SHORT-TERM RESPONSES OF VASCULAR PLANTS AND BRYOPHYTES IN FOREST PATCHES RETAINED DURING STRUCTURAL RETENTION HARVESTS.

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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 (or "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, their ecological functions may be diminished as a result of fragmentation or edge influences. We examined first- and second-year responses of understory plants to disturbance and creation of edges in structural retention harvest units at two sites in western Washington. Our design utilizes pre- and post-treatment measurements of permanent plots, allowing us to quantify the spatial pattern, magnitude, and time course of vegetation response. We pose four general questions:

- Do species richness and community composition remain stable in forest aggregates?
- Do aggregates retain disturbance-sensitive plants that decline in, or are lost from, adjacent harvest areas?
- Within forest aggregates, are there edge-related gradients in vegetation response (changes in species richness, community composition, or abundance of individual species)?
- Do edge-related gradients in vegetation response correlate with changes in light availability or disturbance?

40% Aggregated Retention Harvest Unit

Forest Aggregate

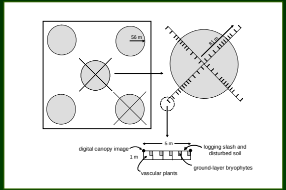
Harvest Area

Study Areas

This study was conducted as part of the Demonstration of Ecosystem Management Options (DEMO) experiment. Sampling occurred in the 40% aggregated retention treatment at two sites on the Gifford Pinchot National Forest in southwestern Washington. Forests were dominated by mature, Douglas-fir that regenerated after wildfire. Retention harvests occurred in 1997.

Sampling Design

- Sampling locations: two 13-ha harvest units, within which five 1-ha (56-m radius) forest aggregates were retained (all merchantable trees were cut and removed from surrounding "harvest areas").
- Sampling dates: pre-treatment = 1996; post-treatment = 1998 (year 1), 1999 (year 2).
- Replication: four forest aggregates (two per site).
- In each aggregate, sampling occurred along four perpendicular transects (81m) spanning forest aggregate, edge, and harvest area.
- Transects consisted of 12 "bands": eight in the aggregate and four in the harvest area.
- Bands contained five 0.1-m^2 microplots for frequency of ground-layer bryophytes (year 1), and five 1-m^2 subplots for cover of vascular plants (years 1 and 2).
- Two additional measurements were taken:
  - cover of logging slash and disturbed soil (5-m line intercepts; year 1)
  - light availability (2 photos at 1-m height using a CI-110 digital canopy imager with a 150° lens; year 2). Digital images were analyzed with Scanopy 2.0b software to calculate percent open sky.



Analysis

- We considered three types of response variables: richness, community composition, and species abundance (bryophyte frequency, vascular plant cover).
- Separate richness calculations were made for vascular plants classified as "forest understory" and "early-seral" species, and for ground-layer bryophytes (liverworts and mosses).
- Changes in community composition were expressed as percent dissimilarity (PD) between pre- and post-treatment measurements (vascular plants only) using the quantitative form of Sørensen's community coefficient.
- Tests of abundance of individual taxa were limited to "common species" (present in ≥3 forest aggregate/harvest area pairs with >10% frequency).
- To standardize for spatial variation in species richness and abundance prior to treatment, a "change value" was computed for each variable (arithmetic difference between pre- and post-treatment values).

Responses in forest aggregates vs. adjacent harvest areas

- Bryophytes: paired *t*-tests to compare pre- and post-treatment values within each environment (harvest areas and forest aggregates; $n = 4$).
- Vascular plants: two-sample *t*-tests to compare mean "change values" (or mean PD) between environments.

Edge-related gradients in physical environment and vegetation response within forest aggregates

- Physical environment: Spearman rank correlations between percent open sky, logging slash, or disturbed soil and distance from forest aggregate edge.
- Vegetation: Spearman rank correlations between mean values (change in richness, frequency, and cover, or PD) and distance from aggregate edge. Separate analyses were conducted for first- and second-year responses.

Results

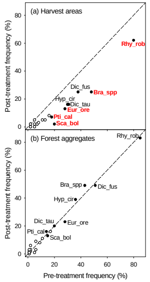
Responses in forest aggregates vs. adjacent harvest areas

(1) Physical environment

- Percent open sky and cover of logging slash were significantly lower ($P < 0.002$) in forest aggregates than in adjacent harvest areas.
- Cover of disturbed soil did not differ between environments.

(2) Ground-layer bryophytes

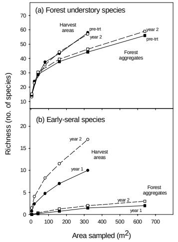
- 90% of bryophyte species declined in harvest areas.
- Five of eight common taxa (those in red, below) showed significant declines in harvest areas.



Mean frequency of bryophyte taxa before and after treatment in (a) harvest areas (25 taxa) and (b) forest aggregates (28 taxa). Only taxa present before treatment are shown. "Common" taxa are plotted with closed circles, and coded as: Bra_spp = *Brachythecium* spp., Dic_fus = *Dicranum fuscescens*, Dic_tau = *Dicranum tauricum*, Eur_ore = *Eurhynchium oreganum*, Hyp_cir = *Hypnum circinale*, Pti_cal = *Pilidium californicum*, Rhy_rob = *Rhytidiopsis robusta*, and Sca_bol = *Scapania bolanderi*. Less common taxa are plotted with open circles.

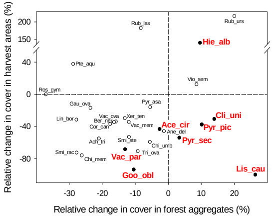
(3) Vascular plants

- Richness of forest understory species changed little within forest aggregates.
- Early-seral species showed limited recruitment into forest aggregates.



