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Location relative to a retention patch affects the ECM fungal community more than patch size in the first season after timber harvesting on Vancouver Island, British Columbia

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Abstract

Silviculture systems that include retention of green trees are becoming more common in North America. The goals of green tree retention are to maintain forest structural diversity, preserve species associated with mature forests and to support faster post-harvest recovery of biodiversity. We studied the proportion of living roots and ectomycorrhizal (ECM) fungal communities in, and adjacent to, aggregated retention patches of coastal western hemlock forest on Vancouver Island, 4–6 months after harvest. Our objectives were to determine, for the window of time during which replanting typically occurs, (i) whether aggregated patches of green trees had retained ECM fungal communities similar to uncut forest and whether this depended on patch size; (ii) how far the influence of the patch extended into the harvested area, and whether this depended on patch size. These factors will influence the effectiveness of the aggregated patches as inoculum sources for seedlings planted in adjacent harvested areas. Soil samples were collected at the center and edge of 16 patches: four replicates each of 5, 10, 20, and 40 m diameter patches, as well as at 10 and 20 m into the harvested area around each patch. A control-forested area was also sampled. The state of the stele was used to designate 25 lateral roots from each sample as live or dead. One hundred active mycorrhizas per sample were then examined and described morphologically. The internal transcribed spacer region of the fungal rDNA was amplified and sequenced from representative tips of each morphotype. ECM communities were indistinguishable between uncut forest and the aggregated retention patches. This was true for patches as small as 5 m in diameter, with no significant overall effect of patch size on ECM fungal species richness, Shannon Diversity Index, or the proportion of live root segments. Sampling location, however, significantly affected all these variables, with the influence of the patch disappearing by 10 m into the harvested area. The only indication of a patch size effect was that ECM species richness at the edges of the 5 m plots was slightly lower ($P < 0.1$) than the edges of larger patch sizes. Based on these results, we recommend that patch sizes be at least 10 m in diameter for coastal western hemlock forests. Since the edge:area ratio of smaller patches is higher, more small patches of at least 10 m diameter would be more effective than a few large patches in supplying ECM inoculum to adjacent harvested areas during the first year after harvest.

Keywords: Variable retention harvesting; Ectomycorrhizas; Species diversity; Community composition; Root death; Western hemlock

1. Introduction

Sustained forest productivity and resilience after disturbance depend on an active soil microbial community. In forest soils, fungi, including ectomycorrhizal (ECM) fungi, form a substantial component of the soil microbial community and play important roles in mineralization of soil organic matter (Schimel and Bennett, 2004). Clear-cut logging reduces the fungal:bacteria ratio and changes the species composition of the ECM fungal community (Kranabetter and Wylie, 1998; Durall et al., 1999; Hagerman et al., 1999a,b; Siira-Pietikainen et al., 2001; Twieg et al., 2007). Many ECM fungal species disappear, while others that are resistant in one way or another to the disturbance increase in abundance, resulting in a community shift rather than a reduction in overall mycorrhizal colonization. In their recent review, Jones et al. (2003) suggest

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two possible explanations for this species shift: (i) that the ECM fungal communities on seedling roots in clear-cuts are better adapted to taking up nutrients under the altered conditions or (ii) that inoculum of some ECM fungi is destroyed during harvest and so the pool of fungi effectively able to colonize seedlings is reduced. If the range of fungal species able to colonize seedlings after harvest is reduced, this may be a reason for concern because ECM fungi vary greatly in physiology, and so some major ecosystem functions could be lost (Read and Perez-Moreno, 2003; Read et al., 2004).

