**Notes on spatial pattern on the Malheur National Forest**

**Patch dynamics**

The study of spatial pattern in ecological systems is an acknowledgement that vegetation changes over time and drivers of change operate at discrete spatial scales. Studies of forest patch dynamics most often assume that patches result from disturbance events that reset succession (Pickett and White 2013). A commonplace example of a patch is a group of trees that were killed by fire or insects and replaced by younger trees that contrast with surrounding older forest.

Most scientific research about the patches that result from fire and insect disturbance has been conducted in closed canopy forests, especially boreal and sub-boreal systems (see, for instance, Frelich and Reich 1995). Dry mixed conifer forests east of the Cascades in Oregon and Washington are also often assumed to have experienced mixed severity fire that results in distinctive patches composed of trees in similar successional states. Perhaps the most frequently cited and influential study is Paul Hessburg’s 2007 study of patch dynamics using historical (circa 1930s) photography in 38 randomly selected subwatersheds in eastern Oregon and eastern Washington (only two of these subwatersheds were in eastern Oregon, and none were in the Blue Mountains). Hessburg identified “highly variable mixed severity fire as the prevailing fire process” that resulted in a “complex patchwork of fire regimes and patch sizes.”

Did Malheur NF forests historically exhibit coherent age structure, i.e., trees of roughly the same age that suggest they originated together in a patch? And if so, at what scale were these patches typically found? From 2011-2015 I collected detailed age structure data (tree cores and partial cross sections from dead trees) along three 584 foot transects located along lower, middle, and upper slope positions in ten randomly selected sites that had experienced no previous timber harvest. The total area sampled in each transect was 1.25 acres. Two transects in two sites (4 out of 30 total transects) showed coherent age structure throughout the transect, suggestive of mortality patches that affected more than an acre of the total area sampled. No other transects exhibited mortality patches greater than 0.25 acres in size. All four of these transects were found on sites with slope or available soil water characteristics that were 90th and 10th percentile for the forest (i.e., steeper and drier than most sites on the Malheur NF). Mortality in all four transects was attributable to pine beetle attack rather than direct fire effects. Interestingly, all four transects were located on dry pine sites. No mixed conifer sites exhibited coherent age structure indicative of stand replacing mortality at scales greater than 0.25 acres.

There are many areas of even-aged trees on the Malheur National Forest where there were historically no overstory trees present. But I am aware of no evidence that fire disturbance on the MNF frquently regenerated trees in patches much greater than 0.25 acres in size. This should not be surprising given what we know of historical fire disturbance on the Malheur. Frequent fire usually resulted in open, low-density stands where fire did not spread easily between trees. Mortality from fire or insects was generally confined to individual trees or small groups of trees.

Patches of dead trees ranging in size from one to several hundreds of acres in size are readily observable within many contemporary Malheur NF wildfire perimeters. But there is no evidence from my research or other research that I am aware of that indicates that fire mediated patch dynamics as commonly described in the ecological literature are an important or commonplace feature of the southern Blues landscape. As noted above, there are extensive forested areas on the Malheur that historically supported few if any trees. Removing trees in these areas may enhance the resilience of the larger forested landscape and support non-forest biological diversity. But leaving extensive patches of un-thinned dense forest as part of restoration treatments probably does not emulate historical conditions and seems unlikely to facilitate desired future fire processes.

**Within-stand spatial structure**

If disturbance mediated tree mortality and the characteristic spatial pattern that results is primarily manifested at relatively fine (<0.25 acre) scales in the southern Blues, what does this spatial pattern look like? Larson and Churchill (2012) describe within-stand spatial pattern using three elements: Individual trees, clumps of trees, and openings with no trees. Trees are either individuals or members of a clump depending on an inter-tree distance, *d*. If *d* equals zero, then no trees in a stand belong to a clump—they are all individuals. All trees belong to the same clump if *d* equals more than the greatest pairwise distance between trees. Some studies define *d* as a function of some biologically meaningful parameter, for instance, the distance at which trees compete for light, water, or nutrients, or simply as the average distance at which tree crowns interlock. In my view, if *d* is not based on an objective analysis of the environmental factors that mediate ecological relationships between trees, you are not measuring biologically meaningful clumpiness, you’re simply measuring the distances between trees.

