Forest Ecology and Management 370 (2016) 45–55

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Short-term effects of three commercial thinning treatments on diversity of understory vascular plants in white spruce plantations of northern New Brunswick

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ARTICLE INFO

Article history:
Received 6 August 2015
Received in revised form 28 March 2016
Accepted 29 March 2016
Available online 2 April 2016

Keywords:
Understory
Sub-boreal forest
Biodiversity
Plantation
Commercial thinning
Functional group

ABSTRACT

Plantation forestry is increasing in frequency and extent across the landscape, but can negatively impact biodiversity by promoting stand homogeneity and early-seral species dominance. Modifying silvicultural prescriptions in plantations, particularly with respect to creating or retaining more coarse woody debris (CWD), may improve their ability to support biodiversity, by mimicking some aspects of natural disturbance. We used a modified before-after-control-impact design to examine the response of understory vascular plants to four treatments in 25-year-old white spruce plantations of northwestern New Brunswick. Treatments included commercial thinning (CT) with enhanced, moderate, or no debris, as well as an unthinned control. Understory composition was analyzed using complementary methods that summarize biological communities at different resolutions: indicator species analysis, functional group responses, ordination, and biodiversity indices. Understory plants increased in overall richness and abundance after thinning, particularly in no-debris treatments. This was driven by (1) expansion of pre-established clonal forest herbs and (2) invasion of graminoids and long-distance dispersers. Several disturbance-sensitive species were significantly more abundant in unthinned controls. Few compositional differences were observed between the moderate and enhanced debris treatments, perhaps because the effects of CWD creation require longer to detect than those of thinning and ground-layer disturbance (from debris-removal). We recommend (1) continued monitoring of changes in moderate and enhanced treatments to determine the effects of debris-modification and (2) avoiding silvicultural prescriptions that remove branches, tree-tops, and other non-merchantable wood, which appear to facilitate early-seral species, and negatively impact disturbance-sensitive species.

1. Introduction

As plantation silviculture increases in areal extent (FAO, 2015), studies indicate the potential for negative impacts on native biodiversity (Fleming and Freedman, 1998; Freedman et al., 1996; Ramovs and Roberts, 2005; Ross-Davis and Frego, 2002). In particular, those species characteristic of mature forest interiors may be reduced or absent from plantations (Freedman et al., 1996; Roberts, 2002; Schieck et al., 2000). Impacts may be due to a combination of the immediate and direct killing effects of clearcutting with site preparation (to initiate plantations), or the longer-lasting effects of the altered habitat they create (Fenton and Bergeron, 2008; Ohlson et al., 1997). Short stand rotations may also prevent recolonization of inherently rare or dispersal-limited species (Frego, 2007; Zobel et al., 2006), and promote non-native or invasive species (Decocq et al., 2004; Roberts and Zhu, 2002). New strategies are needed to reduce the potential negative impacts of plantation silviculture on biodiversity.

In comparison to naturally regenerated, unmanaged forests, plantations are more structurally homogeneous (including canopy, understory, and forest floor or soil; Roberts, 2004), with the degree of homogenization corresponding to the intensity and frequency of disturbance. For example, plantations predominantly contain a single age-cohort of one or two tree species, tree removal leaves little coarse woody debris, scarification and lack of tip-up mounds result in low microtopographic variation and homogeneous soils, and understory and shrub layers are reduced, initially by scarification, often with the addition of herbicide (Berch et al., 2011; Freedman et al., 1996; Karlsson and Nilsson, 2005; Lorente et al., 2012; Ma et al., 2010; Tárrega et al., 2011; Yoshida et al., 2005). In addition, increasing interest in biomass harvesting (removing

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http://dx.doi.org/10.1016/j.foreco.2016.03.055
0378-1127/

small woody debris and unmerchantable stems for biofuel) could effectively eliminate both the protective influence of debris for soils (Dynesius et al., 2008) and the recruitment of xylicolous microhabitats (Berch et al., 2011). Higher disturbance intensity, of both canopy and the forest floor, tends to result in a more dramatic shift toward generalist or early-seral vascular plants at the expense of late-seral species, probably because late-seral species rely on short-distance dispersal strategies, a vernal-flowering phenology, or mycoheterotrophy (Aubin et al., 2007; Battles et al., 2001; Decocq et al., 2004; Ellum, 2009; Haeussler et al., 2002; Meier et al., 1995; Ramovs and Roberts, 2005; Roberts, 2002).

In New Brunswick, Canada, intensive management appears to be favoured over extensive or ecosystem-based management, perhaps because there are few virgin forests, thereby reducing the perceived conservation value of forests in general, and because many of the forests are privately owned and therefore maximized for timber production (CAFO, 2012; Loo and Ives, 2003). Nevertheless, despite this long history of active management, managed forests still clearly have some conservation value, and our knowledge of forest biodiversity is incomplete, suggesting a need for caution with management decisions. For example, while many species of conservation concern are reduced or lost following clearcutting (Fenton et al., 2003; Ross-Davis and Frego, 2002), some may survive or recolonize young, managed forests (e.g. Haughian and Frego, 2014). If the conservation value of managed forests can be explicitly quantified and ecologically understood, we may be able to reduce the negative impacts of intensive management practices, and improve biodiversity conservation over the landscape.

