Forest Ecology and Management 336 (2015) 44–51

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Short-term response of coleopteran assemblages to thinning-induced differences in dead wood volumes

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ARTICLE INFO

Article history:
Received 25 April 2014
Received in revised form 27 September 2014
Accepted 5 October 2014
Available online 31 October 2014

Keywords:
Beetle
Coleoptera
Commercial thinning
Forest plantation
Woody biomass harvesting

ABSTRACT

Recent studies have commonly demonstrated the sensitivity of beetles (order Coleoptera) to forest management practices, managed forests generally supporting fewer beetles, fewer species, and a different community than unmanaged forests. In this study, we examine whether commercial thinning strategies that produce different dead wood volumes in plantations could be used to promote beetle diversity, abundance, and abundance across feeding guilds. To this end, we sampled beetles in the first two summers following thinning using flight intercept traps distributed in intensively-managed white spruce plantations and unmanaged, old coniferous forests. 60,385 beetles representing 48 families and 219 species were collected in the study. During both summers that followed thinning treatments, beetle abundance, richness, and abundance per feeding guild were similar to those observed in old forests. However, these effects began to fade during the second summer in plantations where woody debris had been removed. These results suggest that strategies of commercial thinning could be used to create resource pulses for beetles and favor their conservation in plantation landscapes, as long as woody debris are not harvested.

1. Introduction

In trying to maximize sustainable fiber production, modern forestry has often modified the biotic and abiotic conditions of forests, triggering a significant decline in biological diversity in some of these ecosystems (Brockerhoff et al., 2008; Pawson et al., 2013). For example, even-aged plantations, a type of intensively managed stands, are lacking continuity of important structures such as dead wood (Jonsson et al., 2005), understory vegetation (Ito et al., 2006), and pioneer trees (Paillet et al., 2010), which has been associated with a decline in the survival of several forest species (Bengtsson et al., 2000; but see Eycott et al., 2006). To mitigate these adverse effects and prevent further habitat loss in landscapes dominated by plantation forests would require forest management approaches seeking to increase habitat heterogeneity and structural complexity at both the stand and landscape levels to improve the conservation of biological diversity within these habitats (Lindenmayer et al., 2006).

Commercial thinning is an intermediate partial harvest in stands where trees have reached merchantable size. This management approach is used to avoid the decline of growth rates occurring in unthinned conditions when the growing space is occupied (Mayor and Rodà, 1993). Commercial thinning reduces competition between remaining trees for light, soil moisture, and nutrients (Canham et al., 2004) and thus improves the growth, size, proprieties, and value of remaining crop trees (Smith et al., 1997; Mäkinen and Isomäki, 2004). Incidentally, commercial thinning adds dead wood to the ground, creates openings in the canopy that favor the growth of understory vegetation (Zeide, 2001), and enhances species dispersal through thinning corridors, thereby increasing the availability and accessibility of microhabitats and resource for colonization and feeding (Curtis et al., 1997). Thus, commercial thinning and variants of this approach may diversify microhabitats in plantation forests, which has been shown to increase the abundance and/or richness of insects (Ohsawa, 2004; Maleque et al., 2010; Taki et al., 2010) and to affect communities of spiders at the stand level (Huang et al., 2011). However, because previous studies have shown the negative impact of woody debris removal on arthropods (e.g., Gunnarsson et al., 2004; Nittérus et al., 2007; Castro and Wise, 2010), we suspected that potential habitat gains from commercial thinning on invertebrates could be threatened by the ever-increasing use of whole-tree and woody biomass harvesting. Conversely, we speculated that additional habitat gains could be achieved if snags, a scarce resource in managed forests

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http://dx.doi.org/10.1016/j.foreco.2014.10.012
0378-1127/

(Wilhere, 2003), would be artificially created (see Ulyshen and Hanula, 2009; Jacobs et al., 2007).

In this study we compare beetle assemblages in white spruce [*Picea glauca* (Moench) Voss] plantations that have been subjected to four different commercial thinning strategies – standard thinning, thinning with biomass removal, thinning supplemented with girdled trees, and unthinned. Beetles (order Coleoptera) are a taxonomically diverse order (Gaston, 1991) comprising many feeding guilds (Crowson, 1981). Within forests, beetles can be found in many microhabitats unevenly-distributed both horizontally and vertically (Siitonen, 2001; Hammond et al., 2004) and have been demonstrated to be good indicators of the effects of forest management (e.g., Müller et al., 2008; Brunet et al., 2010; Lassauce et al., 2011). Knowing from contemporaneous studies that our thinning treatments have altered stand structure, tree growth, herbaceous vegetation, and dead wood availability (Thibault and Moreau, unpublished; MacLean et al., unpublished), we test the following hypotheses:

(H_1) if the diversification of stand conditions favors beetles, then beetle abundance and richness will be higher in thinned plantations than in homogenous, unthinned plantations. Because the diversification of microhabitats is reduced by the removal of dead wood and increased by the artificial creation of snags, we expect that biomass harvesting and tree girdling will respectively reduce and enhance beetle response to thinning.