Even when *d* is based on objective knowledge about the relationships between individual trees, the distribution of trees in clumps could be a matter of chance. Most tree spatial pattern analyses explicitly account for this problem by comparing the observed distribution of tree-to-tree distances to randomly generated tree-to-tree distances. I am somewhat skeptical about determining tree distributions to be biologically significant because inter-tree distances are dissimilar from randomly generated inter-tree distances. Generating random data assumes an equal probability of any tree distance within a specified maximum and minimum distance. But the distribution of actual tree distances in most southern Blues stands are constrained by the spatial pattern of areas where trees do not grow, usually thin rocky soils or low depressions with standing water or frost that inhibits tree regeneration. Without parameterizing random data simulations with *a priori* knowledge of tree growth and establishment constraints, the finding that trees are clumped to different degrees at different sites may simply reflect edaphic controls on tree growth and establishment (Abella *et al.* 2013). Pattern in nature is the rule not the exception. Observing a pattern in nature, i.e., a configuration of trees that is non-random, is not necessarily interesting or significant unless we can describe how the pattern varies in time and space and identify the environmental drivers that influence this variation.

A meaningful analysis of tree clumping should also acknowledge that tree spatial patterns likely vary as a function of stand age with all other environmental factors that influence tree relationships held constant. For more than 120 years, scientists and managers have noted that regeneration in western North America ponderosa pine forests generally occurs in patches that range in size from 0.002-1.5 acres. These patches contain dozens or thousands of seedlings. In my experience, these regeneration patches are very common on the MNF, although they tend to be smaller than the largest sizes noted in other studies.

To what extent do older ponderosa pine trees in eastern Oregon tend to clump? I am aware of two peer-reviewed studies that quantify within-stand clumpiness in our region. Harrod et. al.’s (1999) study on the Wenatchee National Forest in eastern Washington showed strong clumping of historical (>140 year old) trees in warmer and drier sites, but a decrease in tree clumpiness, a decrease in clump size, and a decreasing average inter-tree distance, *d*, at which trees were clumped on moister and more productive sites. Youngblood *et al.*’s (2004) study documented non-random clumping of old growth trees at study sites along the Metolius River in eastern Oregon but randomly distributed older trees at another study site near Pringle Falls southwest of Bend.

A recent study of tree spatial pattern on the Malheur National Forest by Churchill *et al.* (in press) documents clumping of historical tree structure in 14 reconstruction plots at three sites. While I think this study will be useful for comparing historical southern Blues within-stand tree distributions to other regions and for informing restoration treatments on the Malheur in a general sense, I would be cautious about using this data to strictly parameterize restoration treatments throughout the Malheur NF.

First of all, recent monitoring of Galena and other restoration projects does not actually describe *spatial pattern*, it simply reports how many trees are in clumps of different sizes. This monitoring assumes that if the proportion of post-treatment trees falling within different clump size bins is the same as the proportion of trees falling within the same clump size bins in reference stands, then the spatial pattern of treated stands and references stands is the same. But we don’t necessarily know from this data whether spatial pattern in treated stands is similar to reference stands. It is possible for treated stands to exhibit a different distribution of trees within clump bins but be similar in spatial configuration to reference stands, or exhibit a similar distribution of trees in clump bins but be quite different from references stands in spatial configuration.

Second, all of the sites in Churchill *et al.’s* study were subjectively located. It is problematic to apply results from study sites to a larger area unless those study sites were randomly selected from within the larger population of sites or represent the full range of conditions present throughout the larger population. All three sites where Churchill *et al.* located plots (the Dugout Creek Research Natural Area, the Canyon Creek Research Natural Area, and a site above the Malheur River Ford) are on the drier end of site conditions on the Malheur National Forest. Only 3 of 14 plots had any significant grand fir cover. Most if not all of these sites are drier and less productive than Galena units the BMFP visited on a recent field trip. Galena unit #37, which has post-treatment tree clumps that are supposedly departed from the historical reference conditions documented in Churchill *et. al.*, has soil available water holding capacity, a variable that is highly correlated with site productivity, that ranges from 4.4-5.9 inches. All three of Churchill *et al.’s* references sites have soil available water capacities that generally range from 1.4-3.9 inches. Other predictors of site productivity, including incident solar radiation, vapor pressure deficit, and climate water deficit derived from MODIS data, are generally an order of magnitude different between Churchill’s reference sites and Galena units.

Third, even if results from subjectively located reference stands could be applied throughout the forest, there is significant variation in tree spatial pattern observed by Churchill *et al.* within reference sites and no reliable method that I am aware of for describing the variability in spatial pattern across the Malheur NF based on the data collected in reference plots. Churchill *et al.* noted the proportion of individual trees in reference plots ranged from 10%-53%, with the remaining trees as clumps. It is not even the case that we can conclude from this data that 10%-53% of trees within Churchill’s study sites were individuals and the rest were clumps—there was undoubtedly some variability on both sides of that estimate that was not captured within plots. It is impossible to say that 10%-53% of trees across the larger Malheur NF landscape were historically found as individuals absent a statistical procedure for quantifying the variability around observations in reference plots.

