compositional objective. Silvicultural intensity is determined by the degree of investment in vegetation management and artificial regeneration. Compositional objectives are set by the manager and determine whether conifer, hardwood, or a mixture of species is desired in the final stand. A long-term study is being established on the Penobscot Experimental Forest in central Maine that will (1) quantify the growth and development of early successional stands to varying intensities of silvicultural intervention and compositional objectives, (2) document ecophysiological mechanisms affecting the dynamics and productivity of young forest stands, and (3) compare the energy requirements and financial returns associated with early intervention in these cutover stands. A 3 x 3 factorial design with four replications of 30 m x 30 m (0.09 ha) treatment plots is being used. Three levels of silvicultural intensity (low, medium, high) and three compositional objectives (conifer, mixed wood, hardwood) are being compared. An initial question being addressed in the early phase of the study is whether silviculture can be used to mitigate any negative effects of global climate change on soil temperature and moisture regimes by either encouraging or discouraging the germination and establishment of various Acadian tree species.

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Leave Islands as Refugia for Low-Mobility Species in Managed Forests

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In the past decades, forest management in the U.S. Pacific Northwest has shifted from one based largely on resource extraction to one based on ecosystem management principles. Forest management based on these principles involves simultaneously balancing and sustaining multiple forest resource values, including silvicultural, social, economic, and ecological objectives. Leave islands, or green-tree retention clusters, have been proposed as an alternative silvicultural strategy designed to sustain the ecological integrity and biological diversity of managed forests. However, pertinent questions regarding the relation of the physical structure of leave islands to their associated microclimates, flora, and fauna remain largely unanswered. This study evaluates the effectiveness of three sizes of leave islands within a thinned forest matrix relative to thinned and unthinned forest in providing refugia for low-mobility, ecologically-sensitive species 1 to 5 years following timber harvest. Specifically, we are examining differences in microhabitat and amphibian, mollusk, arthropod, and vascular plant abundance and diversity with respect to the size of leave islands in managed forests. By determining habitat correlates of species and functional group occurrence, we envision that this study will provide vital information regarding leave islands in managed forest landscapes. Initial results indicate treatment effects relative to microclimate, amphibian and arthropod density, and vascular plant diversity and ground cover. These results suggest that leave islands may provide short-term refugia for some low-mobility, ecologically sensitive species in managed forests of the Pacific Northwest.

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Effects of Partial Logging on Community Parameters in a Northern Japanese Mixed Forest

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We investigated heterogeneity in community parameters and its determinant factors, with emphasis on effects of human disturbances (logging activities) in a northern Japanese mixed forest. We used data from 50 study stands (0.25 to 0.50 hectare in area) located in the Nakagawa Experimental Forest, Hokkaido University (lat 44º48'N, long 142º14'E). These stands were partially logged between 1969 and 1985. Trees with diameter at breast height larger than 6 cm were measured at intervals of 5 to 8 years.

In this paper we analyzed data collected over 16 years following a partial logging and calculated demographic parameters (growth rate, recruitment rate, and mortality; $m^{-2}year^{-1}$) for three species groups (conifers (mostly *Abies sachalinensis*), shade-tolerant hardwoods (mainly *Acer mono* and *Tilia japonica*), and shade-intolerant hardwoods (mainly *Betula ermanii* and *Quercus crispula*)). Then we conducted multiple regression analysis to explain causes of the heterogeneity among the stands. The independent variables considered were sum of basal area (BA: m^2ha^{-1}), sum of logged basal area (LOG: m^2 ha^{-1}), and species diversity (Shannon H', based on the basal area). The basal area were increased or decreased during the 15-year period, depending on the stands (the percentage of the term-end basal area to the initial basal area ranged from 70 to 145 percent). Conifers generally showed higher recruitment rate and mortality than hardwoods. The growth rates seemed to be regulated mainly by a crowding effect (i.e., negative effects of BA as well as positive effects of LOG). In contrast, the recruitment rates correlated with species diversity better than basal area or LOG. The species diversity also displayed significant correlations with recovery (growth + recruitment - death; m^{-2} $year^{-1}$) of both conifers and shade-tolerant hardwoods. Although the heterogeneity in community parameters seem to be caused by multiple factors including variation of topography and climate, our study demonstrated the significance of the species diversity on the recovery process of the mixed forests following a partial logging.

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Photo by Tom Iraci

BALANCING ECOSYSTEM VALUES: INNOVATIVE EXPERIMENTS FOR SUSTAINABLE FORESTRY

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UNIT CONVERSION TABLE

When you know:	Multiply by:	To find:
Meters (m)	3.28	Feet
Square meters (m^2)	10.8	Square feet
Centimeters (cm)	.394	Inches
Hectares (ha)	2.47	Acres
Trees per hectare	.405	Trees per acre
Kilometers (km)	.62	Miles
Kilogram (kg)	2.205	Pounds
Gram (g)	.0352	Ounces
Liters (l)	.265	Gallons
Degrees Celsius (C)	1.8C + 32	Degrees Fahrenheit
Feet (ft)	.305	Meters
Square feet (ft^2)	.093	Square meters
Inches (in)	2.54	Centimeters
Acres	.405	Hectares
Trees per acre	2.471	Trees per hectare
Miles	1.609	Kilometers
Pounds (lbs)	.454	Kilograms
Ounces (oz)	.0296	Liters
Gallons (gal)	3.78	Liters
Degrees Fahrenheit	(F-32)/1.8	Degrees Celsius

Pacific Northwest Research Station

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