Biodiversity Responses to Green Tree Retention Practices in the Pacific Northwest: A Regional Forestry Experiment

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Preface: This project was conceived in 2012 as part of NCASI's Western Wildlife Biodiversity Initiative, which broadly sought to answer forestry-biodiversity questions in the Pacific Northwest. We relied on a manipulative experiment for this study, meaning that different treatments were preconceived and subsequently implemented by timber harvesting operations. In our case, 5 different retention treatments were replicated over 10 experimental blocks throughout the Pacific Northwest (Figure 1). Forest Practices Rules in Oregon and Washington defined the density of green trees retained, so in our case treatments represented different locations and sizes of that green tree retention within clearcut forest harvest units (Figure 2). Treatments started in 2013 and concluded in 2015, with sampling for this study starting in 2017.

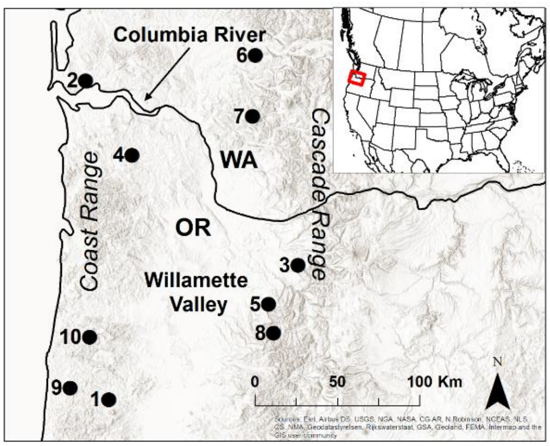

Figure 1. Study area in western Oregon (OR) and Washington (WA), USA, depicting 10 experimental blocks (black filled circles), each containing five structural retention treatments.

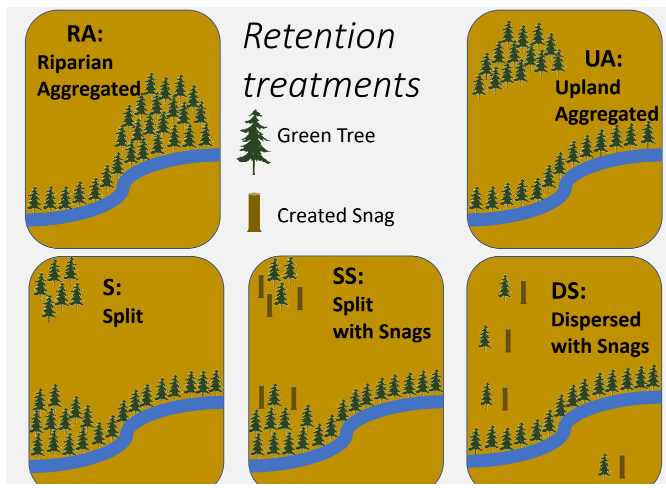

Figure 2. Green tree retention treatments where: 1) all retention trees are grouped along riparian protective zones (RA), 2) grouped in an upland area away from riparian zones (UA), 3) half occur in an upland area and half along riparian zone (S), 4) same as S, but half of the trees were turned into created snags (SS), and 5) retention trees (groups of 15) were dispersed throughout the harvest units, not adjacent to riparian zones (DS).

Deliverables: The final report for this project includes broad generalizations on how green tree retention relates to biodiversity, and four draft manuscripts for submission to peer-reviewed journals. We provide the generalizations below, followed by abstracts from each chapter with summative bullet points from each abstract.

Generalizations:

- No individual green tree retention treatment consistently increases "biodiversity" as a wildlife management objective, emphasizing the importance of more explicitly defining desired wildlife outcomes. Our results indicate that wildlife outcomes are better expressed through taxonomic groupings (e.g., small mammals, ground beetles). Additionally, our results point to the shortcomings of using simple biodiversity metrics (e.g., species richness) to represent community responses to forest management treatments, as subtle nuances in community composition or function can be lost.

