RESPONSES OF VASCULAR AND NON-VASCULAR PLANTS TO STRUCTURAL-RETENTION HARVESTS IN THE PACIFIC NORTHWEST

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Abstract

We studied the responses of understory plants to structural retention harvest of mature, coniferous forests in the Pacific Northwest. We addressed the following questions: How do level and spatial pattern of retention affect the abundance and diversity of vascular plants? Do 1-ha forest aggregates provide refugia for late-seral herbs? Does substrate quality affect the responses of bryophytes (mosses and liverworts) to level of retention? After 6-8 yr, most plant groups showed significant responses to level of retention, but not to pattern. Forest aggregates provided refugia for late-seral herbs, but over time aggregates may be compromised by edge effects. Mosses were highly sensitive to overstory removal, experiencing significant declines even at moderate levels of retention. Losses were greater on decayed wood than on the forest floor; exposure to light and elevated temperature greatly diminished the quality of this important substrate. Our results suggest that a combination of large aggregates and dispersed retention, at levels greater than current minimum standards, may be the most effective strategy for ensuring persistence and recovery of forest-dependent species.

Introduction

Structural or green-tree retention has been adopted in many forest ecosystems managed for both ecological values and timber production. Live trees within harvest units can provide structure and support species associated with older forests, reduce abiotic stress, and accelerate ecosystem recovery. Two elements of overstory structure can be readily manipulated to achieve these goals: level of retention (proportion of basal area) and the spatial distribution of trees (dispersed or aggregated). Greater levels of retention should yield greater persistence of species sensitive to disturbance, abiotic stress, or changes in substrate quality. Dispersed retention can provide more uniform moderation of understory microclimate, but may not be sufficient for species that are sensitive to disturbance. Alternatively, forest aggregates may provide refugia for species sensitive to disturbance, but may be compromised by edge effects (elevated light or temperature).

The Demonstration of Ecosystems Management Options (DEMO) Study examines the responses of forest ecosystems to structural-retention harvests in mature coniferous forests of the Pacific Northwest (PNW). In this region, federal regulations require managers to retain trees across at least 15% of each harvest unit, with 70% of this in aggregates of 0.2-1.0 ha. We report results from studies that examine responses of vascular plants and bryophytes to contrasting levels and patterns of retention 6-8 yr after experimental harvest treatments.

Questions

Q1. Vascular plants: effects of level and pattern of retention. How do level and pattern of retention affect the cover and diversity of vascular plants (herbs and shrubs)? Do functional groups – early seral herbs, late-seral herbs, early seral shrubs, and forest shrubs – differ in their sensitivities to level and pattern of retention?

Q2. Vascular plants: role of forest aggregates. Do 1-ha forest aggregates serve as refugia for late-seral herbs that are sensitive to disturbance or abiotic stress? Are aggregates susceptible to edge effects?

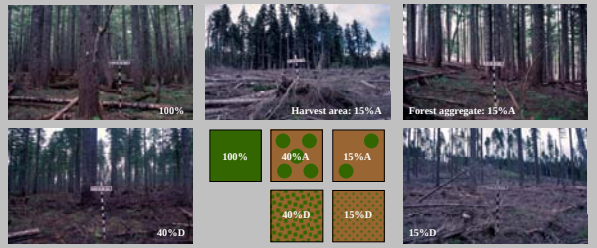
Q3. Bryophytes: role of substrate. Does substrate quality affect the responses of bryophytes (mosses and liverworts) to level of retention?

Study Area

- Locations: Five sites in the western Cascades of Oregon and Washington
- Elevation: 825-1710 m
- Slope: 4-66%
- Dominant tree species: *Pseudotsuga menziesii, Tsuga heterophylla*
- Forest age: 70-170 yr
- Tree density: 180-1780 stems/ha
- Basal area: 36-106 m²/ha

Experimental Treatments

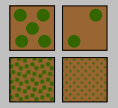
100% Control. No harvest.
40%A 40% aggregated. 40% of basal area retained in five circular 1-ha aggregates.
40%D 40% dispersed. 40% of basal area retained as dispersed dominants and co-dominants.
15%A 15% aggregated. 15% of basal area retained in two circular 1-ha aggregates.
15%D 15% dispersed. 15% of basal area retained as dispersed dominants and co-dominants.



