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Reductions in downed deadwood from biomass harvesting alter composition of spiders and ground beetle assemblages in jack-pine forests of Western Quebec

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ABSTRACT

Renewed interest in biomass harvesting has underscored the need for ecologically relevant thresholds and empirical validation of species responses for deadwood retention if biodiversity is to be preserved in managed landscapes. We experimentally reduced volumes of downed deadwood in clear cut jack-pine stands in Western Quebec, Canada and then monitored changes in spider and ground beetle assemblages 1 and 2-years following biomass removal as well as in uncut stands. We reduced volume of downed deadwood by (1) removing residual deadwood placed on machine corridors during the initial harvest of the stand to minimize soil compaction and (2) removing all residual deadwood material throughout the experimental plots. Ground beetle and spider assemblages from deadwood depleted plots were then compared with those in clearcut plots where no additional biomass had been removed and with uncut stands to assess the incremental effect of overstory removal and subsequent biomass removal using multivariate regression trees. We identified 13,822 individual arthropods representing 177 species. We observed differences in species assemblages attributable to the effects of overstory removal (35% of the explained variance) as well as biomass removal, particularly between plots with intensive removal of biomass and those with no additional or moderate removal of biomass (11% of the explained variance). As expected we observed a range of individual species response patterns. Of particular concern were species that experienced incrementally negative effects of overstory and biomass removal and those that were strongly promoted by biomass removal. These species showed responses atypical of those observed following clear cutting and may fall outside both the range of natural variability observed in this region as well as the range of current forest management intensity practiced in North America.

1. Introduction

Renewed interest in the exploitation of forest biomass for bioenergy has been met with concerns related to the negative ecological impacts on biodiversity (Abbas et al., 2011; Berch et al., 2011). Biomass harvesting relies on increased utilization of logging residues such as tree tops, branches and stumps as well as previously non-commercial trees species. The increased use of biomass feedstocks will necessarily reduce availability and diversity of downed deadwood post-harvest (Littlefield and Keeton, 2012; Klockow et al., 2013) and this reduction could possibly create a lasting rupture in the continuity of the deadwood profile for decades (Stokland, 2001). As biomass harvesting often occurs in concert with or soon after harvesting for lumber or pulp it is likely biomass reductions and their initial impacts on biodiversity will play out in the context of overstory removal (Briedis et al., 2011).

Biomass harvesting has been shown to affect a large variety of organisms, both saproxylic and non-saproxylic (Riffell et al., 2011; Bouget et al., 2012). The responses of saproxylic organisms, which require deadwood to complete their life-cycle, have been increasingly well-studied primarily because of the close ecological link with specific deadwood substrates (Hjältén et al., 2012) and the reduced availability and diversity of deadwood substrates following recuperation of biomass. However, for other more generalist organisms, responses to biomass harvesting may reflect a variety of other non-exclusive mechanisms ranging from modification of habitat conditions (Pearce et al., 2003) to more complex changes in detrital based food-webs (Birkhofer et al., 2008).

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Spiders and ground-beetles are abundant, generalist predators which have been widely used to assess the impacts of forest management (Niemelä et al., 1993; Buddle et al., 2000; Martikainen et al., 2006; Halaj et al., 2008; Work et al., 2010; Paradis and Work, 2011; Pinzon et al., 2012). Moreover, compositional changes in both spider (Castro and Wise, 2009, 2010) and ground beetle assemblages (Ulyshen and Hanula, 2009) have both been linked experimentally to changes in the abundance of downed deadwood. Changes in ground beetle composition have been further linked to post-harvest recovery of logging slash (Nittérus et al., 2007) and to whole-tree harvesting (Work et al., 2013). For such speciose groups of animals, multiple mechanisms will likely interact to determine assemblages and perhaps individual species responses to biomass harvesting.

Residual deadwood may serve as a favorable microhabitat for spiders and ground beetles. Increased spider densities (Castro and Wise, 2010) and higher species richness (Varady-Szabo and Buddle, 2006) in close proximity to downed deadwood have been attributed to increased litter layers adjacent to logs and a presumably favorable microclimate. Pearce et al. (2003) suggested that downed deadwood buffers ground beetles from the increased temperature and reduced humidity that accompanies removal of the overstory. Thus deadwood may only become a critical habitat for spiders and ground beetles after overstory removal.

Loss of deadwood following biomass harvesting could also result in a loss of available prey (Komonen et al., 2000). In detrital-based food webs other than forests, reductions in quantities of detrital biomass can increase the incidence of intra-guild predation and alter entire food webs by reducing the abundance of detrital consumers (Polis et al., 1998; Birkhofer et al., 2008). Any interaction among generalist predators related to loss of deadwood following biomass harvesting will likely be intensified by the absence of forest overstory as intensive harvesting often results in massive increases in species that prefer open-habitats such as clearcuts (Paradis and Work, 2011).

