VEGETATION RESPONSES TO VARYING LEVELS AND PATTERNS OF OVERSTORY RETENTION: EARLY RESULTS OF THE DEMO EXPERIMENT.

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Abstract

The practice of retaining overstory trees through 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. We used a randomized block design in mature, coniferous forests at six locations in the Pacific Northwest to examine vegetation responses to overstory retention at two levels (15 vs. 40% of initial basal area) and spatial patterns (dispersed vs. aggregated). Cumulative post-harvest mortality of overstory trees was 2.1-2.4 times greater at 15 than at 40% retention and 2 times greater in dispersed than in aggregated treatments, due to wind damage of newly exposed trees. Ground-layer bryophytes showed large, but comparable declines in abundance and richness among all harvest treatments. Declines in abundance and richness of vascular understory plants and changes in species composition were significantly greater at 15 than at 40% retention, yet pattern of retention had little effect on understory response. Within aggregated treatments, changes in plant abundance and richness were small within the 1-ha forest patches, 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 extirpation from the harvested portions of aggregated treatments than from dispersed treatments. Initial understory responses may be explained, in large part, by variation in the amount and distribution of ground disturbance and logging slash, but as effects of disturbance diminish with time, overstory structure will increasingly shape patterns of understory development.

Study Areas

Studies are ongoing at 6 locations (blocks) in southwestern Oregon and Washington (see map). Douglas-fir is the dominant tree species at all blocks, but stand age, structure, and understory vegetation differ among blocks. At each block, harvest was completed within a period of 3-7 months in 1997 or 1998.

Block	Elevation (m)	Slope (%)	Forest zone*	Stand age (yr)	Tree density (no./ha)	Basal area (m^2/ha)
Watson Falls (WF)	945–1310	4–7	TSHE	110–130	310–500	36–52
Dog Prairie (DP)	1460–1710	34–62	ABCO	165	258–475	72–106
Butte (BU)	975–1280	40–53	TSHE	70–80	759–1781	48–65
Little White (LW)	825–975	40–66	ABGR	140–170	182–335	61–77
Paradise Hills (PH)	850–1035	9–33	ABAM	110–140	512–1005	59–87
Capitol Forest (CF)	210–275	28–52	TSHE	65	221–562	54–73

*ABAM = *Abies amabilis*, ABCO = *A. concolor*, ABGR = *A. grandis*, TSHE = *Tsuga heterophylla*

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 retention has replaced clearcut logging on federal lands within the range of the northern spotted owl. The expressed goal of variable retention is to enhance 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 persistence and recovery of biological diversity. Here we explore some of the early responses of forest communities to variation in the level and pattern of overstory retention. We focus on post-harvest mortality of trees and on responses of two groups of understory plants likely to be sensitive to changes in forest structure – ground-layer bryophytes and herbs associated with late-seral forests.

Experimental Design

The full experiment consists of 6 retention treatments assigned randomly to 13-ha experimental units within each block:

- **100% retention** (control): no harvest.
- **75% aggregated** (75%A): all trees were cut from three 1-ha circular "harvest areas".
- **40% aggregated** (40%A): retained five 1-ha circular "forest aggregates". All other trees were cut in "harvest areas".
- **40% dispersed** (40%D): retained the same basal area as in 40%A, as evenly dispersed co-dominant trees.
- **15% aggregated** (15%A): retained two 1-ha circular "forest aggregates". All other trees were cut in "harvest areas".
- **15% dispersed** (15%D): retained the same basal area as in 15%A, as evenly dispersed co-dominant trees.

Sampling Design

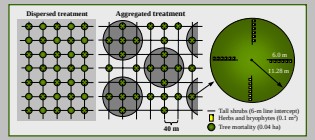
A systematic sampling grid (40-m spacing) with permanent sample plots was established in each experimental unit before harvest. The number and distribution of plots vary by treatment.

Overstory trees (post-harvest mortality)

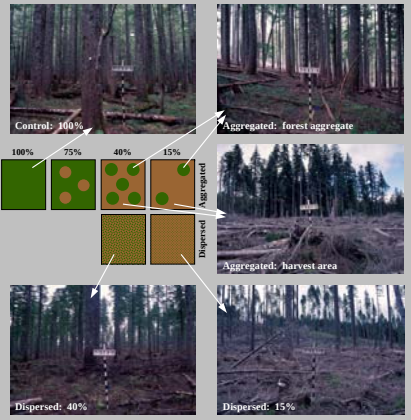
- After harvest, all residual trees (≥ 5 cm dbh) within each 0.04-ha tree plot were tagged, identified to species, measured for diameter, and assigned to a canopy class (suppressed, intermediate, or co-dominant).
- Mortality was assessed annually for 2-3 yr.

Ground-layer bryophytes and vascular plants

- Understory plants were sampled before and 1 yr after harvest.
- For shrubs, height and cover were estimated along four 6-m transects.
- For herbs and bryophytes (mosses and liverworts), total cover and species presence were recorded in twenty-four 0.1-m^2 microplots (to yield species frequencies).
- Herbs were classified *a priori* as "early seral", "forest", or "late-seral" to facilitate analyses of groups of species with differing successional roles and sensitivities to disturbance.



Experimental design with examples of post-harvest conditions within each treatment.



