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Effects of experimental forest harvesting on oribatid mite biodiversity

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ABSTRACT

Ecosystem-based management (e.g. partial cut harvesting) attempts to mimic natural forest dynamics and maintain structural complexity, and this less intense harvesting may minimize the impact on forest floor fauna and help maintain soil system biodiversity. We tested how different experimental harvesting regimes affect the diversity, abundance and composition of Oribatida at the sylviculture et aménagement forestiers écosystémique (SAFE) research forest located in the Abitibi region in NW Québec. Litter and soil were sampled in June 2006 in the mixedwood boreal forest at SAFE where the following treatments were applied and replicated three times: clear cut harvest, 1/3 partial cut harvest, 2/3 partial cut harvest, prescribed burn (after clear cut harvest) and uncut control. Eight years after harvest, partial cuts had more similar species composition to the uncut control within their respective blocks; however, burned habitat showed a shift in species dominance patterns and harboured a relatively distinct composition and species richness compared to treatments. With the exception of samples from clear cuts, species composition of the harvesting treatments was more similar within blocks than among blocks, suggesting that for less intense harvesting practices, spatial scale (i.e. regional factors) could have a greater influence in structuring oribatid assemblages than harvesting regime, but in more severe disturbances such as burn-after-clear cut harvest, habitat is altered enough to affect oribatid biodiversity.

1. Introduction

Forest ecosystem function is inextricably tied to its structure, but intensive forest management decreases structural complexity, which reduces species diversity and likely affects ecosystem function (Hansen et al., 1991; Hooper et al., 2005). In an unmanaged forest, naturally occurring cycles of disturbance at different spatial and temporal scales produce stands of variable age and composition (Bergeron et al., 1998; Perry, 1998), resulting in high habitat heterogeneity and structural complexity that support high diversity (Hansen et al., 1991). Anthropogenic disturbances such as large-scale clear cutting alter forest structure and composition in ways that are very different than natural disturbance events. Clear cut harvesting alters soil structure and forest floor habitat (Battigelli et al., 2004; Kuuluvainen and Laiho, 2004), contributes to substantial loss of nutrients and food resources, decreases organic inputs (Ballard, 2000; Covington, 1981; Perry, 1998), modifies abiotic conditions (Ballard, 2000; Esseen et al., 1997) and reduces soil fungal biomass (Pietikainen and Fritze, 1995). These changes, taken together, undoubtedly affect litter and soil biodiversity and influence their functioning as part of the decomposer community.

In boreal forests, several ground-dwelling arthropod taxa show variable responses to clear cutting (e.g. Buddle et al., 2006; Coyle, 1981; Niemelä et al., 1993) but effects on soil fauna are largely unknown. Oribatida is the most diverse and abundant suborder of mites in litter and soil (Norton, 1985, 1994) and may be considered a useful bioindicator group for soil ecosystem functioning (Behan-Pelletier, 1999). Oribatid mites are recognized as vital members of the decomposer community, that is, secondary decomposers that contribute to decomposition (e.g. Heneghan et al., 1999; Seastedt, 1984b) and nutrient cycling (e.g. Moore et al., 1988; Setälä and Huhta, 1991) by mediating microbial populations through grazing activity and by fragmenting organic material, thus facilitating further decomposition (Behan-Pelletier, 1999). Oribatid mite assemblages have been shown to be negatively impacted by clear cutting in the short-term, usually due to microclimatic changes.

In mixedwood forest, Bird and Chatarpaul (1986) demonstrated a reduction in oribatid abundance and a shift in species dominance in the first two years after clear cutting but did not find a change in species composition. In the southern Appalachians, immediately after and for up to eight years after clear cutting there was a reduction in oribatid mite abundance and a shift in species dominance patterns (Abbott et al., 1980; Blair and Crossley, 1988),

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but after 21 years, oribatid density and morphospecies richness recovered, exceeding that in the control forest (Heneghan et al., 2004). Huhta et al. (1967) showed a slight increase in oribatid mean density immediately after clear cutting, which then significantly decreased eight years later (Huhta et al., 1969). Changes in oribatid mite assemblages after clear cut harvesting may persist for several years (Blair and Crossley, 1988; Siepel, 1996), but there are very few long-term studies to verify this.

Ecosystem-based management is a coarse filter approach that attempts to emulate natural disturbance with the goals of maintaining essential ecosystem processes and preserving forest biodiversity (Armstrong, 1999; Fries et al., 1997; Harvey et al., 2002), thus ensuring long-term ecological sustainability (Hooper et al., 2005; Loreau et al., 2001, 2003). Alternatives to clear cutting, such as partial cutting, are thought to spatially emulate natural disturbance by maintaining some structural heterogeneity from the pre-harvest stand through the retention of live trees, snags and logs in clear cuts (Hansen et al., 1991; Harvey et al., 2002). Prescribed burning of clear cuts is thought to imitate natural fire and create some of the abiotic conditions (e.g. light and temperature regimes) and structural heterogeneity associated with burned stands (Bergeron et al., 1998; Fries et al., 1997).

Compared to clear cuts, partial cutting has been shown to decrease canopy openness, and therefore solar radiation (Brais et al., 2004a), decrease N mineralization and nitrification rates (Prescott, 1997), increase decomposed CWD (Brais et al., 2004a), increase habitat structural complexity (Esseen et al., 1997) and maintain more similar soil pH, microbial biomass (Siira-Pietikainen et al., 2001) and soil temperature and moisture levels (Barg and Edmonds, 1999) to uncut sites. These studies suggest that less intense harvesting may minimize some microhabitat changes important to ground-dwelling arthropods; however, other authors have found no difference in litter decomposition rates (Prescott, 1997), N availability, soil pH (Lapointe et al., 2006) or microbial biomass (Jerabkova et al., 2006) among clear cut, partial cut and uncut stands.