The potential risks of biomass harvesting for biodiversity will obviously depend on how much biomass is removed. While recommendations and guidelines for biomass harvesting have been proposed for some regions (Briedis et al., 2011), significant knowledge gaps on the impacts of biomass harvesting have persisted concerning soil properties (Thiffault et al., 2010) , stand structure (Littlefield and Keeton, 2012) and biodiversity (Verschuyl et al., 2011). And as such, few studies are available that provide retention targets for biomass harvesting specific for biodiversity (Work and Hibbert, 2011).

Here we have reported the 1- and 2-year responses of spiders and ground beetle assemblages to two increasingly intensive levels of post-harvest biomass removal. To better delineate species responses attributable to silviculture from those specifically attributable to biomass removal, we also compared the response of these assemblages to stem-only harvesting, where the overstory was removed but significant amounts of residual forest biomass were left on site. We hypothesized that increasing intensive levels of biomass removal will cause shifts in spider and beetle assemblages and create assemblages that have yet to be observed following intensive forest harvesting.

2. Materials and methods

2.1. Study site

This study took place within the Lake Duparquet Research and Teaching Forest (LDRTF), 45 km northwest of Rouyn-Noranda, north-western Quebec, Canada (48°86′–48°32′N, 79°19′–79°30′W). The region is situated in the boreal forest and the climate is continental with a mean annual temperature of 0.8 °C and annual precipitation of 890 mm (Environment Canada; Canadian climatic normals 1971–2000, www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html). Located within the Precambrian Shield, the regional topography is generally gentle with short slopes.

2.2. Biomass removal experiment

The experiment was established within a ca. 85 year old jack pine (*Pinus banksiana* Lamb) forest originating from a 1923 wildfire (Dansereau and Bergeron, 1993) and growing on coarse-textured thin till deposits. The experiment included two overstory treatments, clear cut and uncut, and three levels of biomass removal nested within clear cut treatments. These four treatments were randomly allocated within experimental blocks. Each experimental block was replicated three times resulting in 12 experimental units. The design allowed us to delineate the relative importance of overstory removal vs the cumulative impacts of overstory removal plus biomass removal.

In the winter of 2008–2009 overstory was removed via stem only harvesting in accordance with careful logging guidelines creating an alternating pattern of protection strips, where no traffic is allowed, and trails to which movement of multifunctional shortwood harvesters and transporters were restricted. Trees were delimbed directly on site and unmerchantable portions of the trees such as tops and branches were left in machine trails in front of the harvester, providing a concentrated row of residual green wood intended to minimize soil disturbance.

In the fall of 2009, three levels of biomass removal were applied to 0.25 ha plots nested within clear cut plots using a modified harvester with a retractable arm: (1) residual deadwood including branches and unmerchantable pieces of the trees were left on site (clear cut), (2) residual deadwood along trails and within reach of retractable arm was removed but the harvester was not allowed to leave trails (path), (3) residual deadwood was removed along and between trails and the harvester systematically passed throughout the entire experimental block (intensive) (Fig. 1). Deadwood recovered with the retractable arm was then deposited in an attached transport container as the harvester moved through experimental units. Recovery of forest biomass with this type of harvester is novel in North America.

2.3. Deadwood sampling

In May 2010, in each of 12 experimental units, deadwood volume was estimated using the line intercept method (Van Wagner, 1968). Accordingly, along each side (30 m) of an equilateral triangle, the frequency of pieces of wood was recorded by diameter and decomposition classes. Decomposition classes were based on visual criteria such as the presence of branches, bark and mosses and on the relative softness of the wood (Szewczyk and Szwagrzyk, 1996). Wood pieces intercepting the sampling transect were classed into 1 of 7 diameter classes including 0–0.5, 0.51–1, 1.01–3, 3.01–5, 5.01–7, 7.01–17.5 and >17.5 cm. The length of each transect used to tally wood pieces depended on diameter class; that is, smaller diameter classes were tallied along shorter sections and larger diameter classes were tallied along the entire 30 m length. Thus within first 5 m, all diameter classes were counted; over the first 10 m, all diameter classes except the 0–0.5 cm class were counted and so on. This strategy was applied to subsequent diameter classes such that only pieces greater than 7 cm were sampled over the entire length of each 30 m transect. The total number of pieces were then summed over the 3 transects and the Van Wagner formula was applied using the corresponding sampling distance for a given diameter class to estimate volumes of deadwood (Van Wagner, 1968).