Forest Ecology and Management 358 (2015) 98–107

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Retention patch size and conservation of saproxylic beetles in boreal white spruce stands

Seung-Il Lee [a,*], John R. Spence [a], David W. Langor [b], Jaime Pinzon [a]

[a] Department of Renewable Resources, University of Alberta, 442 Earth Sciences Building, Edmonton T6G 2E3, Alberta, Canada
[b] Natural Resources Canada, Canadian Forest Service, 5320-122 Street, Edmonton T6H 3S5, Alberta, Canada

ARTICLE INFO

Article history:
Received 21 May 2015
Received in revised form 1 September 2015
Accepted 1 September 2015
Available online 10 September 2015

Keywords:
Aggregated retention
Forest management
Edge effect
Saproxylic beetles
Coarse woody debris
White spruce

ABSTRACT

Green tree retention is thought to conserve biodiversity in harvested landscapes; however, the amount and distribution of retention that best meets conservation goals remains unclear. To clarify size of retention patches needed to effectively conserve saproxylic (i.e., deadwood-associated) beetles in western Canada, we compared beetle assemblages among patches of three size categories (small: 0.63–1.06 ha, medium: 1.43–2.93 ha, and large: 3.34–5.93 ha) left in harvested areas with those from intact forests and harvested matrix. To understand edge effects as a potential driver of faunal changes associated with patch size, we also compared assemblages from edges and centers of retention patches. Saproxylic beetle assemblages similar to those in intact forests were well maintained in all patch centers, but assemblages in small and medium patches were strongly influenced by edge effects and were least similar to those in intact forests. Particular trophic guilds showed distinct responses to patch size. Predator assemblages showed negative edge effects in small and medium patches, while phloeophage assemblages did not differ between edges and centers of different patch sizes. Although smaller patches may better emulate historical size distributions of fire skips, conservation value is likely maximized in large patches, mainly by decreasing edge effects. Our study dealt mainly with 'initial colonizers', but further studies to define minimum patch size for retention harvest must be conducted over time to incorporate effects on species associated with well-decayed deadwood.

1. Introduction

Since its publication, the theory of island biogeography (MacArthur and Wilson, 1976) has strongly influenced conservation-oriented thinking about species distribution and permanence in fragmented landscapes (Laurance, 2008). For example, principles derived from island biogeography have been used for management of size, shape, dispersion, etc. of residual unharvested forest patches and legacies thought to function as biodiversity reserves for biota characteristic of pre-harvest conditions. Nonetheless, defining landscape targets for these traits remains a challenge for management of specific systems.

The general Natural Disturbance Model (NDM) was proposed as a new paradigm for guiding and improving forest landscape management over 20 years ago (Hunter, 1993). Proponents of the NDM approach hold that biodiversity and ecosystem functions can be maintained on forest landscapes by adopting logging practices that emulate dominant natural disturbances, e.g., wildfire, as much as possible to retain appropriate structural legacies (Hunter, 1993; Lindenmayer and Franklin, 2002). Under the broad NDM-based approach, retention of patches of uncut trees on harvested landscapes is promoted as an emulation of unburned 'fire-skips' that are thought to maintain populations of species that eventually colonize regenerating forest, thereby promoting recovery of biodiversity (Gandhi et al., 2001; Lindenmayer and Franklin, 2002; Work et al., 2003; Pinzon et al., 2012). Number and distribution of residual trees critically influence conservation and recovery of arthropod populations, especially 'saproxylic' insects that use deadwood as a resource (Langor et al., 2008; Hyvärinen et al., 2010; Légaré et al., 2011), because such elements provide the diverse characteristics of deadwood essential for persistence of such species (Siitonen, 2001). However, it remains unclear if conservation value is maximized by emulating post-fire patterns with harvest residuals (Gandhi et al., 2004).

Deadwood, especially as coarse woody debris (CWD), and associated organisms are critical to forest ecosystem function, because of connections to wood decomposition and nutrient cycling (Stokland et al., 2012). Saproxylic beetles (Insecta: Coleoptera) receive considerable attention in forest conservation science,

* Corresponding author.
E-mail address: seungil.lee@ualberta.ca (S.-I. Lee).

http://dx.doi.org/10.1016/j.foreco.2015.09.002
0378-1127/

because they are among the most diverse and abundant of deadwood-associated organisms, are sensitive to environmental change, their natural history is relatively well-known, and sufficient taxonomic resources for rigorous scientific work are available for many groups (Gibb et al., 2006; Langor et al., 2008; Cobb et al., 2011). In northern Europe, extensive forest harvest has led to reductions in amount and quality of coarse woody material, which has contributed to local extirpation of some saproxylic beetle species (Siitonen, 2001). Thus, there has been increasing focus on saproxylic insect assemblages worldwide in relation to forest management and conservation (Speight, 1989; Økland et al., 1996; Langor et al., 2008; Grove and Forster, 2011; Bouget et al., 2014), and deadwood management is widely accepted as an important part of sustainable forest management (Hagan and Grove, 1999; Langor et al., 2008).