Several studies suggest that less intense harvesting may have less impact on oribatid mites. A loss of their dominant status and a decrease in their density was demonstrated in intensely managed oak-beech forest compared to less managed forest (Cancela da Fonseca, 1990), and in a partially cut hardwood stand, Abbott et al. (1980) showed a moderate level of similarity in dominance ranks among oribatid species compared to a control, but similarity between the partial cut and clear cut was significantly different. Lindo and Visser (2004) found microarthropod suborder abundance in partial cut retention patches to be more similar to uncut conifer forest than to clear cuts, but Peck and Niwa (2005) showed that thinned conifer stands had significantly lower oribatid mite abundance on the forest floor than unthinned stands.

Managed forests lack variability in age structure and stand composition due in part to fire suppression (Armstrong, 1999; Bergeron et al., 1998; Esseen et al., 1997). Prescribed or controlled burning is a management strategy used to reduce fuel buildup, control competing understory vegetation and prepare seedbeds for replanting (Pietikainen and Fritze, 1995) and can also be used in an attempt to restore natural forest structure and to reintroduce fire to the ecosystem (Bergeron et al., 1998; Fries et al., 1997). Impacts of prescribed burning include loss of nutrients (Ballard, 2000), changes in nutrient availability (Frey et al., 2003), increased soil pH (Pietikainen and Fritze, 1995) and loss of vegetation, litter and slash cover, which increases soil surface temperature and moisture fluctuations (Ballard, 2000; Vlug and Borden, 1973).

The impacts of prescribed burning after clear cutting are variable for oribatid mites. Oribatid abundance was significantly lower in burned stands (Seastedt, 1984a), particularly in more frequently burned sites (Dress and Boerner, 2004) and in burned-after-harvest sites (Vlug and Borden, 1973). However, five years after controlled burning in clear cuts, Berch et al. (2007) showed no difference in oribatid density compared to an unburned clear cut, but species richness was lower in the burned clear cut.

The objective of the present study was to test the effects of different forest management practices on oribatid mite abundance, species richness and composition in mixedwood boreal forests of eastern Canada. To address this objective, we had the following research question: How do oribatid mite assemblages differ among uncut forest, partial cut (one-third and two-third) forest, clear cut and prescribed burned-after-harvest?

2. Methods

2.1. Study area

The study was conducted in Phase 1 of the sylviculture et aménagement forestiers écosystémique (SAFE) research site located in the Abitibi region of Québec's northwestern boreal forest (48°86′N–48°32′N, 79°19′W–79°30′W). Phase 1 of SAFE consists of a cohort of aspen (*Populus tremuloides* Michx.) dominated stands (67%) originating from a fire in 1923 (Brais et al., 2004b; Dansereau and Bergeron, 1993). Other tree species in the study area include grey pine (*Pinus sabiniana* Dougl.; 16%) and eastern white cedar (*Thuja occidentalis* L.; 4%); dominant shrubs include beaked hazel (*Corylus cornuta* Marsh.) and mountain maple (*Acer spicatum* Lam.), and the dominant herbaceous plants are wild sarsaparilla (*Aralia nudicaulis* L.) and big-leaved aster (*Aster macrophyllus* L.) (Brais et al., 2004b). Mean annual temperature in the area is 0.8 °C, with a June mean temperature of 14.3 °C, and total annual precipitation is 889.8 mm (Environment Canada, 2003). Soils in the area are Grey Luvisols (Canada Soil Survey Committee, 1987) with a high clay content (>75%), and the forest floor is classified as a thin mor, 2–7 cm thick (Brais et al., 2004a).

In the winter of 1998–1999, the following treatments were applied and replicated three times as a randomized complete block design: clear cut harvest (CC), one-third (30% merchantable basal area removed) partial cut harvest (1/3PC), two-thirds (61% merchantable basal area removed) partial cut harvest (2/3PC) and no harvest (uncut control, CTL). A prescribed burn-after-clear cut harvest (BRN) was applied in August 1999. These treatment units ranged from 1 to 2.5 ha, and in all treatments, harvesting was done manually (Brais et al., 2004a,b).

2.2. Sampling

Over three days in mid-June 2006, we took three samples each of litter and soil in each of the five treatments in each of the three blocks, for a total of 45 samples for each layer. The three samples taken in each treatment unit were pooled for analysis to avoid pseudo-replication. Litter (i.e. freshly fallen leaves, needles, twigs, stems and bark (Hoover and Lunt, 1952)) was haphazardly collected along 25 m transects (three per treatment unit), gently mixed and a 1 l sub-sample was taken in order to obtain samples representative of the entire unit. At each transect, a soil core (6 cm diameter) of the H layer (i.e. well decomposed organic matter of unrecognizable origin (Hoover and Lunt, 1952)) was also taken to the depth of the mineral soil horizon. All samples were taken at approximately the same time of day to minimize abiotic and vertical migratory fluctuations (Seastedt and Crossley, 1981). Immediately after collection, samples were placed into individual cloth bags and kept in a cooler until extraction later the same day. All microarthropods were extracted in a nearby laboratory using Tullgren-type funnels for five days at an average temperature of 32 °C for litter and 36 °C for soil. Tullgren-type extractors produce 98% extraction efficiency for adult oribatid mites (Marshall, 1972),