(H_2) if the sequential arrival of beetle feeding guilds in thinned areas is determined by secondary succession in thinned corridors and heterotrophic succession on woody debris (see Vanderwel et al., 2006), then based on Essen et al. (1992), we predict that (i) xylem, phloem, and sap beetles will quickly increase in abundance following thinning, (ii) beetles feeding on fungi will increase in abundance after xylem, phloem, and sap beetles because they depend on the presence of bark-inhabiting fungi, (iii) herbivorous beetles feeding on understory vegetation and predacious and saprophytic beetles will increase in abundance as their food resource become available.

2. Material and methods

2.1. Study area

The study was conducted in the J.D. Irving, Limited Black Brook District (Fig. 1) located in northwestern New Brunswick (47°18′44″N, 67°42′38″W), in the hemiboreal vegetation zone of Canada. The privately owned district covers an area of 220,000 ha and is characterized by a mosaic of spruce plantations (37%), as well as deciduous (25%), coniferous (20%), and mixedwood (18%) forest stands. Details about the district management can be found in Etheridge et al. (2005). Two types of sites were selected for this study: white spruce plantations and unmanaged, old coniferous forests, hereinafter referred to as reserves.

2.2. Plantations

Six plantations aged between 25 and 30 years and covering on average (±SD) 27.50 ± 1.99 ha (range = 24.98–30.52 ha) were selected (Fig. 1). Each plantation originates from a clear-cut treatment and was composed of white spruce trees planted at a mean spacing of 1.8 m (3000 stems/ha) and conifer ingrowth. Within the first 3 years of stand establishment, 1–3 applications of broad-cast herbicide were carried out to remove herbaceous competition. Before commercial thinning treatments were applied, species composition was 51–92% of *P. glauca,* 1–30% of *P. marina* (Mill.) Britt., 5–18% of *Abies balsamea* (L.) Mill., and 0–8% of hardwood (mostly *Acer* spp and *Populus tremuloides* Michx.). Each plantation was split in four rectangular experimental units that had a 5-ha minimum size and a ~250-m minimum width. Four commercial thinning treatments were randomly allocated to each of the units in a plantation.

The first treatment, the control, was left intact. The second treatment, referred to as "biomass removal", was commercially thinned to extract 40% of the basal area but all woody debris from thinning were removed from the site. The only debris left behind were needles or small twigs (<0.5 cm in diameter) that were not attached to a branch. The third treatment, referred to as "status quo", was commercially thinned as above but slash and tops remained on site, along the corridors produced by thinning treatments. The fourth treatment, referred to as "enhanced", was a commercially thinned as above, with slash and tops remaining on site. In addition, 2.5% of the standing trees were girdled to remove all of the bark and cambium on a 30-cm section of the tree located at DBH, thus creating vertical dead/dying wood. The girdling was applied to eleven or twelve clumps of five adjacent trees distributed systematically in the central portion of enhanced experimental units. Thinning treatments were carried out between September 2010 and January 2011, a period in which flying beetles are largely inactive in Northern New Brunswick (MacLean et al., unpublished). Girdling was conducted between 6 and 10 July 2011. Following thinning, the mean (±SD) tree density was 2095 ± 465 stems/ha (range = 1788–2875 stems/ha) and the mean (±SD) DBH was 13 ± 1 cm (range = 12–15 cm).

2.3. Reserves

Three coniferous forests covering on average (±SD) 576.27 ± 206.94 ha (range = 383.20–794.70 ha), composed of at least 75% of *P. glauca* and *A. balsamea*, and that had not been managed or logged for at least 70 years were selected (Fig. 1). Fewer reserves than plantations were used in this study because large, unmanaged sites dominated by white spruce are scarce in the district and because beetle communities are expected to be less variable in undisturbed conditions than in recently thinned stands. Each reserve contained one experimental unit since no treatment was applied.

2.4. Beetle samples

We used flight intercept traps to optimize performance in terms of cost and efficiency for the collection of beetles, but especially saproxylic beetles (Langor et al., 2008). Traps were made of two sheets of acrylic glass of 30.5 × 61 cm, perpendicularly nested one inside the other. At the base of acrylic sheets, a styrene funnel with a diameter of 61 cm was attached. A glass of semi-translucent plastic filled with a solution of 70% ethanol and 2% liquid soap was inserted at the lower opening of the funnel. The solution was used to break the surface tension, prevent insect escape, and maintain specimen quality until harvest. Although ethanol-baited traps can attract more beetles than unbaited traps in terms of abundance and species richness (Bouget et al., 2009), this effect is counterbalanced by the kairomone released by a fresh input of woody debris (Bouget et al., 2009). The top of the trap was covered with a 61 cm circular piece of styrene to reduce the input of debris and rain. The rivets used to build funnels produced orifices that limited the accumulation of water in the traps.

In each of the experimental units, traps were placed along a transect parallel to the commercial thinning corridor (when present) and perpendicular to an extraction road contiguous to each experimental unit. The transects were placed approximately in the middle of the forest bands located between two thinning corridors. Each transect was at least 200 m from other transects and 100 m from other sides of the experimental unit. On each transect,