Species area curves for (a) forest understory species (before and 2 yr after treatment) and (b) early-seral species (1 and 2 yr after treatment), in forest aggregates and harvest areas. Points along individual curves represent (from left to right) means for bands, transects, aggregates or adjacent harvest areas, sites, and the entire study.

- Changes in community composition (PD) were ca. 20% greater in harvest areas than in forest aggregates ($P < 0.001$; data not shown).
- Eight of 29 common species (those in red, below) showed significant differences in response between environments. For seven of these, declines were greater in harvest areas than in aggregates.

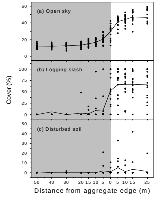


Comparative changes in the cover of vascular plant species in forest aggregates and adjacent harvest areas, 2 yr after treatment. Species codes are: Ace_cir = *Acer circinatum*, Ach_tri = *Achlys triphylla*, Ane_del = *Anemone deltoidea*, Ber_ner = *Berberis nervosa*, Bro_vul = *Bromus vulgaris*, Chi_men = *Chimaphila menziesii*, Chi_umb = *C. umbellata*, Cli_uni = *Clintonia uniflora*, Cor_can = *Cornus canadensis*, Gau_ova = *Gaultheria ovatifolia*, Goo_obl = *Goodyera oblongifolia*, Hie_alb = *Hieracium albiflorum*, Lin_bor = *Linnaea borealis*, Lis_cau = *Listera caurina*, Pte_aqu = *Pteridium aquilinum*, Pyr_asa = *Pyrola asarifolia*, Pyr_pic = *P. picta*, Pyr_sec = *P. secunda*, Ros_gym = *Rosa gymnocarpa*, Rub_las = *Rubus lasiococcus*, Rub_urs = *R. ursinus*, Smi_rac = *Smilacina racemosa*, Smi_ste = *S. stellata*, Tri_ova = *Trillium ovatum*, Vac_mem = *Vaccinium membranaceum*, Vac_ova = *V. ovalifolium*, Vac_par = *V. parvifolium*, Vio_sem = *Viola sempervirens*, and Xer_ten = *Xerophyllum tenax*.

Edge-related gradients in physical environment and vegetation response within forest aggregates

(1) Physical environment

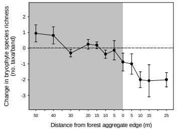
- Percent open sky and cover of logging slash increased significantly with proximity to forest edge ($P < 0.001$); these increases were largely restricted to a distance of 10-15 m from the edge.
- Disturbed soil did not show a significant correlation with proximity to edge.



(a) Percent open sky, (b) cover of logging slash, and (c) cover of disturbed soil with distance from the edges of forest aggregates. Lines represent mean values ($n = 16$) at each sampled distance. Points in the shaded region represent bands within the forest aggregates.

(2) Ground-layer bryophytes

- Within aggregates, richness declined with proximity to edge ($r = -0.48$, $P = 0.017$).

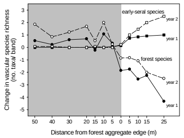


Changes in richness of bryophyte species with proximity to edge. Values are mean differences ($n = 16$) in band-level richness between pre- and post-treatment measurements. Points in the shaded region represent bands within the forest aggregates.

- Of eight common bryophytes, only one liverwort (*Scapania bolanderi*) declined significantly in frequency with proximity to edge ($r = -0.38$, $P = 0.028$; data not shown).

(3) Vascular plants

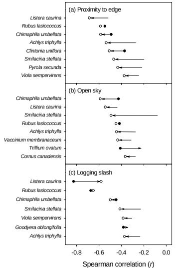
- The relationship between proximity to edge and decline in richness of forest understory species was weak in year 1 ($r = -0.32$, $P = 0.073$), but significant in year 2 ($r = -0.44$, $P = 0.011$).



Changes in richness of forest understory and early-seral species with proximity to edge. Values are mean differences (n=16) in band-level richness between pre- and post-treatment measurements. Points in the shaded region represent bands within the forest aggregates.

(3) Vascular plants - continued

- Herbs were more commonly affected by proximity to edge than were shrubs.
- The number and strength of edge effects increased with time: significant declines in cover were evident for three species in year one and for eight in year two.
- These edge effects corresponded with gradients in light availability (five species) and cover of logging slash (six species).



Spearman rank correlations (n=32) between change in vascular plant abundance within forest aggregates and (a) edge proximity (negative correlations indicate a decline with proximity to edge), (b) open sky, and (c) cover of logging slash, 1 and 2 yr after treatment. Closed circles indicate significant first-year relationships; open circles, significant second-year relationships. No circle indicates non-significant relationships. Arrows illustrate the direction and magnitude of change from year 1 to 2.

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 can also have high conservation value, especially in landscapes that are managed for timber production. Our results suggest that, over *short timeframes*, forest aggregates of at least 1 ha in size play an important role in protecting late-seral plant species through retention harvest. These aggregates are especially important for ground-layer bryophytes; over 90% of bryophyte taxa declined in frequency in harvest areas, and many of these are likely to require long periods of time to recover from disturbance.

Although forest aggregates provide temporary refugia for disturbance-sensitive species and should serve as dispersal sources for re-colonization of harvested areas, their long-term value depends on the degree to which habitat conditions are not compromised by edge phenomena. Our short-term observations indicate that edge effects are present and are likely to increase with time. Richness of ground-layer bryophytes and the abundance of approximately one third of common herbaceous species declined at the edges of forest aggregates. Moreover, a marked increase from year 1 to 2 in the number of species showing significant declines and in the magnitude of these declines suggests that edge effects will become increasingly apparent. Longer-term studies in these and other fragmented forests will be critical for improving standards for plant conservation in managed landscapes.

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For additional information: http://www.cfr.washington.edu/research.demo/