Forest Ecology and Management 347 (2015) 149–155

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Epiphytic macrolichen cover, richness and composition in young successional boreal forest: A comparison of fire and logging disturbance

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ARTICLE INFO

Article history:
Received 23 October 2014
Received in revised form 12 March 2015
Accepted 13 March 2015
Available online 30 March 2015

Keywords:
Boreal forest
Epiphyte diversity
Logging
Macrolichens
Stand-replacing fire
Time since disturbance

ABSTRACT

Epiphytic macrolichens are indicators of environmental quality and forest heath. Stand-replacing disturbances such as wildfire and harvesting may have different impacts on epiphytic macrolichens, but previous studies have confounded the effects of disturbance origin with those of stand age. It remains unknown whether epiphytic macrolichens respond differently to fire *vs.* harvesting. We examined the temporal dynamics of epiphytic macrolichen cover, richness, and composition as affected by disturbance origin, time since disturbance, and forest type over 33-year chronosequences in Ontario, Canada. Epiphytic macrolichens were absent 7 years after fire or logging, but their cover and richness thereafter increased with stand age for all overstory types in both fire and logged stand. While macrolichen cover and species richness did not differ in stands ⩽15 years old between the two disturbance origins, post-logged stands had lower macrolichen cover in conifer and mixedwood stands, but similar species richness compared with post-fire stands after 33 years. More pronounced was the compositional difference of epiphytic lichens among overstory types, stand ages, and disturbance origins. Our results demonstrate that epiphytic macrolichen cover and richness increase with stand age and logging reduced macrolichen cover compared with fire. Furthermore, logging resulted in epiphytic macrolichen communities different from fire. The differences in macrolichen cover, richness, and composition between logging *vs.* fire could be attributed to several stand-level differences including initial stand composition, regeneration density, and tree species diversity.

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1. Introduction

Epiphytic macrolichens are ecologically significant component of forest ecosystems (Bergamini et al., 2005). They play crucial roles in nutrient and mineral cycling (Knops et al., 1996; Matzek and Vitousek, 2003). As structurally dependent flora, epiphytic lichens are sensitive to changes in forest structure and composition that are caused by natural disturbances and forestry practices (Hyvärinen et al., 1992; Bartels and Chen, 2012).

Epiphytic macrolichens are slow colonizers; therefore, time since disturbance, i.e. stand age, constitutes a determining factor of epiphytic lichen development (Hyvärinen et al., 1992; Hedenås and Ericson, 2000; Price and Hochachka, 2001; Bartels and Chen, 2012, 2015). In addition, canopy tree species composition has strong influence on epiphytic lichen communities (Esseen et al., 1996; Uliczka and Angelstam, 1999; Bartels and Chen, 2015). In the boreal forests of North America, stand-replacing disturbances such as fire initiate stand development in multiple successional pathways, such that stands at any given stage of stand development can be dominated by either broadleaf or conifers or mixed species dominance (Chen and Popadiouk, 2002; Taylor and Chen, 2011). Yet, the independent effect of stand composition on the temporal development of epiphytic lichens in fire *vs.* logged stands has not been previously examined.

Wildfire is the most prevalent natural, stand-replacing disturbance that shapes the structure and function of North American boreal forests (Payette, 1992; Johnson, 1996). However, harvesting mostly in the form mechanical clearcut harvesting (hereafter logging) has emerged as an important stand-replacing disturbance in boreal forests as a result of increased demand for forest resources in the 21st century. In the managed landscapes harvesting is designed to emulate the natural wildfire disturbance, but few have examined its conservation potential for macrolichens relative to wildfire (Johansson, 2008). Many previous studies have examined the consequences of disturbance on epiphytic lichens (Rolstad et al., 2001; Hilmo et al., 2005; Storaunet et al., 2008). However, the effect of disturbance origin is too often confounded with stand age as most studies compare young managed stands with old fire-origin stands (Hyvärinen et al., 1992; Esseen et al.,

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http://dx.doi.org/10.1016/j.foreco.2015.03.025
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1996; Dettki and Esseen, 1998; Kuusinen and Siitonen, 1998; Ódor et al., 2013).

Our objective in this study was to evaluate the influences of disturbance type, stand age, and composition on epiphytic macrolichens during early forest development in post-fire and post-logged stands in the boreal forest of central Canada. Specifically, we determined whether the temporal dynamics of epiphytic lichen abundance, diversity, and composition differ between stands originating from wildfire and logging. We expect epiphytic lichen abundance and diversity to continuously increase with time since fire and logging due to the slow biomass accumulation of lichens. We hypothesize that with similar stand age and overstory tree species composition, epiphytic lichen abundance, diversity, and composition do not differ between postfire and post-logged stands. We focused on epiphytic macrolichens (foliose and fruticose forms) because of their indicator status and conservation values (McCune, 2000; Will-Wolf, 2002; Bergamini et al., 2005). Previous studies of epiphytic macrolichens have indicated differences related to dispersal and colonization in foliose and fruticose macrolichens in managed boreal forest stands (Esseen et al., 1996; Dettki et al., 2000); therefore, we examined whether disturbance origin, stand development and overstory composition effects on macrolichens differ among these growth forms.