Question 1. Vascular plants: effects of level and pattern of retention

Methods

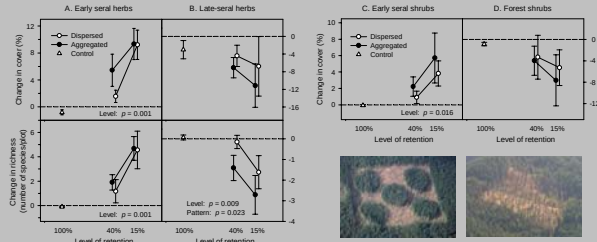
- Sampling design: Five sites, five treatments per site, 32-37 plots per treatment.
  - Herb species: 24, 20 x 50 cm quadrats per plot.
  - Shrub species: four 6 m long line intercepts per plot.
- Sampling dates: Before and 6-7 yr after harvest.
- Response variables: Changes in cover (%) and species richness of functional groups: early seral herbs, late-seral herbs, early seral shrubs, and forest shrubs.
- Analysis: One-way ANOVA followed by *a priori* contrasts to test main effects and interactions.



Treatments used to test responses to level and pattern of retention

Results

- Early seral herbs (A): Significant effect of level but not pattern of retention.
- Late-seral herbs (B): Significant effects of level and pattern of retention on richness but not cover. Greater loss of richness in aggregated than in dispersed treatments.
- Early seral shrubs (C): Significant effect of level but not pattern of retention.
- Forest shrubs (D): No effect of level or pattern of retention on rates of decline.



Conclusions

- Most groups of plants are sensitive to level of retention, but effects of pattern are more subtle. In aggregated treatments, the benefits of undisturbed patches are balanced by large changes in adjacent harvested areas. Thus, average responses are similar to those in dispersed treatments.

Question 2. Vascular plants: role of forest aggregates

2a. Forest aggregates as refugia

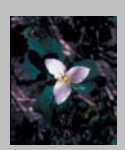
Methods

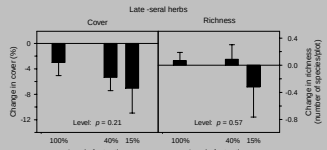
- Sampling design: Plots in 100% (controls) and forest aggregates of the 40%A and 15%A treatments.
- Response variables: Changes in cover (%) and species richness of late-seral herbs.
- Sampling dates: Before and 6-7 yr after harvest.
- Analyses: One-way ANOVA.

Treatments used to assess forest aggregates as refugia

Results

- Trends suggest declines in late-seral herbs within forest aggregates, particularly at low levels of retention (15%A), but differences in cover and richness were not significant.





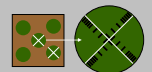
Conclusions

- In the short term, 1-ha aggregates can serve as refugia for species that are sensitive to disturbance and environmental stress.

2b. Susceptibility of forest aggregates to edge effects

Methods

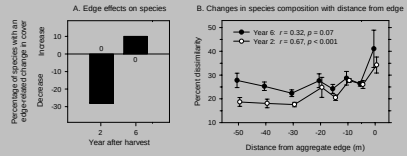
- Sampling design: 40%A treatments at two Washington sites, two aggregates per treatment, four transects per aggregate, and eight distances to edge (1 x 5 m quadrats) per transect.
- Response variables: Changes in cover (%) of individual herb species; changes in species composition (percent dissimilarity, PD).
- Sampling dates: Before harvest and 2 and 6 yr after harvest.
- Analyses: Pearson correlations between proximity to edge and (a) change in species cover and (b) percent dissimilarity.



