FUNGAL ECOLOGY 6 (2013) 430–438

available at www.sciencedirect.com

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journal homepage: www.elsevier.com/locate/funeco

Effectiveness of green-tree retention in the conservation of ectomycorrhizal fungi

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ARTICLE INFO

Article history:
Received 9 January 2013
Revision received 8 April 2013
Accepted 22 April 2013
Available online 12 June 2013
Corresponding editor:
Jacob Heilmann-Clausen

Keywords:
Habitat fragmentation
Habitat thresholds
Pseudotsuga menziesii
Species–area curve
Variable retention

ABSTRACT

Habitat fragmentation stresses may reduce the long-term effectiveness of green-tree retention as refugia for ectomycorrhizal fungal (EMF) species. We tested for a minimum retention patch size where EMF species abundance (morphotyping with molecular analysis), richness and reproduction (epigeous sporocarps) aligned with interior *Pseudotsuga menziesii* habitat on Vancouver Island (Canada). Ten years after logging, species richness was altered along the entire gradient of patch sizes (single trees to 0.12 ha), while % abundance and fruiting had significantly declined for some prevalent EMF species. Retention patches 20 m in diameter, on average, were therefore insufficient in size to ensure the continuity of mature-forest dependent EMF species. Refugia effectiveness would also correspond with habitat extent, and α and γ diversity estimates indicated retention patches approximately 0.2 ha in size, and culminating in at least 3 % of the cutblock area, would capture much of the spatial heterogeneity and species diversity of this EMF community.

Introduction

In the practice of retention forestry, refugia for forest-dependent biota are provided within timber harvested areas by live, mature ('green') trees retained in distributions ranging from lone individuals to large clusters of trees (retention patches) many hectares in size (Gustafsson *et al.* 2012). Green-tree retention is considered an effective tool in support of stand-level biodiversity, and provides one of the indicators of sustainable forestry currently monitored in British Columbia (Canada). A recent coastal assessment, for example, of 405 cutblocks (over 9 000 ha) found 23 % of the area in retention, on average, with 7 % set aside as dispersed trees and 16 % as retention patches, most of which were less than 2 ha in size (Densmore 2011). The long-term effectiveness of retention forestry, where forest-dependent taxa are not extirpated over the duration of a stand rotation, remains an important question, especially in regard to minimum thresholds in retention patch size (Aubry *et al.* 2009) and extent of habitat retained (Fahrig 2003).

Finding a consensus on biotic responses to forest fragmentation is challenging, however, as many highly mobile taxa such as birds and mammals do not respond as strongly to patch size as short-lived, small-bodied organisms such as

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1754-5048/$ – see front matter
http://dx.doi.org/10.1016/j.funeco.2013.05.001

arthropods (Bender *et al.* 1998; Debinski & Holt 2000; Ewers & Didham 2006). The effectiveness of refugia should be evaluated not only by species richness, as the number of taxa invariably increases with patch size, but also species density and composition, which might be altered in smaller retention patches by changes in the physical environment with increased exposure to forest edges (Saunders *et al.* 1991; Fisher & Lindenmayer 2007). Short-term postharvest results, in addition, do not necessarily capture the full ecological integrity of retention patches as species are often lost over time by the changes invoked by fragmentation, including low rates of reproduction and recruitment (Saunders *et al.* 1991; Debinski & Holt 2000). Conversely, for some taxa the configuration of habitat may be of less consequence to population fitness than the overall amount of habitat retained (Fahrig 2003). Radford *et al.* (2005), for example, found woodland-dependent bird diversity declined precipitously at landscape tree cover <10 %, with only minor effects of habitat configuration on this threshold.

Ectomycorrhizal fungi (EMF) are a diverse biota of boreal and temperate forests that are sensitive to timber harvesting (Jones *et al.* 2003), and typically benefit from retention practices in the conservation of species (Rosenvald & Lõhmus 2008). Both single and aggregated green trees have been effective in retaining many mature-forest EMF taxa within cutblocks, particularly on the root systems within the crown dripline of the overstory (Kranabetter 1999; Cline *et al.* 2005; Lazaruk *et al.* 2005). Some indication of a patch size effect was noted by Jones *et al.* (2008) as a slight reduction in EMF species richness on the edges of 5 m compared to 10 m diameter patches, whereas Lazaruk *et al.* (2005) found no difference in EMF richness at the centres of 0.25 ha and 0.75 ha retention patches. Much less studied is the continuation of EMF fruiting in relation to green-tree retention, but spore dispersal is likely to be of some consequence to population viability (Redecker *et al.* 2001; Bergemann & Miller 2002). Luoma *et al.* (2004) reported greatly reduced sporocarp biomass and richness of EMF mushroom taxa (up to 90 %) in retention harvest systems, in approximate correlation with basal area removed, especially where the trees were widely dispersed rather than aggregated.