(I was confused by a handout distributed at the Galena field trip that claimed that between 18%-38% of trees in reference plots were individuals not associated with a clump. This is a narrower range than the reference conditions documented in Churchill *et al*. This is a very narrow range of tree distributions that cannot possibly be applied to the entire forest, particularly given other research, e.g. Harrod and Youngblood, that find far more variability within other eastside national forests.)

Fourth, even if more productive sites exhibit the same clumpiness as less productive sites (which is not what I’ve observed on the Malheur NF), it seems unlikely that the distance, *d*, at which tree crowns tend to interlock is the same between sites. In October I visited Galena unit #37 and measured the crown radius of 14 randomly selected trees older than 150 years within and immediately adjacent to the unit. The maximum crown radius was 14.1 feet and the average was 7.2 feet, implying that the maximum distance between trees at which their crowns are interlocking is greater than or equal to 28 feet and the average distance at which crowns of older trees interlock is about 14.5 feet. Churchill *et al.* consider any trees in their reference plots that are within 20 feet of one another to be a clump, and this same distance metric is used in calculating clumpiness in Galena units (see Figure 1).

Fifth, I see little evidence that post-treatment Galena spatial pattern is in fact significantly different than historical conditions. During my visit to Galena I randomly located ten points in Galena unit #37. I recorded the pith-to-pith distance between all stumps, snags, live trees and tree remnants that I estimated were established more than 150 years ago. I found that 43% of 150+ year old trees were more than 20 feet away from other 150+ year old trees, a somewhat higher figure than the 18%-38% “reference” condition. Given that most of the post-treatment tree structure is relatively young, and future trees are more likely to establish in areas that have trees than areas that don’t have trees, I see no reason to believe Galena units are outside the historical range of variability in terms of clumpiness, or will not be within the historical range of variability at some point in the near future given future growth and establishment.

Sixth, I see no reason to believe that the distribution of trees observed in older forests should be precisely replicated in younger forests. Most tree clumps on the Malheur National Forest that I have sampled exhibited uneven aged structure, meaning that at various points in time there was a clump composed of greater or fewer trees, or an individual tree (see Figure 2). Most of the trees that remain after harvest in Galena units are young trees, and there is no reason to think that just because they do not exhibit the same clumpiness as older forest they won’t develop desirable clumpiness in the future (see Figure 3).

**Conclusions**

Spatial pattern research of the sort that’s been undertaken by Churchill *et al.* is valuable to the extent it yields insights into forest structural development over time and elucidates the different edaphic, climatic and disturbance controls on forest structure in the interior Pacific Northwest. This research suggests a broad range of tree aggregation distributions that should inform restoration treatments in a general sense. I would support future research that compares and contrasts the spatial pattern that emerges in restoration treatments over time, particularly at longer time spans that incorporate the interactions of restoration treatments and future disturbance. I certainly would encourage restoration treatments to maintain a large proportion of residual trees in clumps on many sites. But I think it is inappropriate to simply report on the distribution of trees within clumps in subjectively located stands, assume that these statistics serve to represent historical spatial pattern, and then insist that forests of different ages in different environmental settings conform to this distribution.

I would strongly support research that attempts to identify the disturbance regimes and/or edaphic conditions associated with areas that were historically tree-less (research of the type described in Abella *et al.* 2013 would be extremely valuable on the Malheur NF). Probably the biggest challenge with respect to restoring historical and future sustainable spatial patterns is removing trees from areas that historically did not support tree cover and are not likely to support tree cover in the future. The proportion of trees in different clump sizes seems relatively unimportant to me compared to the challenge of developing a better understanding of where openings are likely to increase forest resilience and landscape-scale biological diversity.

I would strongly urge the BMFP and MNF to consciously develop a *process*-based rather than a *structure*-based approach to silviculture. The structure-based approach uses silviculture to create desired point-in-time forest structure and composition, usually without conscious or explicit reference to how this structure and composition will change in response to future climate and disturbance. A process-based approach explicitly identifies likely future climate and disturbance regimes and alters structure and composition not to achieve point-in-time desired conditions but to facilitate the desired tempo and intensity of future disturbance.

**Literature**

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**Figures**