Analyses

Treatment-level means were calculated from plot-level values. For the aggregated retention treatments, weighted means were computed to account for the unequal areas of the two distinct post-harvest environments.

Tree mortality

- To compare rates and forms of mortality: two-way ANOVA models (2 levels x 2 patterns).

Ground-layer bryophytes

- To compare changes in total cover and richness, and proportion of species showing declines in frequency: one-way ANOVA models (followed by Tukey HSD tests).
- Three separate tests were run for: (i) treatment means; (ii) uncut areas (i.e. forest matrix in 100% and 75%A, forest aggregates in 40%A and 15%A); and (iii) harvest areas within each treatment.

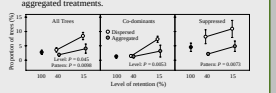
Vascular plants

- To compare compositional changes: detrended correspondence analysis.
- To compare changes in abundance and richness of major plant groups: two-way ANOVA models (2 levels x 2 patterns).
- To examine variation in response *within* aggregated retention treatments: one-way ANOVA models (forest aggregates vs. harvest areas).

Tree Mortality

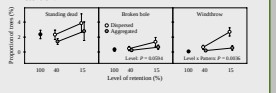
Patterns among canopy classes

- Cumulative mortality was greater at 15 than at 40% retention.
- Aggregation of trees significantly reduced mortality.
- Co-dominants had greater mortality at 15 than at 40% retention.
- Suppressed trees had greater mortality in dispersed than in aggregated treatments.



Forms of mortality

- Standing dead: no treatment effects.
- Broken bole: greater mortality at 15 than at 40% retention.
- Windthrow: significant treatment interaction; greater mortality in dispersed than in aggregated treatments at 15 but not at 40% retention.



Ground-layer Bryophytes

Treatment-level responses

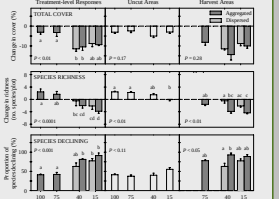
- Large, comparable declines at 15 and 40% retention.
- Minimal response to pattern of retention.

Uncut areas (100%, matrix of 75%A, and forest aggregates)

- Magnitude of change was surprisingly large, but differences among treatments were relatively small.

Harvest areas

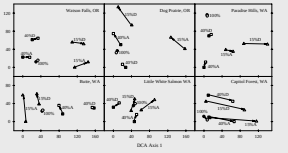
- Large, comparable declines at all levels of retention.
- Mixed response to pattern of retention: comparable declines in dispersed and aggregated treatments at 15%, but greater declines in aggregated treatments at 40% retention.



Vascular Plants

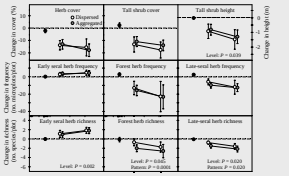
Compositional changes

- Controls showed little change in species composition.
- Greater compositional change at 15 than at 40% retention.
- No consistent response to pattern of retention.



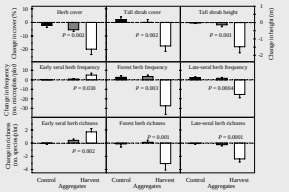
Changes in abundance and richness

- Consistently greater change at 15 than at 40% retention.
- Pattern of retention had minimal effect.



Variation in response *within* aggregated retention treatments

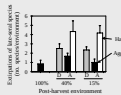
- Significantly larger changes in harvest areas than in forest aggregates.



Vascular Plants (cont.)

Local extirpations of late-seral species

- Loss of species was more common in harvest areas of aggregated treatments than in dispersed treatments.



Conclusions

In designing variable-retention harvests, two attributes of forest structure are commonly manipulated: level of overstory retention and the spatial distribution of stems. Early results of the DEMO experiment suggest that both elements of structure elicit significant vegetation responses. These lead to the following conclusions:

- Mortality of residual trees can be reduced by retaining greater numbers of stems and by aggregating them. Aggregated retention minimizes bole damage during logging and lowers potential for post-harvest windthrow. Rates of mortality within 1-ha aggregates are no different from rates in mature, undisturbed forests.
- Aggregation of stems is particularly important when retention is low (e.g., at 15%, the minimum standard on federal "matrix" lands). Even co-dominant trees – preferentially selected in dispersed settings – are susceptible to windthrow.
- Ground-layer bryophytes are sensitive to overstory removal and exhibit major declines in abundance and richness, even at intermediate (40%) levels of retention.
- Most groups of vascular understory plants respond positively to increasing levels of retention. However, at the scale of harvest units, aggregated retention offers few short-term benefits over dispersed retention. Although aggregates provide local protection from disturbance, losses in adjacent harvest areas can be extreme. Late-seral herbs are particularly sensitive to these effects, experiencing more frequent extirpations from harvest areas in aggregated treatments than from dispersed treatments.
- In the short-term, forest aggregates serve as temporary refugia for bryophytes and late-seral herbs that are sensitive to disturbance or environmental stress. To what extent they serve their intended function – as dispersal sources for recolonization of adjacent harvest areas – remains unclear.
- Initial responses of vegetation to level and pattern of retention are consistent with treatment-level variation in ground disturbance and slash accumulation. Future sampling will allow us to distinguish between transient responses to logging disturbance and the more persistent effects of overstory structure.

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