2. Materials and methods

2.1. Study area

The study was conducted in the boreal forests north of Lake Superior and west of Lake Nipigon in the Black Spruce Forest, located approximately 100 km north of Thunder Bay, Ontario, Canada (49°23′N to 49°36′N, 89°31′W to 89°44′W). This study area falls within the Moist Mid-Boreal (MBX) ecoclimatic region (Ecoregions Working Group, 1989) and is characterized by warm summers and cold, snowy winters. The mean annual temperature is 2.5 °C and annual precipitation is 712 mm (Environment Canada, 2014). The soils on our sample sites are composed of deep glacial tills of the Brunisolic and Podzolic orders (Soil Classification Working Group, 1998). The dominant overstory tree species in the area include jack pine (*Pinus banksiana* Lamb.), trembling aspen (*Populus tremuloides* Michx.), white birch (*Betula papyrifera* Marsh.), black spruce (*Picea mariana* [Mill] B.S.P.), balsam fir (*Abies balsamea* L. Mill), and white spruce (*Picea glauca* [Moench] Voss). Common understory shrub species in the area as studied by Hart and Chen (2008) include mountain maple (*Acer spicatum* Lam.), alder (*Alnus* spp.), and beaked hazel (*Corylus cornuta* Marsh.).

Stand-replacing fire is the primary natural disturbance in the study area. Recent fire history constructed for the area suggest that fire activities have increased with a fire cycle of 295 years for the period prior to 1921 and between 96 and 156 years for the period of 1921–2008 (Senici et al., 2010). The increased fire activities appear to be a result of climate change and increased human activities in the central boreal forest region. Commercial harvesting, mainly clearcut harvesting began in the area in the 1970s. Dependent on management objectives for tree species composition, burned and logged sites are left to naturally regenerate for broadleaf forest type, whereas jack pine is usually planted or aerial seeded for conifer and mixedwood forest types, with no intensive management such as thinning and pruning.

2.2. Sampling design

Using information from detailed fire records and silviculture and forest management records, we selected two 7–33-year chronosequences of fire and logging origin that shared similar developmental histories. Early studies have demonstrated that chronosequences and associated space-for-time substitutions are well suited for studying temporal dynamics of plant communities over decadal to centennial time scales, given careful site selection, replication, and demonstration of developmental links between downed woody debris and live trees (Walker et al., 2010). Unlike the postfire stands that extended across many stand age classes, 7–209 years since fire (Bartels and Chen, 2015), the temporal scale of our sampling for post-logged stands was limited to available harvested stands from the past 35 years because commercial harvesting in the study area only began in the 1970s (*Paul Poschmann*, *General Manager, Red Lake Forest Management Company, personal communications*). Our comparison was further constrained by the limited availability of independent, large, stand-replacing fires that occurred during the same time period as harvesting. We were, however, able to sample three age classes (7, 15, and 33 years since fire or logging) that represented the stand initiation, early stem exclusion, and late stem exclusion stages of boreal stand development, respectively (Chen and Popadiouk, 2002). Time since last stand-replacing fire (TSF) was determined from detailed fire records (Senici et al., 2010) and time since harvesting was obtained from silviculture and forest management records.

Since stands of both fire and logging origin on mesic sites in the region can be dominated by conifer, broadleaf or mixed-wood in the overstory at any given stage of stand development (Frelich and Reich, 1995; Chen and Popadiouk, 2002; Ilisson and Chen, 2009; Taylor and Chen, 2011), we sampled all three overstory types for each age class. We sampled three replicates for each combination of stand age and overstory type for each stand origin (27 post-fire and 27 post-logged stands) (Table 1). We avoided sampling stands of the same age in close proximity to one another to ensure interspersion of stands sampled and to minimize the impact of spatial autocorrelation (Legendre and Legendre, 1998). This was achieved by selecting stands of the same age class from different road accesses, resulting in distances between stands in the range of 0.5–10 km. In order to minimize site variability, we selected only stands located on mesic sites on flat-mid-slope positions, with no slope exceeding 5%. The stands were located on well-drained (sandy or silty loams) glacial moraines, which is the prevailing soil type in our study area. To ensure that each sample stand met this criteria, soil pits were dug in each candidate stand to verify whether the site was mesic, following the procedures described in Taylor et al. (2000). The selected stands were >1 ha in area, visually homogeneous in stem density and composition.

2.3. Data collection

In each selected stand, we established a 400-m^2 circular plot within which all data was collected. The plots were located at least 50 m from the forest edge in order to avoid edge effects. We identified all tree species and measured the diameter at breast height (DBH; 1.3 m above the root collar) of all trees of each sample plot for the 33-year old stands. For the younger (7- and 15-year old) stands, tree stems were counted by species. Stand density and basal area by species were summed to plot level and scaled up to level per hectare (Table 1). Overstory types were classified based on the relative density or basal area of broadleaf and conifer tree species in a plot. Broadleaf and conifer stands composed of ⩾65% broadleaf or conifer tree species by stand basal area or stem density. Mixed-wood stands had <65% of broadleaf or conifer tree species by stand basal area or stem density (Table 1).

In each plot, we conducted a thorough reconnaissance of the entire plot area similar to the whole-plot ocular method of McCune and Lesica (1992), and sampled epiphytic lichens on all

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