- Aggregated and split retention support ground-beetle communities with different composition than surrounding clearcuts due to species associated with forest interiors persisting in these patches. Upland aggregated retention was relatively ineffective at increasing stand-level small mammal diversity whereas aggregated retention along riparian zones provides habitat for small mammal species that depend on older forest conditions.
- Dispersed retention, often through the process of retention tree blowdown over time, provide small mammal and ground beetle communities that are redundant with adjacent clearcuts early during plantation establishment. However, these localized changes in habitat structure (e.g., increased amounts of downed wood) result in higher densities of small mammals.
- If conserving small mammal and ground beetle diversity are both wildlife objectives, our results suggest that split retention is the best choice. For these taxonomic groups, we recommend against mechanically creating snags as blowdown will add structural heterogeneity to the ground layer over time. If increasing the abundance of small mammals in clearcut stands is an objective, dispersing retention in multiple small patches is most effective.
- Our results indicate that in recently disturbed ecosystems like clearcuts, environmental filters (i.e., things like vegetation, elevation) are more important determinants of wildlife responses to timber harvest and green tree retention than biotic filters (e.g., competition among species). We note that this finding may in part be explained by the newness of the ecosystem and how animal communities re-organize following major disturbances.

Draft Manuscripts (Abstracts):

1. CARABID BEETLE FUNCTIONAL AND TAXONOMIC DIVERSITY RESPOND CONSISTENTLY TO SPATIAL ARRANGEMENT OF RETENTION TREES

Managing forests intensively for wood production can homogenize components of forest structure, which can alter species richness and functional composition of native species communities. Retention forestry can increase species diversity in recently harvested forests but its effect on community functional diversity, defined as diversity in morphological, physiological, and life history traits, is less understood. We implemented an experimental study that manipulated retention tree patch size and location at a constant proportion of retention within harvested areas. We evaluated the effectiveness of five retention patterns at increasing the species and functional diversity within early seral, production forests in the Pacific Northwest U.S.A. Using ground beetles (Family: Carabidae) as a focal taxonomic group, we tested whether species and functional richness or community dissimilarity between patches and clearcuts varied among the five treatments. We found no evidence for differences in carabid species or functional richness among treatments when considering species present in both retention and clearcut areas of harvested stands. However, within harvested stands, we found evidence for lower taxonomic and functional variation between carabid communities present in retention and clearcut areas when retention was allocated to several small patches. Furthermore, the lower levels of functional variation between carabid communities in retention and harvested areas in the treatment containing several small retention patches was primarily driven by lower abundances of specialized predators in small retention patches compared to aggregated or riparian-associated retention patches. We found that relative to single large or riparian-associated patches, small retention patches function similarly to clearcuts within harvested stands and several small patches does not increase species or functional

richness. *At levels of retention currently required in the Pacific Northwest, retention trees should be allocated to a single upland patch or split between riparian and upland patches to increase variation in ground beetle taxonomic and functional composition within clearcut forests.*

2. SMALL MAMMALS WITH VARYING DEGREES OF FOREST SPECIALIZATION DIFFER IN RESPONSES TO SIZE AND LOCATION OF RETENTION TREE PATCHES

Many forest wildlife species depend on structurally complex forest conditions, including downed wood and understory vegetation, which are often reduced or lost in forests managed for wood production. In forests harvested on even-aged rotations, retention forestry can help meet biodiversity conservation goals by retaining trees and deadwood at time of harvest. However, the relative effectiveness of different retention strategies at increasing structural complexity and animal populations is not well understood. We used an experimental study to evaluate changes in population density of three small mammal species in response to different size and location (riparian or upland) of retention tree patches within clearcut harvested forests in the Pacific Northwest, U.S.A. We also assessed whether small mammal densities varied in relation to measured structural complexity within retention patches. Within experimental treatment stands, deer mice (*Peromyscus* spp) population density did not differ between retention and clearcut areas ($\beta = -0.05$, SE = 0.06), Townsend's chipmunk (*Neotamias townsendii*) density was higher in retention compared to clearcut areas ($\beta = 1.61$, SE = 0.10), and creeping vole (*Microtus oregoni*) density was highest in clearcut areas ($\beta = -0.68$, SE = 0.10). At the experimental treatment stand, the lowest deer mouse densities occurred in stands with large, isolated upland patches of retention (mean = 83, SD = 28 trees) and was highest in stands with multiple isolated, small patches of upland retention (mean = 8, SD = 2 trees). Creeping vole density followed the opposite pattern, highest in stands with large isolated upland patches and lowest in stands with multiple small, isolated patches. Densities of each species were intermediate in treatments where at least a portion of the retention trees were connected to forested riparian buffers. We found that Townsend's chipmunk density increased with increasing retention tree blowdown in the patches, a proxy for downed wood resources, whereas creeping vole density decreased. Deer mice density did not change consistently in response to tree blowdown. Furthermore, retention tree mortality was highest in the treatment with several small, isolated patches (mean = 0.49 down, SD = 0.21) and lowest in the treatment with a single large patch (mean = 0.10 down, SD = 0.09). *Our results demonstrate that smaller, dispersed retention increases abundances of small mammals in recently clearcut, early seral forests (2-6 years after tree planting) in the Pacific Northwest. This relationship is at least partly mediated through higher levels of structural complexity within small retention patches caused by increased retention tree blowdown compared to larger patches.*