Transect design to test for edge effects in forest aggregates

Results

- Species' declines (A): 28% of species (n = 29) showed edge-related declines in year 2, but none did in year 6.
- Changes in species composition (B): PD increased toward the edge in year 2, but not in year 6. PD tended to be greater in year 6 than in year 2, particularly toward the centers of aggregates. In both years, PD was high at the edge but declined steeply within 5 m.



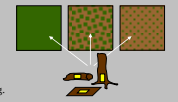
Conclusions

- Forest aggregates appear susceptible to edge effects soon after harvest. However, longer term trends are more difficult to interpret. The absence of edge-related gradients in species abundance or compositional change suggests recovery, but may also reflect incursion of edge effects to the centers of aggregates. Aggregates smaller than 1-ha may be susceptible to edge effects.

Question 3. Bryophytes: role of substrate

Methods

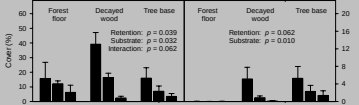
- Sampling design: Three sites, each with:
  - Three levels of retention: 100%, 40%D, and 15%D.
  - Three substrates: forest floor, decayed wood, and tree base.
  - 16, 20 x 50 cm quadrats per substrate per level of retention.
- Response variables: Total cover (%) of mosses and liverworts.
- Sampling date: Once, 8 yr after harvest.
- Analysis: Randomized complete block split-plot with sub-sampling.



Treatments and substrates used to assess bryophyte responses

Results

- Substrate associations:
  - Mosses: Most abundant on decayed wood (~40% cover in controls).
  - Liverworts: Much less abundant (<5% cover), mainly on decayed wood and tree bases.
- Responses to level of retention:
  - Mosses: Significant effect of retention; marginally significant interaction with substrate (greater decline on decayed wood than on forest floor).
  - Liverworts: Marginally significant effect of retention; nearly eliminated from decayed wood.



Conclusions

- 15% retention, the minimum permitted in harvest units on federal lands in the PNW, greatly diminishes the suitability of decayed wood as a substrate for bryophytes. Conserving these epixylic species in managed forests will require significantly greater levels of retention.

General Conclusions

Two components of forest structure are typically altered by structural-retention harvests: the abundance of trees and their spatial distribution. Both are hypothesized to affect the persistence and post-harvest recovery of forest organisms through direct and indirect effects on disturbance and moderation of abiotic stress. Our experimental studies of understory plants lead to the following general conclusions:

- Most plant groups are sensitive to level of retention. As predicted, early seral herbs and shrubs, which typically respond positively to disturbance and increases in resource availability, showed greater development at lower levels of retention. In contrast, late-seral herbs, which are sensitive to disturbance and abiotic stress, showed greater declines at lower retention.

- Most plant groups are relatively insensitive to pattern of retention at the scale of harvest units. In aggregated treatments, the localized benefits of undisturbed forest patches are offset by large declines in the adjacent harvest areas where trees are completely removed. When averaged, these produce responses of comparable magnitude to those in dispersed treatments where ground disturbance and stress are moderated by residual trees.

- However, late-seral herbs appear sensitive to pattern of retention, exhibiting greater loss of richness in aggregated than in dispersed treatments. That similar trends were not observed for cover suggests that losses were of relatively uncommon species.

- Forest aggregates of 1-ha can serve as refugia for late-seral herbs that are sensitive to disturbance and environmental stress. Over time, however, aggregates may be compromised by edge effects, particularly when overall retention is low (i.e., greater ratio of harvest area to aggregate area). Smaller patches, as permitted by the Northwest Forest Plan, may not provide the same function.

- Forest bryophytes are sensitive to overstory removal. Mosses and liverworts were greatly reduced even at moderate retention (40%) and were largely lost from decayed wood at low retention (15%). Exposure to light and higher temperature can reduce moisture retention by wood, reducing its value as a substrate; effects are less extreme on the forest floor. Because bryophytes have strong substrate affinities, these effects can have importance consequences for community composition and diversity.

- A combination of large aggregates and dispersed retention at levels greater than current minimum standards may be most effective for ensuring persistence and recovery of forest-dependent species.

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