Applying some principles of ecosystem-based management to plantation silviculture may be an effective way to reduce its negative impact on the landscape. Ecosystem-based management assumes that non-timber management objectives can be achieved by ensuring that residual forest structure in harvested stands is similar to that in naturally disturbed stands (Hansen et al., 1991; Volney et al., 1999). In Atlantic Canada, the primary natural disturbance agents (insect outbreaks and windthrow) are partial, i.e. non-stand-replacing, disturbances (Loo and Ives, 2003). Some forms of partial harvesting can approximate these in terms of residual stand structure and canopy composition (Belle-Isle and Kneeshaw, 2007; Kneeshaw et al., 2011), and some forms of group-selection harvesting may mimic the gap-dynamics of old forests (Keeton, 2006; Smith et al., 2008), but few of these methods has been tested in mid-rotation plantations. Whether the same potential benefits can come from modified plantation management (e.g. extended rotations, partial harvesting, creating residual structures) is uncertain, but should be tested (French et al., 2008; Hartley, 2002).

In northern New Brunswick conifer plantations, a rotation typically lasts 50–60 years, with commercial thinning done 25–30 years after initiation; this timing lends itself to mimicking spruce budworm (SBW) outbreaks, which occur over a 19 to 34-year cycle in the region (Blais, 1983) and have been documented in stands as young as 25 years old (Piene et al., 2003). Thinning operations tend to preferentially remove budworm-susceptible trees (e.g., balsam fir and poor-condition spruce) to reduce the chance of an outbreak, inadvertently mimicking some of the stand-level changes observed in an SBW outbreak. Nevertheless, important differences remain with respect to woody debris management: managed forests have a reduced supply of woody debris, including both standing and fallen dead trees, compared to unmanaged forests subjected to natural disturbance (Berch et al., 2011; Kneeshaw et al., 2011). Improving biodiversity conservation in New Brunswick plantations should therefore focus on increasing the supply of standing and downed dead wood at the commercial thinning stage.

Our objective was to evaluate the early responses of the understory vascular plant community to alternative silvicultural prescriptions, representing a gradient of disturbance intensity and structural enhancement at the commercial thinning stage, in comparison to each other and a pre-disturbance state. If the relationships observed between forest biodiversity and natural disturbance regimes in unmanaged forests also hold true for mid-rotation Acadian conifer plantations, then we expect to see greater abundance of interior-forest, disturbance-sensitive, and dispersal-limited species, and lower abundance of roadside or ruderal species, in treatments that are (1) undisturbed, or (2) structured to mimic aspects of unmanaged forests, as compared to other treatments.

2. Methods

2.1. Study area(s)

This study took place in the 220,000 ha Black Brook experimental forest, northeast of St. Leonard, New Brunswick. Black Brook is a silvicultural land-base privately owned by J.D. Irving, Ltd. It is part of the Sisson Ecodistrict, in the Central Uplands Ecoregion (Province of New Brunswick, 2007), underlain by non-calcareous sedimentary bedrock, and covered by thick, loamy soils in low-lying terrain, or more coarse-textured soils in uplands (Province of New Brunswick, 2007). Historically the area was covered with coniferous and mixedwood forests. The former were dominated by balsam fir (*Abies balsamea* (L.) P. Mill.), white spruce (*Picea glauca*), or red spruce (*Picea rubens* Sarg.), while the latter were dominated by tolerant hardwoods (e.g., *Acer rubrum* L.) with subdominant fir and spruce (Province of New Brunswick, 2007). Commercial forestry has increased the dominance of white spruce (*P. glauca*) such that almost 40% of Black Brook is now occupied by white spruce plantations (Maclean et al., 2015). while balsam fir and hardwoods have diminished, although most native species are still present due to their retention in reserves or for their economic value (Amos-Binks et al., 2010; Montigny and MacLean, 2005).

In 2010, six 25-year old conifer plantations (20–40 ha) were selected as part of a larger collaborative study (Maclean et al., 2015). Selection was based on similar site quality-scores, and having been planted with predominantly white spruce (with lesser components of black spruce and balsam fir) in 1985 after a spruce budworm outbreak. Prior to plantation initiation, the stands were naturally-regenerated mixed-wood forest, that had last been disturbed during the spruce budworm outbreak of the 1950 s (Amos-Binks et al., 2010); at this time, managers focused on harvesting merchantable stems while non-merchantable species were typically felled by 'tree-crushers' (i.e., site-preparation) and left on site (G. Pelletier, J.D. Irving, Limited, personal communication 2011). Most of the currently available coarse woody debris (CWD) therefore resulted from budworm-related disturbance events (outbreak, harvest, and site-preparation; G. Pelletier, J.D. Irving, Limited, personal communication 2011). Although information specific to our chosen plantations was limited, plantation initiation in the area typically consists of (1) harvest, (2) mechanical site preparation to create favorable planting microsites, (3) planting, and (4) herbicide-based control (aerial spraying) of competing vegetation. Pre-commercial thinning is often applied at 10–15 years of age, to maintain appropriate densities, and commercial thinning is applied between 20 and 40 years of age, to remove low-quality stems. Final harvests are done between 35 and 55 years of age.

Within the selected plantations, canopy trees ranged from approximately 10–18 cm in diameter at breast height (DBH), with stocking densities of approximately 2700 stems/ha. Coarse woody debris volume ranged from 10 to 100 m^3/ha (L. Amos-Binks, unpubl.