3. THE EFFECT OF AGGREGATION AND LOCATION OF RETENTION TREE PATCHES ON SMALL MAMMAL SPECIES AND FUNCTIONAL RICHNESS IN EARLY SERAL CONIFER PLANTATIONS

Green tree retention during forest harvesting is a common practice for biodiversity conservation in wood producing regions globally. Yet, experimental evaluations of different retention patch configurations are lacking for many regions and taxonomic groups. We implemented an experimental study that manipulated the size, number, and location (riparian or upland) of retention patches in five different experimental treatments, using a constant level of retention among treatments, replicated across the Pacific Northwest, USA. Within these experimental treatments, we measured small mammal (<1kg) species and functional trait (i.e., body size, diet, activity stratum) richness in both retention areas, surrounding clearcuts, and in closed-canopy forests. We captured 21 species of small mammals and found limited effects of treatment on species richness. We also found no differences in small mammal functional trait richness among treatments. Species richness was highest in the treatment where all retention trees were aggregated into one patch that was connected to a forested riparian buffer (mean = 6.6, SE = 0.46), and lowest in the treatment containing one retention patch isolated in the upland portion of early-seral (2-6 years after harvest) conifer plantations (mean = 4.7, SE = 0.47). Furthermore, estimates of species richness within only retention areas (i.e., not considering species in the early-seral conifer plantations) did not differ among treatments, indicating that the slightly elevated species richness in riparian-associated retention results from 1-2 species in these patches that do not occur in adjacent regenerating forest areas. *Species and functional richness were both lower in unharvested closed-canopy forests. Our results indicate that at retention levels currently required in the Pacific Northwest, decisions on where to allocate retention trees are not overly consequential for small mammal species or functional richness in early seral conifer plantations, but local increases in species richness can be achieved by connecting all retention trees to riparian buffers.*

4. ABIOTIC AND BIOTIC CORRELATES OF SMALL MAMMAL ABUNDANCE ACROSS SCALES: INSIGHTS FROM A JOINT SPECIES DISTRIBUTION MODEL

The distribution and abundance of species within ecological communities are influenced by both abiotic conditions, such as climate, and biotic interactions with other species, with importance of each potentially varying among scales. To better understand the relative influences of these processes, joint species distribution models (JSDMS) can be used to estimate the effects of environmental variation on multiple species, and subsequently infer biotic interactions between species from residual correlations. Although these models are strictly correlative, including functional traits and examining species associations across different spatial extents may help detect biotic interactions. Furthermore, JDSMs can quantify environmental conditions associated with high species richness or community abundance patterns that help inform management actions aimed at maintaining diverse ecological communities. We related count data collected on eleven small mammal species in early seral forest plantations in the U.S. Pacific Northwest with forest management and environmental covariates using a JSDM at two spatial extents. After accounting for relevant environmental factors, we expected to find negative residual correlation between functionally similar species at more local spatial extents, which might reflect interspecific competition. Contrary to this expectation we found that most statistically supported species associations were positive at the local spatial extent, while other species pairs were negatively associated at a larger (i.e., multiple stands within an experimental block) extent. Counts of most small mammal species increased with increasing herbaceous or shrub cover in early-seral plantations. *These patterns suggest that rather than competition between species, shared responses to resources within early seral forest stands and broad scale environmental filters underlie community abundance patterns of small mammals in temperate forests.*