Although better understanding of relationships between forest patch size and conservation potential is required to more effectively manage landscapes (Gustafsson et al., 2012), only a little research has addressed this issue for arthropod assemblages in boreal forests (e.g., Halme and Niemelä, 1993; Gandhi et al., 2004; Pearce et al., 2005; Webb et al., 2008; Pyper, 2009). Work in North America and Europe has shown that relatively small patches ($\leqslant$1-ha) are ineffective for conservation of epigaeic species (Matveinen-Huju et al., 2006; Halaj et al., 2008; Aubry et al., 2009). Pyper (2009) suggested that patch sizes of at least 2-ha in coniferous forests and 3-ha in deciduous forests should be retained to conserve assemblages of epigaeic carabid and staphylinid species. Several studies have concluded that even 3-ha patches were likely insufficient to conserve carabid beetles and spiders specialized in coniferous forest (Halme and Niemelä, 1993; Pearce et al., 2005). Larrieu et al. (2014) suggested that at least 20 ha of uncut patches are needed to conserve microhabitats required to maintain local biodiversity in montane beech-fir forests.

We examined relationships between retention patch size and saproxylic beetle assemblages in managed forest landscapes in the western boreal region of Canada. Ours is the first study to consider saproxylic insects in relation to patch size in these extensive forests. Furthermore, we considered the role of edge effects as drivers of response to patch size, and tried to link variation in deadwood qualities to differences in species composition. This study is part of a long-term study of biodiversity responses to logging on an operational forest landscape that is being broadly managed under the NDM paradigm. Thus, we can examine the 'real-world' utility of green-tree retention in an adaptive management framework that embraces practical application of biodiversity data. The overall goal of the study is to explore how retention patches of spruce function for saproxylic beetle conservation on harvested mixedwood landscapes in the boreal forest of western Canada.

2. Material and methods

2.1. Study area

This work was done in three large industrial harvest blocks (56.682°N–56.711°N, 118.605°W–118.781°W), located in the same area of originally homogenous boreal forest, ca. 100 km northwest of Peace River, Alberta, Canada. These blocks, designated A, B, and C (respectively, 379 ha, 44 ha, and 105 ha), were all harvested in 2000, leaving retention patches ranging from 0.03 to 6.64 ha in size in an early application of a NDM-inspired harvest design (Fig. 1). As part of this industrial harvest operation, patch sizes and distributions were arbitrarily chosen at harvest to place a variety of patch sizes on the harvested blocks under the constraint that total within-block retention would not exceed 30% of the original stem density. White spruce (*Picea glauca*) was the dominant tree species in all patches (>70% of all live trees), followed by lodgepole pine (*Pinus contorta*), with smaller numbers of trembling aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), black spruce (*Picea mariana*), and balsam fir (*Abies balsamea*) sprinkled unevenly through the patches. White spruce and lodgepole pine seedlings were planted in the harvested 'matrix' surrounding patches one year after harvest.

2.2. Experimental design and sampling procedure

We focus on two variables in this study, patch size and tree location within a patch, either in the center or on the edge. We selected 15 retention patches for study, ranging in size from 0.63 to 5.93 ha. We were most interested in changes in species composition of retention patches with respect to possible edge effects, how these may be affected over the range of patch sizes presently left behind by the most progressive commercial forestry in this region. Therefore, we subjectively divided the available patches into the following three size categories, with five patches per category: small, 0.63–1.06 ha; medium, 1.43–2.93 ha; and large, 3.34–5.93 ha (Fig. 1; Table 1). In order to better understand how size affects the ability of a patch to retain something close to the fauna of uncut forest, we also sampled five sites in the harvested matrix, and five sites in nearby intact forests.

We also studied the influence of location within a patch (i.e., possible edge effects) on the saproxylic fauna. To do this we girdled one white spruce tree at both the center and edge of every patch and characterized the saproxylic beetle assemblages that initially colonized dying trees in each within-patch location. In intact forests, five trees were girdled ca. 200 m from the harvest edge, four adjacent to harvest block A and one adjacent to block C. No trees of sufficient size remained in the harvested matrix but we sampled beetles there as described below. We also chose one white spruce natural snag near both the center and edge of each patch, and one snag in each intact forest to characterize the saproxylic beetle assemblages that colonize trees dying from natural causes. These snags had similar characteristics, consistent with early stages of decomposition (i.e., >90% of bark and >50% of branches), and were estimated to have died 5–10 years before sampling. We could not consider potential effects of distance of patches from intact forests (e.g., isolation), because all patches available for study were relatively close (<200 m) to continuous forest or other large patches (Fig. 1).

Saproxylic beetles were sampled with window traps attached perpendicularly to stems of girdled trees and snags at 1.3 m above the ground. Traps were a transparent plexiglass panel (20 $\times$ 30 cm) with a cloth funnel and plastic cup (100 mL) attached to the bottom of the panel (Hammond, 1997). Low-toxicity propylene glycol (30 mL) was added to the cups as a preservative. The 80 traps were distributed as follows: one was placed on each of two girdled trees and two snags in each of 15 patches; one was placed on each of five girdled trees and five natural snags in intact forests; and one was placed at breast height on each of ten living trees that had been planted in the harvested matrix. Traps were emptied and serviced every three weeks from early June to mid-September of 2010 and 2011.

Although we did not girdle trees in the harvested matrix, this is not likely to affect our results because diameters of 10-year-old coniferous trees were c. 5 cm, too small to colonize for the majority of saproxylic beetles in our study because they depend on relatively thick phloem as a feeding habitat. Also, there were no snags in the harvested matrix.