The goal of variable retention harvesting, also known as green-tree retention, is to preserve species associated with mature forests, to maintain structural diversity at the landscape level, and to leave a legacy to support faster post-harvest recovery of biodiversity (Luoma et al., 2006; Macdonald and Fenniak, 2007). We expect retention of green trees to fulfill these goals for ECM fungi, at least during the years immediately after harvesting (see Peay et al., 2007). For example, Twieg et al. (2007) have determined that the mycorrhizal communities in stands of mixed birch/Douglas-fir younger than 30-years old differed considerably from those of 65 years and older. Hence, retention of patches of older forest would be expected to increase ECM diversity at a landscape level. Furthermore, variable retention should accelerate the reintroduction of ECM fungal species into the harvested areas by increasing inoculum availability to seedlings. This is because many species of ECM fungi colonize more effectively from the root systems of other trees than from other forms of inoculum (Simard et al., 1997; Kranabetter, 1999). Consistent with this prediction, Outerbridge and Trofymow (2004) found a reduction in mycorrhizal colonization of Douglas-fir seedlings with distance away from patches of aggregated retention. In addition, Luoma et al. (2006) found a 50% reduction in number of types of Douglas-fir ectomycorrhizas in soils 8–25 m from individual trees in a dispersed retention system, 1–2 years after logging. Neither of these studies examined differences amongst patch sizes or interactions between patch size and distance from the patch. Hence, we cannot yet recommend the appropriate size and density of aggregated retention patches needed to obtain a benefit from variable retention to ECM diversity.

Here we study the effect of variable retention harvesting on ECM fungal communities in mature second-growth coastal western hemlock stands on Vancouver Island. The objectives of this study were to determine, for the window of time during which replanting typically occurs: (i) whether aggregated patches of green trees had retained ECM fungal communities similar to uncut forest and whether this depended on patch size; (ii) how far the influence of the patch extended into the harvested area, and whether this depended on patch size. We examined ECM communities at the center and edge of variable retention patches ranging in size from 5 to 40 m, as well as up to 20 m into the harvested areas. We expected that the influence of the patches would extend less than 20 m, based on previous studies that examined ECM communities along transects from uncut forests into clear-cuts (Kranabetter and Wylie, 1998; Hagerman et al., 1999a,b; Cline et al., 2005), from retention patches into harvested areas (Outerbridge and Trofymow, 2004), or from undisturbed forests into abandoned agricultural fields (Dickie and Reich, 2005). We further hypothesized that there would be a minimum patch size below which the species richness of the ECM fungal community would decrease.

2. Materials and methods

2.1. Site description

The Silviculture Treatments for Ecosystem Management in the Sayward (STEMS) experiment tests seven treatments: extended rotation (non-treatment control), extended rotation with commercial thinning, aggregate and uniform dispersed retention systems, group selection and modified patch cut systems, and a 10-ha clear-cut with reserves (de Montigny, 2004). This overall design will be established at three different areas on northern Vancouver Island during different years. In this study, we examine the aggregated retention treatment, control, and clear-cut areas only from the second replicate (STEMS2). In the Sayward Forest the major stand-initiating events are believed to have been infrequent fires of moderate size (20–1000 ha) occurring about every 200 years. Therefore, the natural forest landscapes would have been dominated by roughly even-aged stands greater than 20 ha, less than 200-years old, with pockets of unburned, old-seral stands greater than 200 years. Over the past century, logging or fire has disturbed 63% of the forests in the Sayward Forest (de Montigny, 2004).

The STEMS2 site is located near Elk Bay, BC, at UTM 323800 E 5576300 N in the CWHxm2 (Coastal Western Hemlock biogeoclimatic zone, western very dry maritime subzone, Green and Klinka, 1994). The stand, prior to harvest, consisted of 81–100 years old (age class 5) western hemlock (*Tsuga heterophylla*, 77%), Douglas-fir (*Pseudotsuga menziesii*, 17%), western redcedar (*Thuja plicata*, 5%), and grand fir (*Abies grandis*, 1%). The site index (average tree height in m at 50 years) for the 25.9 ha study site (called Standards Unit 7 in the forest management plan) is 37 for western hemlock and 36 for Douglas-fir. The site is located at mid-lower slope position, aspect N/NE, elevation 37–160 m, and the average slope is 26%. The soil is an Orthic Ferro-Humic Podzol with mormoder humus form. The forest floor is approximately 5 cm deep and overlies a well-drained, loamy soil, with approximately 30% coarse fragment content, and 50 cm rooting depth.

Timber was harvested in mid-March to mid June 2005 using ground-based mechanized equipment (feller bunchers, feller processors, and tracked log loaders). Retention patches are comprised of trees representative of the original stand (western hemlock, Douglas-fir, western redcedar, and minor amount of grand fir). Selected patches were spirally pruned to increase their wind firmness.

2.2. Sample collection

In late October 2005, soil samples were collected at the center and edge of each patch and at 10 and 20 m along a transect north from the patch edge into the cutblock. Four