For the most sensitive forest-dependent taxa, larger retention patches (≥1 ha) have been recommended for temperate forests of the Pacific Northwest (Aubry *et al.* 2009), and Heithecker & Halpern (2007) predicted that the interior environment of small patches, <0.2 ha in size, would be severely compromised by edge effects. In this study we examined EMF communities of retention patches likely encompassing the most vulnerable sizes for conservation (single tree to 0.12 ha), but after an interim of 10 yr to allow for further adjustments of the fungal community to the postharvest environment. Our hypothesis was that fragmentation stresses associated with diminishing retention patch size would cause an increasing divergence in EMF communities from comparable areas of intact habitat. The objective of the study was therefore to establish a minimum critical size for retention patch effectiveness where EMF species abundance, average richness and fruiting would align with interior forest habitat. A second objective was to establish habitat thresholds of the EMF community by extrapolating upon species–area and species–accumulation curves of interior forest habitat. The results of the study will substantiate the more long-term effectiveness of retention forestry in the conservation of EMF species, and provide guidance on the configuration and extent of habitat needed to retain the diversity of a coastal temperate forest EMF community.

Methods

Site description

The study took place at the Silviculture Treatments for Ecosystem Management experiment (STEMS1) in the Snowden Demonstration Forest (50°04′N and 125°25′W) near Campbell River, British Columbia (Canada) (de Montigny 2004). The research site encompasses a 250 ha area located in the Coastal Western Hemlock very dry maritime (CWHxm1) subzone, at an elevation of 175 m, with an average mean annual temperature of 8.6 °C and mean annual precipitation of 1 600 mm. At the establishment of the research trial in 2001, the forest stands were 55–60 yr old, predominantly Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) (83 % by volume), with minor amounts of western hemlock (*Tsuga heterophylla*) (13 %) and western redcedar (*Thuja plicata*) (3 %) established by planting and natural regeneration in the mid 1940's following clearcut logging and wildfire. Stand basal area averaged 51 m^2 ha^{-1}, with stem density of 940 stems ha^{-1}, total volume of 575 m^3 ha^{-1}, and site index of 33 m (at 50 yr) for Douglas-fir. The most common plant association of the research forest is the zonal Douglas-fir–Salal, with moderate to high shrub cover from salal (*Gaultheria shallon*), dull Oregon grape (*Mahonia nervosa*), and red huckleberry (*Vaccinium parvifolium*), along with near continuous moss cover provided by *Hylocomium splendens* and *Kindbergia oregana*. Soils are predominantly Ferro-Humic Podzols with moder humus forms (~6 cm deep), sandy-loam texture, 40 % coarse fragment content and rooting depths of 50–80 cm (de Montigny 2004).

Study design

The STEMS experiment consists of seven silvicultural systems (extended rotation, extended rotation with commercial thinning, uniform dispersed retention, aggregate retention, group selection, modified patch cuts, clearcut with reserves) designed to sustain diversity in the structure, composition and function of forest ecosystems (de Montigny 2004). Harvest treatments were carried out in 2001 and reforestation with Douglas-fir and western redcedar completed in 2002. Fourteen retention patches were located from the aggregated retention treatment (26 ha, 87 % of the area harvested), and ranged in size from a single tree to a cluster of 80 trees. Patches were irregular in shape so equivalent forest area was determined by dividing patch basal area by the preharvest forest basal area (e.g., 5 m^2 basal area of retained trees in a preharvest 50 m^2 ha^{-1} stand would be equal to 1 000 m^2 in equivalent area). For intact forests we utilized the extended rotation (12 ha, no harvesting) and modified patch cut (36 ha, 12 % of the area harvested in three openings of 0.7, 1.4 and 1.8 ha) treatments. These two treatment blocks were contiguous and allowed sampling over a larger area (44 ha) of interior forest habitat. We randomly